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TEXT AND ILLUSTRATION BASED SENARIO EXPRESSIONS FOR CONVEYING FAILURE KNOWLEDGE

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ABSTRACT

For making use of past failure knowledge, we must convey the experience and knowledge to others. Japan Science and Technology Agency (JST, a government agency) is constructing a failure knowledge database for people to make effective use of past failure information and knowledge. Because it has a large base of information, the authors have developed effective representations for the users to reach the target information. They are the failure case illustration and text based diagonal scenario expression. A well-drawn failure case illustration generates a good image of the failure event in the readers mind, thus succeeds in passing the failure knowledge to the reader. A carefully produced diagonal scenario expression has the same effect.

This paper shows how the two fundamentally different representations work. A failure case illustration alone was shown to a group of people who were asked to define a diagonal scenario expression for the case. The reverse test started from a diagonal scenario expression to reach an illustration that the group had no prior knowledge about. Our tests showed that people can produce a fairly good representation in the other form starting from either an illustration or a diagonal scenario alone. The editor of either representation can produce a good illustration or scenario definition by breaking down the failure information and making sure that each element is inserted in them.

Keywords: design, failure, axioms, database, knowledge

1 INTRODUCTION

The "Study of Failure" has triggered several national projects in Japan, one of which is to construct a failure knowledge database so people can look up past failure cases [Hatamura, et al. 2002a]. We call the database, Failure Knowledge Database (FKDB). Here the word "failure" signifies "Human intervened events that unexpectedly produced undesired results" [Hatamura, 2002].

For its effective use this database has to offer ways for users to quickly reach the target information or related failure cases. For example, a library database allows text-matching search for the title, author, keywords and so on. For example, a library database allows text-matching search for the title, author, keywords and so on. Another feature that depends on the purpose of the database is the contents of the entries. An entry in a library database will provide, in addition to all the search fields, a description that summarizes the contents of the book so the information seeker can decide whether the entry is one that he was looking for or not.

Our former papers [Hatamura, et al. 2002b], and [iino, et al., 2002] introduced the "diagonal scenario" for characterizing failure cases, and the "failure illustration" that gives graphic representations. These expressions are effective in relaying the essence of failure cases to the information seeker. In other words, they successfully convey knowledge [Nonaka and Takeuchi, 1995], [Stamatis, 1995], and [Thannhuber, et al.2000]. The purpose of such knowledge transfer is for avoiding errors from repeating, allowing the reader to learn failure modes without having to experience one himself so that he gains more background knowledge for effective axiomatic design decomposition [Suh, 2001].

To demonstrate our claim, we had several groups of people participate in our tests. The tests exposed each group to only one of the two representations, the diagonal scenario, or the failure illustration, and recorded how well they reproduced the other. This paper reports our findings and discusses the effect of these representations.

2 UNDERSTANDING FAILURE CASES

Our earlier work [Hatamura, et al. 2002b] explained the mechanism of the human mind in "understanding" an event, that is, the information receiver has to have or be able to construct a template that matches what he conceives as an event. For understanding a failure case, it is important that the information receiver recognize the basic three elements of the case. These three elements are the "Cause", "Action", and "Result" of the event (Figure 1).

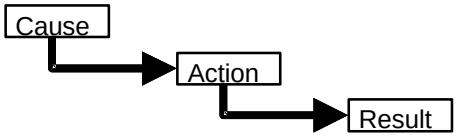


Figure 1. Three basic elements of a failure case

If any of these three elements are missing from the information receiver's mind, then he cannot construct a good understanding of the case.

Figure 2 shows how information about an event enters the mind of the first person, then how it conveys to the second. The quality of description by the first person determines how well the second person reconstructs the event in his mind.

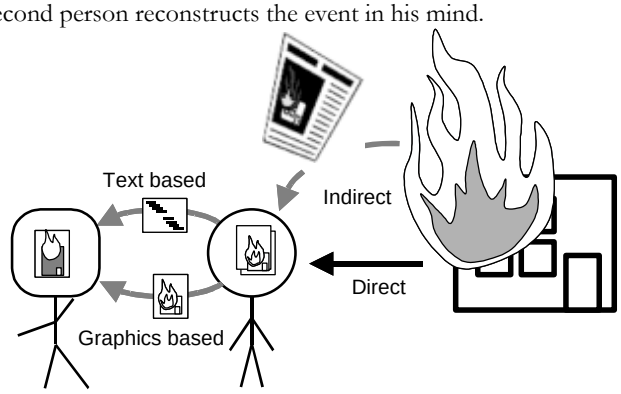


Figure 2. Conveying event information to another person

3 DIAGONAL SCENARIO AND FAILURE CASE ILLUSTRATION

3.1 DIAGONAL SCENARIO

We have introduced the diagonal scenario for expressing failure cases [Hatamura, et al. 2002b].

1. Lacked Analysis
2. Lacked Virtual Exercise
3. Careless
4. Poor Understanding
5. Removed Cover

} Cause

6. Transitional Operation
7. Changed Operation
8. Pressed Test Piece

} Action

9. Breakage
10. Deformation
11. Uneven Bearing
12. Slipped
13. Shot out.

} Result

Figure 1. Three basic elements of a failure case

Figure 3 shows one for an accident that involved a material compression test without protective cover that resulted in the test piece slipping and shooting out from the press machine almost killing the people watching.

The first 5 phrases above the first double line describe the cause of the event. The sequence of phrases start from higher level concepts and move towards lower level ones (more concrete descriptors), however, many failure events have multiple causes and the cause part of the diagonal scenario may contain more than one high level concept.

There are 10 primary factors that we call Level 1 causes and as the phrases descend the hierarchy, their levels drop. Figure 4 shows the Level 1 and 2 causes of failure (We call this diagram the cause of failure mandala from its shape that resembles a Buddhism diagram). The levels of phrases in the diagonal scenario, thus, do not necessarily increase monotonically. In case of the example in Figure 3, the levels change as follows:

Level 1: Lacked Analysis
Level 2: Lacked Virtual Exercise
Level 1: Careless
Level 2: Poor Understanding
Level 3: Removed Cover

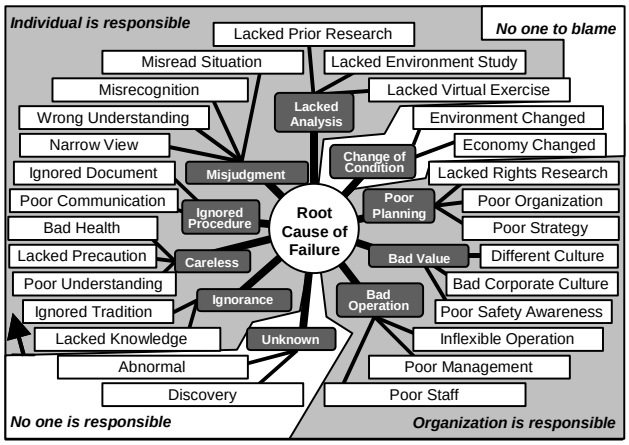
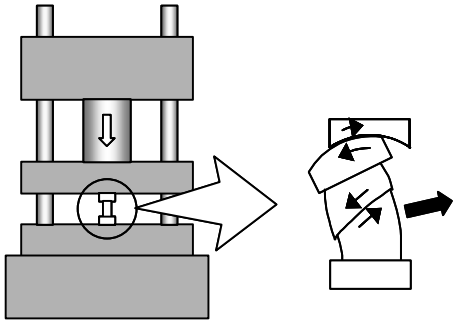


Figure 4. Level 1 and 2 causes of failure

The phrases in the Action and Result sections follow the same convention. Note that the phrases do not necessarily group into sequential three steps, e.g., sometimes an action triggers another cause in which case, some cause phrases follow some action phrases.

3.2 FAILURE ILLUSTRATION

Another representation of failure events is the failure illustration. Figure 5 shows the one corresponding to the diagonal scenario in Figure 3. The illustration consists of a simplified line drawing sketch and a sentence or a phrase that states the most important piece of failure knowledge learned through the experience.



Protective covers have a purpose

Figure 5. Example of a failure illustration

4 EVALUATING DIFFERENT TRANSFER SCHEMES

For displaying a failure case, the two schemes, diagonal scenario and failure illustration side by side better represent the information. For the study of this paper, however, we intentionally hid one, showed only the other to people and had them define or draw the other missing scheme. The purpose was to measure how well the representations transfer the failure knowledge, that is, the cause, action and result to the information receiver.

4.1 DIAGONAL SCENARIO

A well defined diagonal scenario gives the reader a virtual experience as if he went through the failure event himself. In our test for this paper we measured the effect of this transfer by having the test participants read a diagonal scenario and draw a failure illustration based on the image he developed from the scenario. We then scored the drawings by checking if they contained key elements that had been set in advance.

1. Careless
2. Poor Understanding
3. Failed Recognizing Risk
4. Ignored Procedure
5. Ignored Document
6. Ignored Operation Procedure
7. Non-regular operation
8. Emergency Operation
9. Solvent Tank
10. Inspection
11. Night Shift
12. Two persons
13. One Resting
14. One Patrolling
15. Careless Move
16. Valve
17. Left Open
18. Water
19. Tank Overflow

Figure 6. Tank overflow due to a valve left open

For the specific case in Figure 6, we set the following key elements to draw. Figure 7 shows a sample response.

a. One person patrolling at night
b. Forgetting to close
c. Valve
d. Overflowing water tank

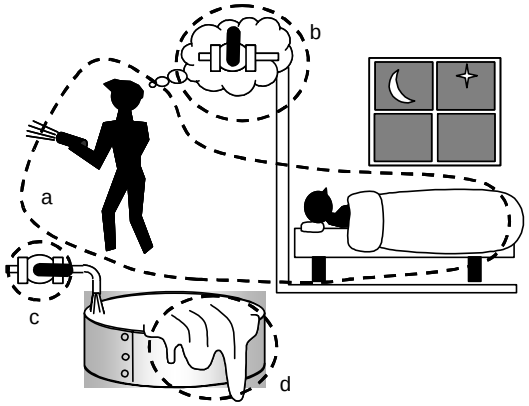


Figure 7. Illustration constructed from the scenario in Figure 6

The sample size was 34. Table 1 shows the detail. In summary each key illustration element had the following score:

a. One person patrolling at night: 53%
b. Forgetting to close: 82%
c. Valve: 94%
d. Overflowing water tank 91%

Table 1. Results of scenario to illustration test

Date Group	Pers.	One Person Patrol	Forgetting to Close	Valve	Overflowed Tank	Score out of 4	Percentage [%]
Sept. 24 Group A	A-1		O	O	O	3	75
	A-2	O	O	O	O	4	100
	A-3	O	O	O	O	4	100
	A-4	O	O	O	O	4	100
	A-5	O	O	O	O	4	100
	A-6		O	O	O	3	75
	A-7	O	O	O	O	4	100
Oct. 6 Group B	B-1		O		O	2	50
	B-2	O	O	O	O	4	100
	B-3		O	O	O	3	75
	B-4	O	O	O	O	4	100
	B-5	O	O	O	O	4	100
	B-6		O	O	O	3	75
	B-7	O	O	O	O	4	100
	B-8	O	O	O	O	4	100
	B-9	O	O	O	O	4	100
	B-10	O	O	O	O	4	100
	B-11			O	O	2	50
	B-12		O	O	O	3	75
	B-13		O	O	O	3	75
	B-14	O	O	O		3	75
Sept. 25 Group C	B-1		O	O	O	3	75
	B-2			O	O	2	50
	B-3			O	O	2	50
	B-4	O		O	O	3	75
	B-5	O		O	O	3	75
	B-6		O	O	O	3	75
	B-7	O		O	O	3	75
	B-8	O	O	O	O	4	100
	B-9		O	O	O	3	75
	B-10		O	O	O	3	75
	B-11		O	O	O	3	75
	B-12		O	O		2	50
	B-13	O	O			2	50
Score		18	28	32	31		
Percentage [%]		53	82	94	91		80

4.2 KNOWLEDGE TRANSFER BY A FAILURE ILLUSTRATION

Like a diagonal scenario, the effect of a failure illustration varies in how it conveys the failure knowledge. We also measured how well a failure illustration works by showing an illustration alone and having the participants define a diagonal scenario. We then evaluated the transfer by checking if the correct Level 1 phrases of Cause, Action, and Result appeared in the scenario. Figure 8 shows the failure illustration we used.

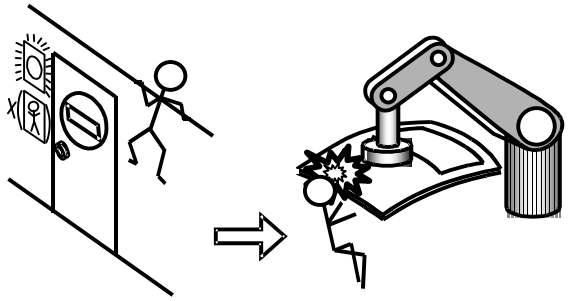


Figure 8. Climbing over a safety fence for movement test

The event in Figure 8 was a fatal accident. A maintenance engineer had to test a robot movement and if he had went through the safety door, an interlock would have kept the robot at still, and the engineer could not have checked the robot movement. He then decided to climb over the safety fence and then the operator that came on duty failed to recognize him on the other side of the fence. The operator activated the robot which then killed the first engineer. The Level 1 scenario elements we looked for in the diagonal scenario were:

Cause: Ignored Procedure, Bad Operation
Action: Dangerous/Careless Move, Poor Act
Result: Bodily Damage

Table 2 shows the detail results. The sample size was 47, and each Level 1 scenario element scored as follows:

a.	Cause: Ignored Procedure:	55%
b.	Cause: Bad Operation:	32%
c.	Action: Dangerous/Careless Move:	43%
d.	Action: Poor Act	40%
e.	Result: Bodily Injury	98%

5 DISCUSSION

The text based diagonal scenario and the graphic failure illustration have their strengths and weaknesses. When we compare the two tables in the Appendix, the scenario more accurately convey the failure knowledge to the reader. The participants in our tests, however, were given the assignment of drawing an illustration from the scenario, thus, they rather carefully read the scenario instead of glancing through them.

The failure illustration cannot effectively express high level causes or abstract background information.

For both representations, editing an effective one requires some skills and experience. It is interesting to note that those who produced poor illustrations tended to edit good scenarios, and vice versa. In any case, we believe intense training will help the editors produce good diagonal scenarios and failure illustrations.

In terms of searching an FKDB, failure illustrations greatly aid the information seeker, however, looking through just a list of sketches makes it difficult to find the target. Combining the text based scenario element and visual illustrations will offer the most effective search.

6 CONCLUSION

By showing only one representation to the information receiver and having the receiver produce the other representation, we quantified how well knowledge transfer methods work. The two methods we evaluated were; i) a text based diagonal scenario expression and ii) a line drawing, failure illustration.

A well written diagonal scenario effectively transfers the failure knowledge, however, it lacks the visual impact of the failure illustration.

The failure illustration helps the information receiver in building an image of the event in the mind. Therefore, having a virtual experience of the event is much easier when a failure illustration is available. It is difficult, however, to draw background information or high level causes in the illustration. Guessing the right causes from the failure illustration rely heavily on the skills and experience of the person.

Our findings greatly help our next step in defining an effective way of searching through failure case data.

Table 2. Results of illustration to scenario test

Scenario Element		Cause		Action		Result		
Date Group	Pers.	Ignored Procedure	Bad Operation	Dangerous/ Careless Move	Poor Act	Bodily Injury	Score	Percentage [%]
Sept. 24 Group A	A-1					O	1	20
	A-2	O	O	O		O	4	80
	A-3			O		O	2	40
	A-4		O	O	O	O	4	80
	A-5				O	O	2	40
	A-6	O				O	2	40
	A-7	O		O		O	3	60
Oct. 6 Group B	B-1	O				O	2	40
	B-2	O		O		O	3	60
	B-3			O		O	2	40
	B-4				O	O	2	40
	B-5			O		O	2	40
	B-6	O	O		O	O	4	80
	B-7	O	O		O		3	60
	B-8			O	O	O	3	60
	B-9	O		O	O	O	4	80
Sept. 25 Group C	C-1	O		O		O	3	60
	C-2	O		O		O	3	60
	C-3					O	1	20
	C-4					O	1	20
	C-5	O				O	2	40
	C-6	O		O		O	3	60
	C-7		O			O	2	40
	C-8		O			O	2	40
	C-9					O	1	20
	C-10					O	1	20
	C-11					O	1	20
	C-12	O	O	O		O	4	80
	C-13				O	O	2	40
Nov. 14 Group D	D-1	O	O		O	O	4	80
	D-2		O			O	2	40
	D-3	O			O	O	3	60
	D-4			O		O	2	40
	D-5	O	O		O	O	4	80
	D-6				O	O	2	40
	D-7					O	1	20
	D-8	O		O		O	3	60
	D-9	O	O	O		O	4	80
	D-10	O	O	O	O	O	5	100
	D-11	O			O	O	3	60
	D-12	O	O		O	O	4	80
	D-13	O	O		O	O	4	80
	D-14	O			O	O	3	60
	D-15	O				O	2	40
	D-16	O		O	O	O	4	80
	D-17	O		O	O	O	4	80
	D-18		O	O		O	3	60
Score		26	15	20	19	46		
Percentage [%]		55	32	43	40	98		54

7 ACKNOWLEDGMENTS

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