Assigning marks to individuals working together to produce a joint product as part of a Project Team

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Introduction

Project work is a very important part of a students training and therefore should not be avoided. It is very important for students to learn to work in groups. A large undertaking requires several students to work together to divide the extensive work required. However, it is also important that team members provide approximately equal amount of effort and if they don't that they be evaluated accordingly.

Ensuring that individuals contribute equally to the product to be produced by the project and evaluation of individuals' contribution is however very difficult. With any team activity some team members will always contribute more to the resulting product than other team members. Thus instead of giving every team member the same mark for the team product it seems fairer to give team members more or less than the team mark dependent on the team member's contribution. This may also serve to motivate individuals to contribute and may help to prevent "free loaders".

Unless the instructor gets very involved in the project he/she is not in a good position to determine the amount of contribution each team member makes since the project that is delivered is the result of many individuals working together without the identification of its parts by contributor. The team members are probably in the best position to determine the contributions of other team members. Following is a procedure to permit evaluation of individuals and to motivate individuals to participate in project tasks using intra-team evaluation.

Procedure

Each team member is evaluated by several evaluators or judges that mainly includes the team members themselves but may also include external evaluators such as the instructor. Each evaluator will assign a mark to each team member. The marks are used to determine participation grades or distribution factors. The individual grade for team work will be equal to the team grade times the participation grade divided by the average participation grade or equivalently the team grade times the distribution factor. Thus some individuals will always get a grade higher than the team grade and other individuals will get a grade lower than the team grade. The sum of the individual marks should be equal to the team mark times the number of team members.
Specifically if n is equal to the number of members on the team, $\mathbf{x}_i$ the contribution by team member i and P the mark for the team's deliverable or product, team member i will receive a grade according to (1.1)

$$\frac{(n \times \mathrm{P}) \times \mathbf{x}_i}{\sum_{i=0,n\text{-}1} \mathbf{x}_i} \tag{1.1}$$

$n \times$P is the value of the total marks assigned to the deliverable. Expression (1.1) is equivalent to

$$\frac{\mathrm{P} \times \mathbf{x}_\mathrm{i}}{\bar{\mathbf{x}}} \tag{1.2}$$

or

$$\mathrm{P} \times \mathbf{d}_\mathrm{i} \tag{1.3}$$

$\mathbf{d}_\mathrm{i}$ are the distribution factors. $\bar{\mathbf{x}}$ is the average of the individual contribution measures. The values for $\mathbf{x}_\mathrm{i}$ may be obtained in several ways. Note that the actual values of $\mathbf{x}_\mathrm{i}$ are not important but only their relative values are. One way is for the team leader to assign the values for $\mathbf{x}_\mathrm{i}$. This is the simplest way but not the best way. Another way is to determine the values of $\mathbf{x}_\mathrm{i}$ on the basis of intra team evaluation whereby each team member evaluates each other team member including him/herself. This is the method proposed here.

The forms in the appendix may be used by the evaluators to obtain a raw score between 0 and 100 for each fellow team member. Note that only the one score is to be input by each evaluator for each team member. The first form in the appendix is strictly a working document. Let the raw scores be represented by the matrix **A**. Let n be the number of evaluators and m the number of persons evaluated. The rows correspond to evaluators and the columns correspond to persons being evaluated. The raw scores obtained by each person evaluated could be summed as in eqn. (1.4) and then used directly in eqn. (1.2).

$$\mathbf{x}_i = \sum_{j=0,m-1} \mathbf{A}_{i,j} \qquad i = 0, n-1 \tag{1.4}$$

However it is better to process the raw scores first for the reasons provided. All the marks assigned by an evaluator will be divided by the maximum to remove the effect of some evaluators tending to score a lot higher than others. This calculation has the effect of normalizing the scores to form the matrix , **B**.

$$\mathbf{B}_{i,j} = \frac{\mathbf{A}_{i,j}}{\max_k \mathbf{A}_{i,k}} \quad i = 0, n-1 \tag{1.5}$$

Next the weighted average for each team member is calculated. There are two kinds of weights here. One set of weights is obtained directly by assigning a weight to each evaluator. This would be done by someone who is not one of the evaluators. The other set of weights is calculated as follows. The evaluator whose scores show a large variation may be considered a better discriminator than the evaluator whose scores are all the same. The former appears to know more than the latter. The former evaluator has probably given it more thought. Her marks should count for more. Just like examinations which have a larger range of scores is better than an examination with a small range

of scores. Thus another set of weights is the variation in the scores for each evaluator. The variation is measured as the mean of the absolute deviations from the mean as in eqn. (1.6).

$$\mathbf{v}_i = \frac{\sum_{j=0,n-1} |\mathbf{B}_{i,j} - \frac{\sum_{k=0,m-1} \mathbf{B}_{i,k}}{m}|}{m} \qquad i = 0, n-1 \tag{1.6}$$

Note that statistical variance is not required since statistical inferences do not have to be made. These two sets of weights may be combined in various ways. Before weights are combined they must be normalized. This is done by dividing by the maximum variation rather than the minimum which may be 0.One way of combining the weights is simply to multiply the two sets of weights together and to use them to obtain a weighted mean for each team member. If for example the means of the deviations from the means are

$$0.15 \quad 0.008 \quad 0 \quad 0.097 \tag{1.7}$$

the normalized weights are

$$1 \quad 0.054 \quad 0 \quad 0.648 \tag{1.8}$$

Now let the weights assigned by the instructor be

$$4 \quad 1 \quad 6 \quad 3 \tag{1.9}$$

In normalized form this is

$$0.666667 \quad 0.166667 \quad 1 \quad 0.5 \tag{1.10}$$

Combining these with the other weights we get

$$0.666667 \quad 0.00900002 \quad 0 \quad 0.324 \tag{1.11}$$

or in normalized form

$$1 \quad 0.0135 \quad 0 \quad 0.486 \tag{1.12}$$

The 3rd evaluator gets a weight of 0 even though the instructor gave him/her a weight of 6. This is as it should be because the evaluator has drawn no distinctions in scoring.

A possible non-desirable effect of using multiplication is that the effectiveness of a particular evaluator may hereby be counted twice. A solution is not to use both sets of weights but to select only one of them. If nothing is known about the evaluators then the weights calculated on the basis of variance should be used and if a great deal is known about the evaluators then weights should be assigned. Of course using the variance has the benefit of non-partiality.

Example

Following is a complete example to illustrate the process described. Assume that the raw scores are

Table 1 Raw Scores

Persons evaluated				
evaluators	1	2	3	4
1	60	70	85	89
2	80	76	95	90
3	90	90	90	90
4	55	70	60	75
5	76	80	95	85

The normalized scores are

Table 2 Normalized Scores

Persons Evaluated				
evaluator	1	2	3	4
1	0.674	0.787	0.955	1.000
2	0.842	0.800	1.000	0.947
3	1.000	1.000	1.000	1.000
4	0.733	0.933	0.800	1.000
5	0.800	0.842	1.000	0.895

The variances in the normalized scores as measured by absolute deviations from the mean are

$$0.123596 \;\; 0.0763158 \;\; 0 \;\; 0.1 \;\; 0.0631579 \tag{1.13}$$

Note that evaluator 3 has shown no discrimination and therefore the variance and consequently the weight is 0. The weighted mean scores using variance as weights are

$$0.762399 \;\; 0.840489 \;\; 0.938764 \;\; 0.960526 \tag{1.14}$$

The distribution factors are

$$0.870771 \;\; 0.959961 \;\; 1.07221 \;\; 1.09706 \tag{1.15}$$

As is to be expected some are less than 1 and some are greater than 1. Given a team mark of 78 the individual marks would be

$$67.9 \quad 74.9 \quad 83.6 \quad 85.6 \tag{1.16}$$

Team members 1 and 2 brought the overall mark down and members 3 and 4 brought the mark up. If additional weights of 1 1 3 1 5 are applied the result is

$$69.3 \;\; 74.3 \;\; 85.93 \;\; 82.2 \tag{1.17}$$

The assumption is that evaluator 2 is the project leader and evaluator 4 is the instructor. Both may be more dependable than the others.
Following is an example of input provided by an evaluator.

Overall Performance Rating
By person D
9471283
Person A 100 Comment:
He always did everything he was asked to do and he is doing a good job especially with the editing of milestone 3. He is very easy to work with and he contributed well to group discussions He also did a good job as a recorder. He has a good understanding of course material as well. I would choose to work with him again on future projects too.

Person B 95 Comment:
I was really impressed with Person B's work for this milestone. He worked hard doing his part and it was good. He also contributed well to group discussion. However, he has not provided any revisions to person A yet.

Person C 100 Comment:
He always did everything he was asked to do and did it well. He always did his best and always contributed well to group discussions. He has a good understanding of the course material. He had to leave early for one meeting but he told me about it well in advance and it was a good unavoidable reason. I would definitely choose to work with him again on future projects.

Person D 100 Comment:
I always had a meeting agenda at least the day before the meeting to inform everyone of the next meeting. I also was always willing to help anyone in the group complete his/her project assignments while completing my own. I also

Person E 85 Comment:
Her work is good it could be better. I have not noticed a vast improvement since the start of this project like I have with Person B. For example, sometimes she sometimes overlooks things we've already talked about in the meeting such as how the Journal interacts with other classes and some of the fields it needs to have. However, when I put out a standard format for the documents that were to be sent to Person A she followed it so at least she didn't overlook that which makes the editor's job easier.

Person F 100 Comment:
She always did the work she was asked to do and it was always her best. Person F is very easy to work with and she contributed well to group discussions. She has a good understanding of course material as well. It was also beneficial to Person A because she helped with the revisions of the milestone. Person F didn't have to email Person A's revision like the rest of us. I would choose to work with her again on future projects too.

Effect of using intra-team evaluation

Intra-team evaluation has been used for many years on the projects required in software engineering after it was determined that there were problems in not using some form of individual evaluation. Without the team evaluation it was too tempting for some team members to let others do the majority of the work. What generally happened is that if an individual on a team was not reliable eventually no work was assigned to that individual since the rest of the team members did not want the project held up. Some team members consequently made no contribution and got away with it. When intra-team evaluation is used individuals that are unproductive for the first few deliverables will tend to improve a great deal after they see that their marks are low.
With team evaluation it has also happened that a student in a project course failed the course because of low participation in team work. In this case the intra-team evaluation did not improve productivity but neither did the team member get credit for a project course whose requirements he essentially did not fulfil.

Adjustment to Procedure

The procedure above may be qualified as follows. In order to permit more accurate evaluation of the students participation in a project the instructor may interview or give an exam to one, some, or all students on the project team. (see below) A student's grade may thereby be reduced if a student appears to have little or no knowledge of the deliverables produced as shown by examinations.
Also the instructor reserves the right to solely determine a student's mark on a project (that is, peer evaluation may be dispensed with in some cases.) An examination may be given to all or some individuals. The exam would be used to determine an individuals knowledge of the project that he/she participated in. (Note: Each team member should be acquainted with all part of the project and not only with his particular contribution.)
Note that the raw scores provided by the evaluators are accompanied by comments that in addition to meeting minutes received by the instructor provide insight into the dynamics of the team work. It is also suggested that the instructor attend some of the team meetings to assist in monitoring. The minutes of meetings held by the teams are a good source of information for monitoring.

Appendix 1

TERM PROJECT TEAM MEMBER EVALUATION FORM

Take a few minutes to carefully evaluate each member of your project team. Focus on their project performance and team contribution. Try to ignore personality conflicts. This evaluation is confidential, subject to the policies and limitations established by your instructor. Evaluate team member's performance, including your own, over the full term of the project. You will be asked to rate each team member's overall performance and contribution to the project on a scale of 0-100. Assume the following grading scale for this evaluation: (put in a number however and not a letter grade)

90 - 100	A	Excellent contribution
80 - 89	B	Above average contribution
70 - 79	C	Average contribution
60 - 69	D	Below average contribution
0 - 59	F	What contribution?

List the team members, including yourself, alphabetically.

Team Member 1 = _____

Team Member 2 = _____

Team Member 3 = _____

Team Member 4 = _____

Team Member 5 = _____

Team Member 6 = _____

Team Member 7 = _____

Team Member 8 = _____

Work Sheet (working document only)
Now, rate each team member on a scale from 0-100 on each of the following questions:

M1	M2	M3	M4	M5	M6	M7	M8		
								1.	This person did his/her fair share of the work.
								2.	When required to do so, this person co-operated with other team members.
								3.	This person is competent in the analysis and design techniques that were taught in this course.
								4.	This person accepted his/her fair share of team responsibilities when asked to do so.
								5.	This person completed his/her assignments on schedule.
								6.	This person always submitted his/her best work and effort.
								7.	This person completed his/her assignments with little or no assistance.
								8.	This person attended team meetings and arrived on time.
								9.	This person was well prepared for team meetings.
								10.	I would like to work with this person on future projects.

Document to be emailed for each deliverable produced as part of a team effort

Overall Performance Rating (scale = 0-100)
The number here will become x_i

Team Member 1 _____ Comment: _____

Team Member 2 _____ Comment: _____

Team Member 3 _____ Comment: _____

Team Member 4 _____ Comment: _____

Team Member 5 _____ Comment: _____

Team Member 6 _____ Comment: _____

Team Member 7 _____ Comment: _____

Team Member 8_____ Comment: _____

Appendix 2

Following is an executable version of the algorithm that determines distribution factors that is written in J code.

```
normalize_by_max=: %>./                          NB. Normalize a series of numbers by dividing by their maximum

normalize_matrix_row_wise=: normalize_by_max "1   NB. Normalize each row of a matrix

det_mean=:+/%#                                   NB. Determine the mean

det_variance=:det_mean@(|@((det_mean@])-]))      NB. Determine the variance

det_weights_from_variance=:normalize_by_max@(det_variance"1@ normalize_matrix_row_wise)
NB. Determine weights from the variance
det_overall_weights=:normalize_by_max@:((normalize_by_max@[)*det_weights_from_variance
@:])     NB. Combine weights

det_weighted_mean=: (+/ . *)%[:+/[               NB. Determine the weighted mean. Variance is used as weights and additional weighting factors

NB. distribution factors are divided by the mean

det_dis_fact=:(%det_mean)@:(det_overall_weightsdet_weighted_mean
normalize_matrix_row_wise @:])

main=:3 : 0

sco '            Computed Data '

sco 'team A'

sco 'raw scores'

sco SA

sco 'normalized scores,      weights,weights_     from_variance,     combined weights'

sco      10.2      format      ((normalize_matrix_row_wise      SA),.(normalize_by_max
WA),.(det_weights_from_variance SA),.(WA det_overall_weights SA)),0

sco  'distribution factors'

sco 10.2 format(dfA=:WA det_dis_fact SA)

sco teamAscores=:markA*WA det_dis_fact SA
```

)

NB. utility functions

from_keyboard=:1

get_character=:get_characters=: 1!:1

get_number=:get_numbers=: ".@get_characters NB. numeric key board input

write_to_screen=: (1!:3)&2

sco=: (1!: 2)&2

format=:form=: ":