A COLLABORATIVE PROBLEM SOLVING METHOD ANALYSIS USING TERMS CLASSIFICATION

S. BASSETTO, A. SIADAT, P. MARTIN

LGIPM, CER ENSAM 4, rue Augustin Fresnel, Technopôle 2000 57074 Metz, France

Abstract
In industrial environments, problems solving methods are used to face production crisis, like shutdown, product major non conformity, or cost issues. 8D, Ishikawa, Brainstorming are well known methods employed to face such crisis. They help to lead teams toward the resolution of a particular problem. These methods mobilise numerous technical “knowledge”. This paper uses this occasion to deep the concept of knowledge and it tries to interact with its producers. A technical problem of a test banc for forged cog is chosen for the application. Cog life time is evaluated with a destructive test of sampled production lots on a test banc. For the experiment 2 tests bancs have been used, one is capable and the other reduces the life time of tested cogs. This solving problem method has been used to understand mechanism of this difference and act for reducing the impact of the measurement system on the parameter: life time.

Keywords:
Problem solving, Knowledge representation, Knowledge Acquisition

1 INTRODUCTION
The handling of technical problems within the framework of an industrial process comprises several difficulties in terms of detection, identification and correction [1]. It involves many variables and the know-how of experts. Several systems have already provided some interesting results (in particular [2] and [3]). Nevertheless, the knowledge acquisition still remains a relatively unexplored research orientation [4]. Moreover, for the time being, there is no method put forward that takes into account the know-how of the experts. It is to this point that we will bring our contribution. What we are proposing constitutes not only a case construction method but also a tool that provides an aid to the resolution of new problems (through vocabulary and group convergence measure). We applied this method to manufacturing systems since the problem of a group convergence was posed to us by microchips manufacturers, but this method can probably be used successfully in other domains such as medicine or chemistry for example.

We propose a structured method providing an aid for problems solving through the measure of group convergence. This method can be presented in 5 steps:

1. Team building: The role of the animator is to build the team and formulate the problem by defining its frame as precisely as possible.

2. First Problem analysis: This step is carried out by each team member. This analysis leads at a first set of keywords, freely expressed, which constitutes a “keywords base” called B0.

3. First Restitution: During this step team members agreed on a common vocabulary, in particular on a set of keywords, which are called aliases. Theses particular words will be used to represent experts’ purposes in next analyses. Each alias is described by a vector in the base B0 called B1.

4. Meeting: A meeting has two main objectives: (1) to solve the problem and (2) to collect the expression of the team members in B1. Each proposal of addition, removal or modification of the alias base is discussed before being voted. At the end of the meeting, each member expresses himself and sum-up his purpose using weighted matrix. Each team member’s meaning is then represented by a vector in the base B1. The concatenation of all summaries leads to a matrix of members’ expressions in the base B1. It is called A

5. Convergence: By using the formalism of weighed keywords a distance between members’ summaries can be calculated. It is possible to reveal the convergence of point of views inside the team. If the distance between summaries is low we consider that the team point out a solution to the problem, the process is ended and the suggested solution is validated. At the opposite if the convergence is insufficient, an additional meeting is planned. If there are several points of view in the team, some experiments can also be carried out before the next meeting. A global convergence can also be calculated between 2 meetings in order to understand point of view evolutions.

In the rest of the paper, we will present in detail this method, related indicators, our experiment and possible extensions.

This paper is structured in five parts: It starts with an introduction, follows in a second one with the presentation of the problem resolution method. In the third part indicators’ construction is discussed. In the four part the test realized on a forget cog test banc issue is presented. The article ends with a conclusion and possible extensions.

2 PROBLEM RESOLUTION METHOD
Brainstorming, ISIKIKAWA, 8D, are well known methods to act as problem solving path. They structured the way an organization can start from a problem to get the solution. It is commonly admit that during brainstorming sessions there is a profusion of information and one of them or a combination of them lead to a possible solution. This paper uses this particular occasion to try modelling experts’ knowledge and using this model to help people involved in the resolution team to converge faster toward a solution.

It consists in holding one or more meetings with chosen people who are experts’ of the organization about the problem to be solved. If needed some experiments can also be lead. Some indicators, estimated with a representation of the idea evoked by each expert, make the choice orientation possible (new meeting, experiment or solution assessment). The animator confirms or invalidates the proposed choices.
2.1 Determination of the expert team
The choice of people involved in the Problem Resolution Team (PRT) is made according to their experience. The experts that have taken part in the construction of a similar problem will be privileged compared to the other ones. Choices are provided by the animator who validates, modifies or supplements the expert team. Let note the set of experts \{Exp_1, Exp_2, ..., Exp_n\}.

2.2 The first Problem analysis and restitution
• First session and sum up: In the first meeting, no particular rule and restriction are applied upon their ideas and the vocabulary used. Each expert sum up freely his/her purpose with between 5 and 10 key words. This method is always used to classify scientific papers and used practically during technological surveys [5].

By following this assumption, we hypothesis that ideas and concepts, are sum up into key words’ vectors. We know that this assumption will lead us to major language and concepts, are sum up into key words’ vectors. We will come back in this assumption.

• Following this expression, a common vocabulary is built inside the team, for the particular problem solving case. Experts agreed on a common vocabulary and particularly on a set of keywords that will serve to estimate the convergence of their ideas. Each keyword has a precise definition common to the group.

After this work; a set of defined keywords \{Kw_1, Kw_2, ..., Kw_m\} is available. The comparison between expert’s expressions through a calculus is then conceivable. This exercise is often practice in infometrics and scientometrics [7].

2.3 Problem solving sessions
One or more meeting are held to solve the problem. Each of them is closed by a sum up of experts’ meaning into the common vocabulary. Each expert sum his opinion up, by using the weighted keywords (keywords with a coefficient), and can also express himself about the sufficiency of a meeting, the need for another meeting or an experiment.

The previous set of keyword is also used by each expert and it constitutes a matrix A of weights wij. Example for 5 experts and 7 keywords:

\[
A = \begin{bmatrix}
   a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\
   a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\
   a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\
   a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\
   a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \\
   a_{61} & a_{62} & a_{63} & a_{64} & a_{65} \\
   a_{71} & a_{72} & a_{73} & a_{74} & a_{75}
\end{bmatrix}
\]

At the end of the meeting, a report is carried out integrating the production of the meeting, the indicators of convergence and sufficiency.

2.4 Convergence, sufficiency
Using the formalism of weighed keywords, it is possible to reveal the convergence of the ideas inside the expert team by using similarity measures presented in, [8] and [9]. For example, we can evaluate simply the distance between expert 4 and expert 7 with the following operation:

\[
D(Exp_4, Exp_7) = \cos \left( \frac{a_{14}}{a_{17}}, \frac{a_{24}}{a_{57}}, \frac{a_{34}}{a_{47}}, \frac{a_{44}}{a_{47}}, \frac{a_{54}}{a_{57}}, \frac{a_{64}}{a_{67}}, \frac{a_{74}}{a_{77}} \right)
\]

The sufficiency is evaluated with the notice given by the experts and also with the production of the meeting.

The application provides an opinion on the steps to be taken after the meeting. The animator decides. The possible proposals are as follows:

• new meeting
• experiment before the meeting
• assessment of the proposed solution (it’s also an experiment)

2.5 Experiments
In the case of an intermediate experiment (followed by another meeting), results are put at the disposal of the experts and a new meeting is held. In the case of the test of the proposed solution, an evaluation is carried out and validated by the animator. If this one is negative, the manual treatment is taken again, beginning with a new choice of experts.

3 INDICATORS DEVELOPMENT

3.1 Indicator constraints
To be able to implement an action, which can be the solution or not, the team have to be agree on a solution. A common solution (for the team) has to emerge from analyses. A good indicator must reflect the situation of group convergence and divergence.

If the group converge the indicator must converge toward a defined value. If the group diverge, if many positions are adopted in the group, the indicator must take opposite values.

Let note I, the indicator, 0 the value taken by I if the group converge and 1 if the group diverge. The previous willing lead at the following rules:

\[
\text{If the group converge: } I \rightarrow 0 \\
\text{If the group diverge: } I \rightarrow 1
\]

To be a manageable indicator, theses rules are not valuables. If the group converge, the work is done and there is no need of an indicator to proof it.

At the opposite, it is valuable to have a look at the indicator and infer what happened on the team. For that, with our notation, a manageable indicator will respect following rules:

\[
\text{If } I \rightarrow 1 : \text{ the group converge} \\
\text{If } I \rightarrow 0 : \text{ the group diverge}
\]

Then a good indicator will respect two equivalences:

\[
\text{The group converge } \Leftrightarrow I \rightarrow 0 \\
\text{The group diverge } \Leftrightarrow I \rightarrow 1
\]

With theses rules we will propose and test two indicators to measure group convergence.
3.2 The distance

The main difficulty is to choose the distance. It has to respect distance properties [10]. This is not the case with operation (1) which do not respect neither the first principle, \( d(x, y) = 0 \iff x = y \) nor the third principle \( d(x, z) \leq d(x, y) + d(y, z) \).

Let note \( X_{\text{EXP}i} \) the vector given by expert i. We choose the distance called similitude [11].

\[
D(\frac{X_{\text{EXPi}}}{X_{\text{EXPj}}}) = \cos(\frac{X_{\text{EXPi}}}{X_{\text{EXPj}}})
\]

3.3 The measure of convergence / divergence

The way to calculate the distance posed, at least two main processes can be chosen to indicate a convergence or divergence.

- The first one is to evaluate the distance within the group after each meeting.
- The second one is to evaluate the evolution of experts meaning after meeting and to summarize this evolution.

This second process is not really in the scope of this paper. It is more convenient to analyse expert behaviour during the Problem Solving Method and neither to get an indication about the convergence nor of the team. To be able to infer something about the team, intermediate artefacts have to be introduced, for example: the mean of expert evolution

In this paper, we retained the first process, which consists in calculating distance between experts after each session.

We introduce two main indicators based on the distance calculation:

1) \( A_{\text{Max}} = \max_{(i,j) \in \{\text{Persons}\} \times \{\text{Persons}\}} [D(\bar{X}_{P_i}/ \bar{X}_{P_j})] \)

This indicator translates the opposition maximum between team members.

If \( A_{\text{Max}} \) is close to 0, the group can converge. If \( A_{\text{Max}} \) is very High, nothing can be inferred, may be one person is diverging, may be the group is divided.

2) \( \text{Spread}(R) = 1 - |(\text{Number of couple at distance of } r) / (\text{Total of number of distances possible in the team})| \)

If spread is close to 0, the number of person at the distance R is very close to the total of possible distances, R is very high, the group is not converging. At the opposite, if R is very close to 0, almost in the group has converge to the same expression and the same key word weighting. The group converge toward a solution.

If the spread is close to 1, the number of distance in the group near R is close to 0. Thus if R is close to 0, the group cannot converge. If R is close to 1, nothing can be inferred about the group.

With these two indicators we can build a global indicator which respects rules 5 and 6:

\( I_r = \sin(\frac{A_{\text{Max}}}{3}) \)

Indicator interpretation:

- \( I_r \) tends toward 1 means that the cumul of distance between persons below \( A_{\text{Max}}/3 \) is very low: the group converge
- \( I_r \) tends toward 0 means that the lot of distance between people are below \( A_{\text{Max}}/3 \). If \( A_{\text{Max}} \) tend toward 0 with all people then it is representative of a global convergence, else its' interpretation is effort less.

Let notes \( I_1 = I_e \cdot I_r \), \( I_2 = (I_e + I_r)/2 \),

These two indicators have been tested during the application of cog forged test banc described in the next paragraph. They are representative of a global convergence or divergence.

4 APPLICATION

4.1 Forged cog

For the application, a technical problem of a test banc for forged cog is chosen. Cog life time is evaluated with a destructive test of sampled production lots on a banc test. For the experiment two test bancs have been used, one is capable and the other reduces the life time of tested cog. A brainstorming session is used to understand mechanism of this difference and act so as reducing the impact of measure system on the measured parameter.

The purpose of this application is first to produce indicators which will help experts to converge toward a solution. For that experiment, five experts in ENSAM organisation have been chosen. Their expertise is confirmed by the fact that each of them is engineer or doctor engineer in materials and conical forged cog.

4.2 Application process

**INITIALIZATION:**

1) The first analysis had to retrieve the expert analysis and their key word: Experts’ analyses are retrieved trough templates so as driving them directly into relevant information. Key words must neither contain quiproquo (several interpretations linked to people using the word), nor polysemy into the group (several definitions into the group) so as being exploited and stored. Examples are given for exceeding theses constraints and helping experts summarizing their analyses with relevant key words. The key word collector is presented Figure 1. At this step: 36 key words have been collected. Even the subject was a technical one and experts were trustrable, none of them employed the same word to say the same purpose!

2) First synthetis: The codesign space has been used by key word.

3) First Group analysis (experts’ reactions and knowledge sharing) toward the development of an ontology: Due to the lack of semantic cross-checking, and experts’ preliminary dialogs a common vocabulary had to be build so as enabling calculation between words explained by experts. It has been done by the use of codesign space [12] and the construction of alias key

---

1 Ecole Nationale Supérieure des Arts et Métiers
word, defined by the “concatenation” of experts’ key words. This is undertaken by a strong hypothesis: if a key word is used into an alias definition, it can not be used in others. This restriction simplify the reality (a word is always used in several definitions) but help in building a group ontology constituted by the alias and exceeding semantic constraints linked to key words. 17 Alias have been founded.

**ANALYSIS – LOOP:**

4) Second Experts’ analyses: After the session, each expert is invited to reanalyse the problem and summarize it only with the set of alias.

5) Synthesis of key word retrieve & convergence measurement: At this point, all experts’ expressions have been compared and by using the chosen metric, distances between expressions have been calculated. The file used to sum up these calculi, is presented Fig 2. All these indicators have been retrieved in the co-design space. After this point, an experiment has been conducted to understand two possible solutions:

**EXPERIMENT:**

6) Experiment definition: The group was saturated of ideas. No evolution could be seen through indicators. An experiment has been leaded so as introducing facts into the “brainstorming” process. An experiment plan and a data analysis has been done so as discover new correlation, validated (or un validated) some hypothesis. The data analysis tool has been done using XmDVTool ™[13].

**CONCLUSION:**

8) The last meeting: at this meeting, the group comes (or is still) agree upon the solution to conduct so as solving the problem. Experts’ analyses are treated with the same manner than others, but this consensus lead to unique analysis, common to the entire group (or in a large part of it), summarized in the alias base. Following the rules of analysis ending (Experts signature, percentage of experts signature, management validation etc.) the process go to the 9th Step

9) Conclusion: the approved analyse is summarized with an approved keyword vector which can be used to store the case.

For the experiment, the two indicators has been constructed as presented figure 4.
4.3 Results

Several results can be point out by this experiment:

• The restriction of the problem at a technological one helps experts to focus on key words without QUIPROQUO and POLYSEMY for the group.

• The use of alias, allow to build a shared terminology, at least for the current problem

• The use of weighted keyword is useful if it exist a correspondence between a weight (0.5 e.g.) and a meaning.

• The use of indicators helps in retrieving heavy and weak signal of the group

• The use of validated and shared key words, open ways for the creation of indexed conclusions on a key word consensus.

5 SHORTCOMING AND CONCLUSION

This paper presents an analysis of a collaborative problem solving method with a key word analysis. Indicators rules have been set and on this basis, two main indicators have been built to catch team convergence and divergence. We show that those indicator are structurally enough to catch only a global team evolution.

Nevertheless, this work open the way at a structured analysis of a team’s model behaviour. Perhaps indicators based on means and range of distance between experts would have been more profitable.

The proposed case construction method makes it possible to systematize case creation with experts’ know-how. Until now, the methods of knowledge extraction were applied mainly on documents. By using the expression of concepts with weighed keywords the meaning of which is clearly defined and common to the expert team (a sort of ontology), it is possible to provide an aid to the resolution of a new problem. At the same time, this makes it possible to build a new case where the progress towards the resolution will be saved.

It is also envisaged to extend this model of problem resolution method to estimate the mechanical parts of manufacturing goods. Nowadays, this activity is carried out by experts. There isn’t any formalism to do this automatically. Each estimate on a part will be considered as a problem. Symptoms will be part characteristics (such as holes, dimensions, tolerances). The defined vocabulary (defined by the experts) could represent the concepts on which the price depends. A solution will consist of the final price but also of the distribution on the causes. It is planned to develop a web application that will support the whole process described. The XML formalism will be used for the data storage concerning the problem.

References


