A Quantitative Evaluation Method for Evaluating the GSN Users’ Ability to Structuralize Systems with Multiple Viewpoints

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Abstract

Having multiple viewpoints is an indispensable capability for persons who lead the development and operation of large-scale, complex, technological and social systems. Previous studies state that structuralization with multiple viewpoints by using Goal Structuring Notation (GSN) refers to connecting multiple viewpoints in layers. If this study can quantitatively evaluate the ability to structuralize systems with multiple viewpoints of users describing GSN, it is likely to show that the evaluation is effective for human resource development. Previous studies have also shown that it is possible to increase the feasibility of accomplishing management vision and management strategy by describing management vision, management strategy, business process and IT system using GSN (D-Case). This study therefore proposes a quantitative evaluation method for evaluating the ability to structuralize systems with multiple viewpoints of users describing GSN. The verification method for the proposed quantitative evaluation method is also presented. The aim of verification in this study is to confirm that the proposed quantitative evaluation method can make a relative evaluation on the ability to structuralize systems with multiple viewpoints of users describing GSN. The subjects first described four themes using GSN. After that, we quantify the description results using the quantitative evaluation method. This study verifies that the proposed quantitative evaluation method is effective for evaluating the ability to structuralize systems with multiple viewpoints of users describing GSN by showing the quantitative evaluation results. Finally, this study concludes with future research topics.

Keywords: Multiple Viewpoints, Structuralizing, Goal Structuring Notation, D-Case, Assurance Case

1. Introduction

Having multiple viewpoints is an indispensable capability for persons who lead the development and operation of large-scale, complex, technological and social systems [1]. Kobayashi et al. (2018) [2] state that structuralization with multiple viewpoints by using Goal Structuring Notation (GSN) [3] refers to connecting multiple viewpoints in layers. Kobayashi et al. (2018) [2] do not show a method to quantitatively evaluate the ability to structuralize systems with multiple viewpoints of users describing GSN. The definition of system in this study is an integrated set of elements, subsystems, or assemblies that accomplish a defined objective. These elements include products (hardware, software, firmware), processes, people, information, techniques, facilities, services, and other support elements [4]. If this study can quantitatively evaluate the ability to structuralize systems with multiple viewpoints of users describing GSN, this study is likely to show that the evaluation is effective for human resource development which was described by Shirasaka et al. (2010) [1]. Kobayashi et al. have also shown that it is possible to increase the feasibility of accomplishing management vision and management strategy by describing management vision, management strategy, business process and IT system with the use of GSN (D-Case [5]) [6] [7]. This study therefore proposes a quantitative evaluation method for evaluating the ability to structuralize systems with multiple viewpoints of users describing GSN.

Next, we state the novelty of this study. Setozaki et al. (2012, 2017) [8] [9] discussed multiple viewpoints by using materials for learning celestial bodies. The reason is that grasping the situation is difficult unless one has multiple viewpoints to understand the situation of the celestial bodies. Setozaki et al. (2012, 2017) therefore is not a study intended for quantitative evaluation method. Kobayashi et al. (2018) [2] showed structuralization with multiple viewpoints based on the descriptive result with the use of GSN. Kobayashi et al. (2018) [2] however did not propose a quantitative evaluation method for evaluating the ability to structuralize systems with multiple viewpoints of users describing GSN. Regarding the evaluation method of GSN, Kobayashi et al. [10] showed quantitative evaluation methods for work improvement. It is a difference from this study that the evaluation method was not an evaluation based on the number of viewpoints. Thus the novelty of this study is a quantitative evaluation method for evaluating the ability to structuralize systems with multiple viewpoints of users describing GSN.

A verification method for the proposed quantitative evaluation method is as follows. The aim of verification in this study is to confirm that the proposed quantitative evaluation method can make a relative evaluation on the ability to structuralize systems with multiple viewpoints of users describing GSN. Subjects describe four themes...
using GSN. After that, we quantify the description results using the quantitative evaluation method. This study verifies that the proposed quantitative evaluation method is effective for evaluating the ability to structuralize systems with multiple viewpoints of users describing GSN by showing the quantitative evaluation results.

Section 2 summarizes GSN (D-Case) description methods. Section 3 describes the proposed quantitative evaluation method. Section 4 shows the verification method for the quantitative evaluation method described in Section 3. Section 5 states the verification results. Section 6 discusses the verification results. Section 7 concludes with future research topics.

2. Previous Studies

GSN [11], which was proposed by Kelly, is one of the notation methods used for assurance cases [12]. The assurance case can express the discussion of the entire quality with an acceptable level. D-Case (Dependability-Case) [5] is a description method that extends GSN. D-Case is a description method using six nodes, including Goal node, Context node, Strategy node, Evidence node, Monitoring node, and Undeveloped node [3] [7] [12]. Table 1 shows the six nodes. The strategy node used in this study is presented in both D-Case and GSN, respectively. We assume that the strategy node relates to structuralizing systems with multiple viewpoints. The reason is that structuralizing systems with multiple viewpoints utilizes the viewpoint of decomposing the target to be discussed by using the strategy node. The nodes used in this study are shown with double quotation marks (" ").

3. Quantitative Evaluation Method

Kobayashi et al. [2] states that combining viewpoints is necessary for structuralization with multiple viewpoints: a viewpoint that is selected from multiple viewpoints aligned in the horizontal direction, and a viewpoint that is selected from multiple viewpoints aligned in the vertical direction. We therefore propose a method using GSN to quantitatively evaluate the results from horizontal viewpoints and vertical viewpoints separately. This study defined six evaluation formulas as follows, in the case where a certain “Strategy Node” is set on the top level.

\[
V(s) = S_u \
\]

\[
H(s) = \sum_{Gd=1}^{Gd} H(s) \quad (1) \]

\[
H(s) = 0 \quad (Gd=1) \quad (2) \]

\[
V(s) = S_s \quad (Gd=1) \quad (3) \]

\[
V(s) = 0 \quad (Gd=1) \quad (4) \]

\[
TH = \sum_{Gd=1}^{Gd} H(s) \quad (5) \]

\[
TV = \sum_{Gd=1}^{Gd} V(s) \quad (6) \]

\[
Gd \quad : \text{GSN} \text{ represents the number of “Goal nodes” positioned directly under the “Strategy node” to be targeted. As an exception, when the number of “Goal node” is one, evaluation method evaluates that } H(s) \text{ equals zero.} \]

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TH \quad : \text{TH is the result of evaluating the total of the viewpoints aligned in the horizontal direction [2] lower than “Strategy node” to be targeted.} \]

\[
TV \quad : \text{TV is the result of evaluating the total of the viewpoints aligned in the vertical direction [2] lower than “Strategy node” to be targeted.} \]

Table 1: Explanation of Six nodes for D-Case

| Node     | Figure | Explanation                                                                 |
|----------|--------|-----------------------------------------------------------------------------|
| Goal     |        | Goal node describes what to assure, with a combination of a subject and predicate. |
| Strategy |        | Strategy node describes how to break down the Goal into sub-goals leading to the lower layer. |
| Context  |        | Context node describes the state, or environment and conditions of the System, and shows ways to lead to the Goal and Strategy. |
| Evidence |        | Evidence node eventually assures that we can reach the Goal, and shows ways to lead to the Goal. |
| Monitoring |      | Monitoring node is intended to represent Evidence available at runtime, corresponding to the target values of in-operation ranges. |
| Undeveloped |   | Undeveloped node shows the status that there is no Evidence or Monitoring, or discussion supporting the Goal. |

\[
S_u \quad : \text{This study counts from the top “Strategy node”, and } S_u \text{ represents the numerical order of “Strategy nodes” to be targeted. As an exception, when the number of “Goal node” is one, evaluation method evaluates that } V(s) \text{ equals zero.} \]

\[
S_{max} \quad : \text{ } S_{max} \text{ is the total number of “strategy nodes”.} \]

\[
TH \quad : \text{TH is the result of evaluating the total of the viewpoints aligned in the horizontal direction [2] lower than “Strategy node” to be targeted.} \]

\[
TV \quad : \text{TV is the result of evaluating the total of the viewpoints aligned in the vertical direction [2] lower than “Strategy node” to be targeted.} \]

Kobayashi et al. [2] show that, when using multiple Strategy notes, connecting multiple viewpoints (“Strategy node”) creates new boundaries, and enables structuralizing what was described with GSN. In other words, the viewpoint aligned in the vertical direction overlaps, each time the “Strategy node” overlaps. This study therefore increases the evaluation, each time the “Strategy node” overlaps. It corresponds to Equation (3).

The viewpoints aligned in the horizontal direction is indicated by how many “Goal nodes” are decomposed using the “Strategy node”. This study therefore increases the evaluation of the viewpoints aligned in the horizontal direction by the number of “Goal nodes”. It corresponds to Equation (1). The results of quantitative evaluation using GSN are shown in Figure 1.

As shown in figure 1, when s = 1, the “Strategy node” is the first layer. This study thus defined V (1) = 1. The number of “Goal nodes” is three, and thus this study...
assumed $H(1) = 3$. Next, when $s = 2$, the “Strategy node” is the second layer. This study thus assumed $V(2) = 2$. The number of “Goal nodes” is two, and thus this study assumed $H(2) = 2$. Next, when $s = 3$, the “Strategy node” is the second layer. This study thus assumed $V(3) = 2$. The number of “Goal nodes” is two, and thus this study defined $V(4) = 3$. The number of “Goal nodes” is two, and thus this study assumed $H(4) = 2$. As a result, the result of evaluating the total of the viewpoints aligned in the horizontal direction is $TH = 3 + 2 + 2 + 2 = 9$ using Equation (5). The result of evaluating the total of the viewpoints aligned in the vertical direction is $TV = 1 + 2 + 2 + 3 = 8$ using equation (6). This study can evaluate GSN by using the proposed equation as shown in figure 1.

As an exception for results of the proposed evaluation method, the “Goal node” may be paraphrased by using “Strategy node”. Only one “Goal node” is given directly under “Strategy node”, when the exception occurs. At this time, even if the number of the viewpoints aligned in the vertical direction actually increases, neither the viewpoints aligned in the horizontal direction nor the viewpoints aligned in the vertical direction are counted in the equation (2) and equation (4). However, when dividing “Goal node” into two or more, we count again in both the viewpoints aligned in the vertical direction and the viewpoints aligned in the vertical direction using equation (1) and equation (3). The above was not to structuralize systems with multiple viewpoints, but this study set to an evaluation that judge to concretize as lower “Goal node” by decomposing using “Strategy node” for “Goal node”.

4. Verification method

The aim of verification in this study is to confirm that the proposed quantitative evaluation method can make a relative evaluation on the ability to structuralize systems with multiple viewpoints of users describing GSN. The verification method is that subjects describe the GSN for four themes without knowing that GSN is the method for structuralizing systems with multiple viewpoints. After that, we quantify the description results using the quantitative evaluation method. This study verifies that the proposed quantitative evaluation method is effective for evaluating the ability to structuralize systems with multiple viewpoints of users describing GSN by showing the quantitative evaluation results. Concretely, this study shows relative evaluation results for each person using both TH and TV, and shows relative evaluation results for each theme by using both TH and TV.

5. Verification Results

The subject profile is shown in Table 2. The quantitative evaluation results are shown in Table 3.

| Age | Male | Female | Total |
|-----|------|--------|-------|
| 20’s| 3    | 1      | 4     |
| 30’s| 9    | 0      | 9     |
| 40’s| 3    | 0      | 3     |
| 50’s| 1    | 0      | 1     |
| Total| 16  | 1      | 17    |

Above average of the horizontal direction: The number that each subject TH is larger than the average of TH.
Above average of the vertical direction: The number that each subject TV is larger than the average of TV.
Total of above average: The total number of both above average of the horizontal direction and above average of the vertical direction.
Average value: Average for the combination of each theme and TH or each theme and TV.
Number of people for above average of the theme: Number of people for above average value of TV and TH.
Easiness of each theme (%): Number of subjects who exceeded the average value / total number of subjects * 100.
Easiness ranking: Ranking by comparison of Easiness of each theme.

6. Discussion

This study showed that the proposed method enables a relative evaluation as shown in Table 3. We can judge the numerical superiority or inferiority from the results of Subject A to Q. As shown in Table 3, we can distinguish, by setting an evaluation criteria, those who can structuralize systems with multiple viewpoints and those who cannot. This study judged that “what you can do” is larger than the average value and “what you cannot do” is below the average value.

However, this study does not show how the actual thinking of the subjects differ given the differences in the number of their viewpoints aligned in the horizontal
direction and the number of their viewpoints aligned in the vertical direction. Future research therefore needs to evaluate the actual thinking of subjects by changing both the numbers of the viewpoints aligned in the horizontal direction and the numbers of the viewpoints aligned in the vertical direction.

Being able to structuralize a certain field with multiple viewpoints does not necessarily ensure being able to structuralize other fields likewise. For example, this study suggested that there is being found fields where structuralizing systems with multiple viewpoints is easy because both the numbers of the viewpoints aligned in the vertical direction and the numbers of the viewpoints aligned in the horizontal direction are greatly different by each theme. This study confirmed that structuralizing systems with multiple viewpoints is easy in some fields, with Table 3 indicating the difference in the number of subjects with more than the average value for each theme. Concretely, the average value for TH of the second theme was more than 1.28 times as great as that for the fourth theme; the average value for TV of the second theme was more than 1.91 times as great as that for the first theme.

Table 3 The results of applying the proposed quantitative evaluation method.

| Subjects | 1st theme TH | 1st theme TV | 2nd theme TH | 2nd theme TV | 3rd theme TH | 3rd theme TV | 4th theme TH | 4th theme TV | Above average of the horizontal direction | Above average of the vertical direction | Total of above average |
|----------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|---------------------------------------------|-------------------------------------------|-------------------------------|
| A        | 11           | 8            | 13           | 13           | 11           | 11           | 9            | 8            | 4                                           | 4                                         | 8                             |
| B        | 12           | 11           | 10           | 12           | 9            | 11           | 10           | 11           | 4                                           | 4                                         | 8                             |
| C        | 27           | 23           | 11           | 12           | 6            | 8            | 15           | 10           | 3                                           | 3                                         | 6                             |
| D        | 12           | 8            | 6            | 5            | 8            | 10           | 10           | 11           | 3                                           | 3                                         | 6                             |
| E        | 12           | 5            | 10           | 11           | 10           | 9            | 6            | 6            | 3                                           | 2                                         | 5                             |
| F        | 10           | 5            | 10           | 11           | 14           | 17           | 6            | 5            | 3                                           | 2                                         | 5                             |
| G        | 9            | 5            | 11           | 11           | 6            | 5            | 11           | 11           | 2                                           | 2                                         | 4                             |
| H        | 8            | 5            | 10           | 11           | 6            | 5            | 8            | 8            | 2                                           | 2                                         | 4                             |
| I        | 8            | 3            | 10           | 11           | 4            | 6            | 6            | 7            | 1                                           | 2                                         | 3                             |
| J        | 10           | 3            | 9            | 9            | 15           | 17           | 4            | 3            | 2                                           | 1                                         | 3                             |
| K        | 3            | 1            | 12           | 14           | 6            | 5            | 6            | 5            | 1                                           | 1                                         | 2                             |
| L        | 5            | 1            | 4            | 3            | 8            | 9            | 4            | 3            | 1                                           | 1                                         | 2                             |
| M        | 7            | 3            | 10           | 11           | 6            | 8            | 6            | 5            | 1                                           | 1                                         | 2                             |
| N        | 2            | 1            | 10           | 12           | 7            | 8            | 6            | 6            | 1                                           | 1                                         | 2                             |
| O        | 5            | 3            | 8            | 8            | 4            | 3            | 6            | 5            | 0                                           | 0                                         | 0                             |
| P        | 7            | 3            | 4            | 3            | 6            | 5            | 5            | 3            | 0                                           | 0                                         | 0                             |
| Q        | 7            | 5            | 8            | 9            | 6            | 8            | 4            | 3            | 0                                           | 0                                         | 0                             |

Average value: 8.8  4.9  8.9  9.4  7.5  8.2  6.9  6.1  1.5  1.4  2.9

Number of people for above average of the theme: 7  4  11  11  7  7  6  7

Easiness of each theme: 41.2  23.5  64.7  64.7  41.2  41.2  35.3  41.2

Easiness ranking: 3  8  1  1  3  3  7  3

Furthermore, the ability of users, who describe GSN to structuralize systems with multiple viewpoints, needs to be measured for each field because users can structuralize systems with multiple viewpoints in some fields, and cannot in other fields. The reason that measuring according to each field is necessary is that subjects have not necessarily solved easy themes from the results of four themes of the subjects A to Q. The tendency of the theme solved by the subjects may be captured. Concretely, TH value for the first theme of the subject K was more than 4 times as great as that for the second theme of the subject K, TV value of the first theme of the subject K was more...
than 10 times as great as that for the second theme of the subject K. TH value for the first theme of the subject N was more than 5 times as great as that for the second theme of the subject N, TV value of the first theme of the subject N was more than 10 times as great as that for the second theme of the subject N.

The results of this study showed that some subjects have difficulty in structuralizing systems with multiple viewpoints since TV of some subjects or TH of some subjects are below each average value. The reason that subjects found it difficult to structuralize systems with multiple viewpoints was that three out of 17 subjects had the result of the total counts above average value being 0 point.

Considering the above, the results of this study show that there are cases where having a conversation about the specific field is difficult, when there are significant differences among people in the ability to structuralize systems with multiple viewpoints. For example, if subject C and subject N talk with each other, clarifying that they want to talk is necessary can be inferred using the result of the first theme in Table 3. The reason why we can guess is that we know that the result of subject C differs from the result of subject N by 10 times or more. Furthermore, Kobayashi et al. [13] propose an assurance case description method to reduce misunderstanding caused by the difference of grasping the objects managed in various departments as a monolithic system or a System-of-Systems. The previous study focused on misunderstanding in various departments due to misrecognition of the structure of the objects. This study will show that one reason for the cause of the misunderstanding caused by the difference of grasping the objects managed in various departments as a monolithic system or a SoS is that the subjects have difficulty structuralizing systems with multiple viewpoints.

7. Conclusions

This study proposed a quantitative evaluation method for evaluating the ability to structuralize systems with multiple viewpoints of users describing GSN. This study suggested the proposed quantitative evaluation method is effective, by confirming that the ability to structuralize systems with multiple viewpoints of users describing GSN can be evaluated relatively.

The results of this study clarified the following three points:
1. Being able to structuralize a certain field with multiple viewpoints does not necessarily ensure being able to structuralize other fields likewise.
2. The ability of users, who describe GSN to structuralize systems with multiple viewpoints, needs to be measured for each field because users can structuralize systems with multiple viewpoints in some fields, and cannot in other fields.
3. Having a conversation about a certain field can be difficult when there is a significant difference in the people’s ability of structuralizing systems with multiple viewpoints.

Next, we discuss possible applications of this research. Given the results of this research, the proposed quantitative evaluation method is likely to be useful for judging people’s ability for a certain work based on the relative evaluation in a company, such as when considering “who to assign a specific work in a company” and “who to assign a specific task in a project”. In addition, using the proposed quantitative evaluation method will be a guideline for both comparing and evaluating to what extent we can consider when we deal with unknown themes.

The limitations of this study, which are future research topic, are as follows:
1. This study does not show how the actual thinking of the subjects differ given the differences in the number of the their viewpoints aligned in the horizontal direction and the number of their viewpoints aligned in the vertical direction.
2. Developing a method to evaluate the evaluation results of the proposed quantitative evaluation method.
3. This study does not make an absolute evaluation.
4. The results of this study are evaluated without an assumption of assuring the goal, which is the original usage, because this study made an evaluation from the perspective of structuralizing systems with multiple viewpoints of users describing GSN.
5. Comparing whether there is any difference in the evaluation results when structuralizing systems with multiple viewpoints with assuring GSN or without assuring GSN is therefore needed.

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