Coloured Cognitive Maps for Modelling Decision Contexts

John Venable
Curtin University of Technology
School of Information Systems
Perth, Western Australia
VenableJ@cbs.curtin.edu.au

Abstract

Cognitive Mapping is a form of Causal Mapping developed and popularised by Colin Eden and Fran Ackermann (Eden, 1988, Eden & Ackermann, 2001, Ackermann and Eden, 2001). This paper reports on research in progress to develop, test, and employ extensions to cognitive mapping to support decision making in the context of problem formulation and solutions derivation, comparison, and choice. The paper describes extensions to the method and notation, include the use of colour (or bolding) to indicate whether nodes are desirable or undesirable, the conception of two forms of cognitive maps, the first of which focuses on the current, undesirable context and the second on a desired, future context (and how to achieve it), and a procedure for developing and converting between these two forms of cognitive maps. The paper also describes the current state of the research on coloured cognitive maps, open issues, and planned and proposed future research.

1. Introduction

Cognitive Mapping is a form of Causal Mapping developed and popularised by Colin Eden and Fran Ackermann (Eden, 1988, Eden & Ackermann, 2001, Ackermann and Eden, 2001). Cognitive Maps are related to concept maps (sometimes called mind maps). In mind maps, though, the links can have any meaning, while in cognitive maps, links are only causal (as described below). Eden & Ackemann's work has focussed primarily on the context of strategic planning and decision making about organisational strategies. The author's work instead focuses on decision making in a context of problem solving, particularly on problem analysis and formulation and the transition to solution identification, analysis, and choice. This paper describes an enhanced version of this diagramming technique as developed by the author.

The enhancements given in this paper to the cognitive mapping technique as developed by Eden and Ackermann include …

1. A conceptualisation of two forms of problem statements and two corresponding forms of cognitive maps: "problems as difficulties" and "problems as solutions"
2. A procedure for straightforward conversion between these two forms of cognitive maps
3. Colouring of nodes to indicate desirability or undesirability
4. An overall process for problem analysis with cognitive maps

David Kroenke has defined a problem as "A *perceived* difference between *what is* and *what should be*" [emphasis added]. It is argued in this paper that the above enhancements provide a straightforward way to analyse a problem, because it aids in exploring first the *what is* about the problem situation and then effectively transitioning to exploring the *what should be* in the problem situation. Thus it explores both *problem diagnosis* first and then problem *solution derivation* second.

Section 2 gives an overview of the enhanced cognitive mapping notation, including coloured nodes (enhancement 3 above). Section 3 gives an overview of a new procedure for problem analysis with cognitive maps (enhancement 4 above), which includes a conceptualisation of two forms of problems (enhancement 1 above). Sections 4 through 6 describe each of the three stages in the procedure (Problem Diagnosis, Cognitive Map Conversion, and Solution Derivation) in more detail. Section 7 describes the current state of the research, open issues, and planned future research. The paper concludes with a summary and review of the more important points covered in the paper.

2. An Enhanced Notation: Coloured Cognitive Maps

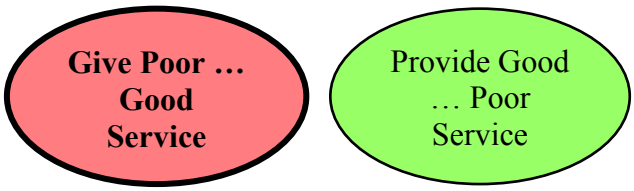
The notation for cognitive maps (CMs) is relatively simple. Only two primary symbols are used: nodes and arrows. See figure 1 for a summary of the notation.

Nodes are drawn with circles or ovals (or some other convenient symbol) and represent some aspect of a problem, whether it be the problem itself, an undesirable consequence or implication of the problem, a cause of the problem, some planned action relating to the problem, or potential solutions to the problem. Text is placed within each node, which captures the meaning of the node. The text in the node can also be split into two parts or poles, which are separated by an ellipsis symbol ("…"). The text in these poles represents opposites and the ellipsis is read as "as opposed to". For example, the text in a node might be "Poor service … excellent service". This would be different from "Poor service … acceptable service".

An extension proposed in this research is that the nodes of a CM can be coloured to indicate whether the node represents something that is desirable or something that is undesirable. Green coloured nodes represent desirable circumstances and red coloured nodes indicate undesirable circumstances. Generally, one of the poles in a node should be desirable and the other one undesirable, with the colour corresponding to the primary pole (the text that comes first). Where colour cannot be used, another indication is needed, such as bold print and darker lines for undesirable nodes (as used throughout this paper). An advantage of using coloured (or bold) nodes is that it gives a quick visual indication of the desirable vs undesirable parts of the CM without needing to read the details of the text.

Node:

- Goal, activity, problem, cause, implication, etc.
- Poles separated by ellipsis,
- Red/bold = undesirable, Green = desirable



Arrow:

- Causal or contributory
- Plus sign or minus sign (plus assumed if absent)

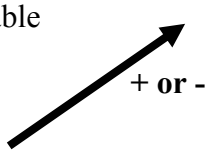


Figure 1: Coloured Cognitive Map Notation

Nodes are connected to each other with arrows. Arrows represent some degree or amount of causality between the nodes, i.e. the node at the tail of the arrow causes (to some extent) the node at the head of the arrow. Figure 2 shows three generalised examples of causality in CMs. Table 1 shows some further synonyms for the various degrees of causality.

The arrows may optionally have plus or minus signs attached to them. If a sign is omitted, a plus sign is assumed. If a minus sign is attached, it means that the causality is reversed; instead of the node at the tail of the arrow *causing* the node at the head of the arrow, the node at the tail *prevents* the node at the head or *causes its opposite pole*. Table 1 also shows alternative meanings for the arrow when it has a minus sign attached.

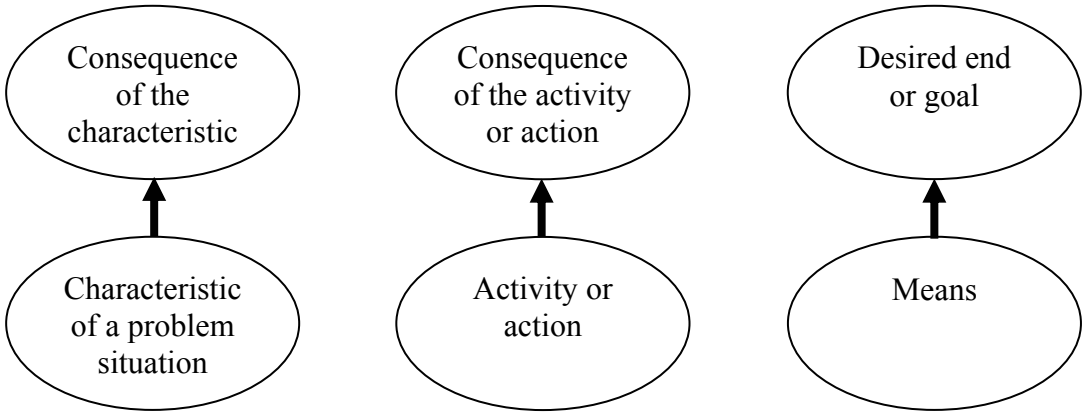


Figure 2: Generalised examples of causality of arrows in cognitive maps

An arrow with a plus (or no) sign means	An arrow with a minus sign means
Causes	Causes the opposite pole
Implies	Implies the opposite pole
Enhances	Reduces
Contributes to	Detracts from
Increases	Decreases
Allows	Disallows
Enables	Prevents

Table 1: Synonyms for the meaning of the arrow

3. A Procedure for Analysing Problems with Cognitive Maps

In order to make effective use of cognitive maps for problem analysis, a procedure is needed to guide the user(s) of cognitive maps as to what specific actions to perform and how. The procedure for problem analysis proposed in this paper is divided into three stages (see figure 3). First is problem diagnosis, in which a cognitive map is developed of the problem as difficulties. The second stage is to convert the cognitive map of the problem as difficulties into a cognitive map of the problem as solutions. The resulting cognitive map is incomplete, but a basis for progressing in the third stage. The third and final stage is solution derivation, in which the cognitive map of the problem as solutions is expanded with various candidate or potential solutions. Each of these three stages is described in more detail in sections 4 to 6.

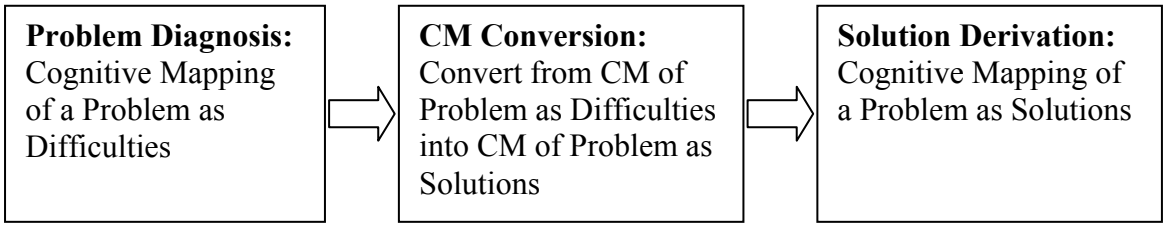


Figure 3: Procedure for Problem Analysis with Cognitive Maps

4. Problem Diagnosis: Analysing the Problem as Difficulties

It is a key assumption of this research that effective problem solving requires problem solver(s) to develop a sufficiently rich understanding of the current, problematic situation (the decision context) before proceeding to solution choice. The problem solvers need to understand what is undesirable about a problematic situation, why it is problematic to the stakeholders, and what the causes of the problem are – i.e. what things allow the undesirable circumstances to exist. These all need to be carefully analysed in order to develop the rich understanding necessary to come up with effective and appropriate solutions to the problem.

Cognitive Maps (CMs) can be used to support this by drawing CMs that focus on the current situation (or context) and what is undesirable about it. We call these CMs of the "Problem as Difficulties". Cognitive maps of problems as difficulties will primarily have nodes that are undesirable (coloured red or bolded). However, some nodes will still likely be desirable ones. As they say, every cloud has a silver lining. A CM of a Problem as Difficulties can be built up by beginning with an initial statement of the problem in one node, splitting that into separate nodes of it is a composite, rather than elementary, problem. Then other nodes are added that explore the consequences of the problem (which are what makes it undesirable) and the causes of the problem. There is a 10-step procedure for carefully doing this, as shown below.

Problem Diagnosis: Procedure to Analyse the Problem as Difficulties

1. Start with a concise statement of a problem in a node.
2. Add nodes above the problem node for symptoms/implications/consequences of the problem and connect with arrows from the problem to the implication/consequence. Note that a problem may have desirable as well as undesirable consequences, so colour the nodes appropriately.
3. Make sure the node text is clear and unambiguous, using opposite poles to clarify.
4. Add nodes further above for implications of the implications, etc., and connect with arrows. Again, colour the nodes appropriately.
5. Add nodes below the problem node for causes and connect with arrows from the cause to the problem.
6. Add nodes further below for causes of causes, etc. and connect with arrows.
7. Add nodes above causes for other consequences of causes, including desirable ones, and connect with arrows.
8. Recheck all nodes that the text is clear and concise and addresses only one thing. If necessary, split complex nodes into two or more nodes and rejoin with new arrows.
9. Recheck all arrows that the causality is clear. If necessary, add new nodes and arrows in between existing nodes to clarify.
10. Stop when all nodes are clear, all arrows correctly show causality, and all relevant areas of the problem as difficulties have been covered.

Figure 4 shows a typical (but very simplified) pattern for a cognitive map of a problem as difficulties. A full CM would be a much larger network of nodes.

Figure 5 gives a simple example of a problem as difficulties. Note that which nodes are called problems, implications, or causes really depends on what level you started at with your initial statement of what is the problem. Ultimately, all of the nodes in figure 5 could be considered problems, just at different levels. The important part is to see how the different aspects of the

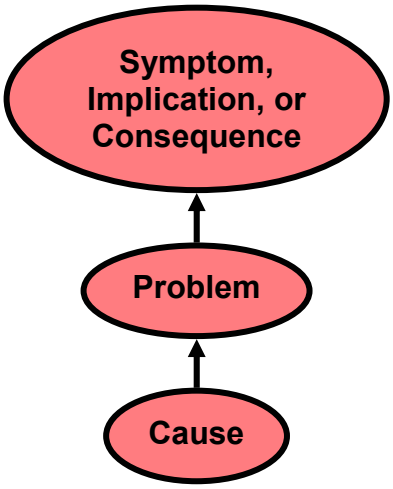


Figure 4: Pattern of cognitive map of problems as difficulties

problem relate to each other. This is captured with the causal arrows. Note as well that the cognitive map in Figure 5 could still be further expanded with other causes toward the bottom (e.g., poor work skills) and other implications or consequences toward the top (e.g., lower profit). It is also important to be sure that you have identified and included all of the relevant aspects of the problem in your cognitive map of a problem as difficulties.

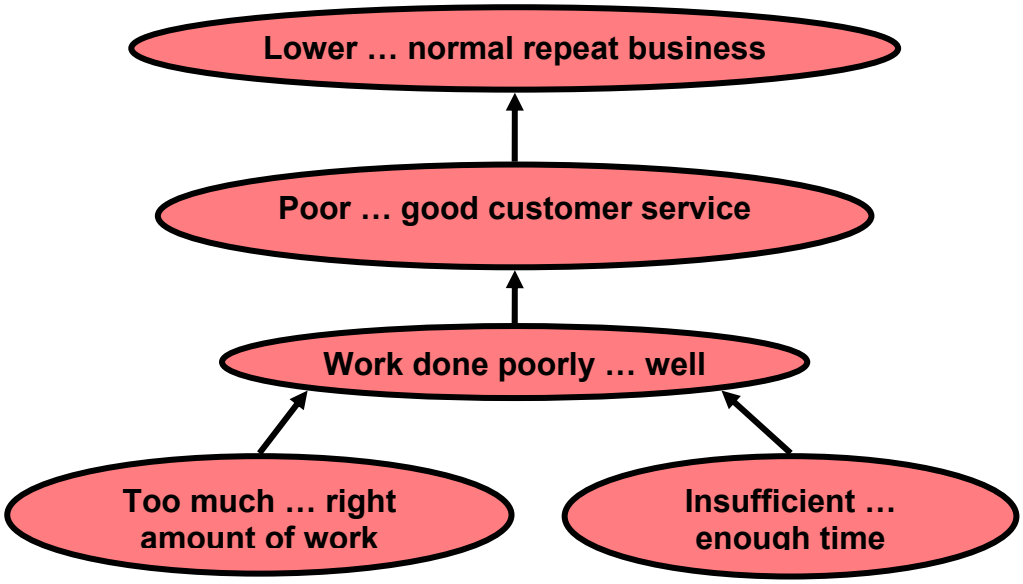


Figure 5: Example cognitive map of a problem as difficulties

5. Cognitive Map Conversion

Once a problem is fully analysed and diagnosed, then we can begin thinking about solutions. However, in order to do that, we need to change our mode of thinking from what is undesirable to what is desirable. We can support that with a simple transformation of our CM of the problem as difficulties into a CM of the problem as solutions. Figure 6 shows a general pattern for an initial cognitive map of a problem as solutions (cf. Figure 4 above).

The conversion procedure is simple and straightforward. Each node that is undesirable is edited so that it is desirable and vice versa. In general, to do so, every node in the cognitive map must have its poles reversed, so that what was once the primary pole is made the

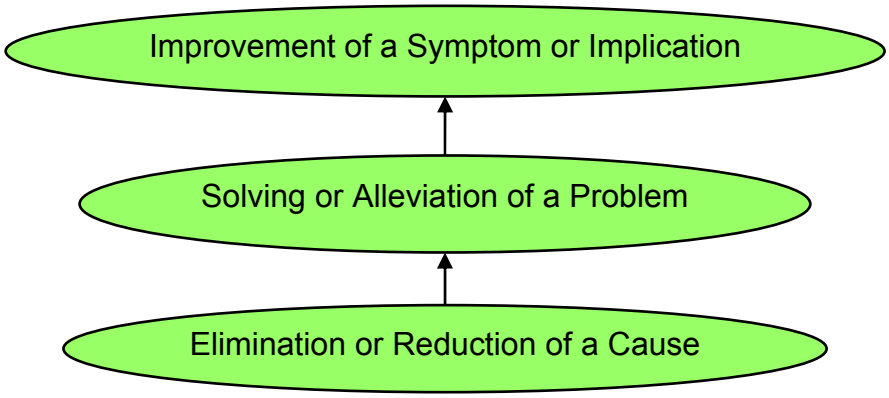


Figure 6: Pattern for an Initial Cognitive Map of a Problem as Solutions

secondary pole and what was once the secondary pole is transformed into the primary pole. The colour of each node is also changed to indicate the change. In switching the poles, usually, one must modify the text for poles of nodes so it makes sense and is appropriate for its colour (desirability). In CMs of problems as solutions, the text of the nodes should be in the imperative tense, i.e. a command, with an action verb first followed by an object noun, such as "Do this" or "Stop doing that". The text is usally changed to be *elimination or reduction* of causes, *solving or alleviation* of problems, or *improvement* of symptoms or implications. There is a step-by-step procedure for carefully doing this, which is given below.

Cognitive Map Conversion: Procedure to Convert the CM of the Problem as Difficulties to a CM of the Problem as Solutions

Reverse all nodes to make undesirable nodes desirable and desirable nodes undesirable

1. Change colour of all nodes – red to green and green to red.
2. Switch the opposite poles of the text – primary pole to secondary, secondary pole (if present) to primary.
3. Add or modify text for poles of nodes so it is appropriate for its colour and matches with the opposite pole. All nodes must begin with a verb in the imperative (command) tense, followed by an object noun.
    a. *Elimination or reduction* of causes
    b. *Solving or alleviation* of problems
    c. *Improvement* of symptoms or implications

Figure 7 gives an example of a conversion, which shows the conversion from the cognitive map given in figure 5.

6. Solution Derivation

Once an initial cognitive map (CM) of a problem as solutions has been derived from the CM of the problem as difficulties, it needs to be enhanced to explore different potential solutions and the consequences if one was to implement one or more of the potential solutions. Solutions cause the reduction or elimination of causes and therefore indirectly solve or alleviate problems. Possibly, a solution may directly solve or alleviate a problem, but the causality of such a link must be considered carefully to determine whether it is correct. One should also explore *undesirable* consequences of implementing a solution as well and append those to the CM accordingly. There is a five-step procedure for carefully doing this, which is shown below.

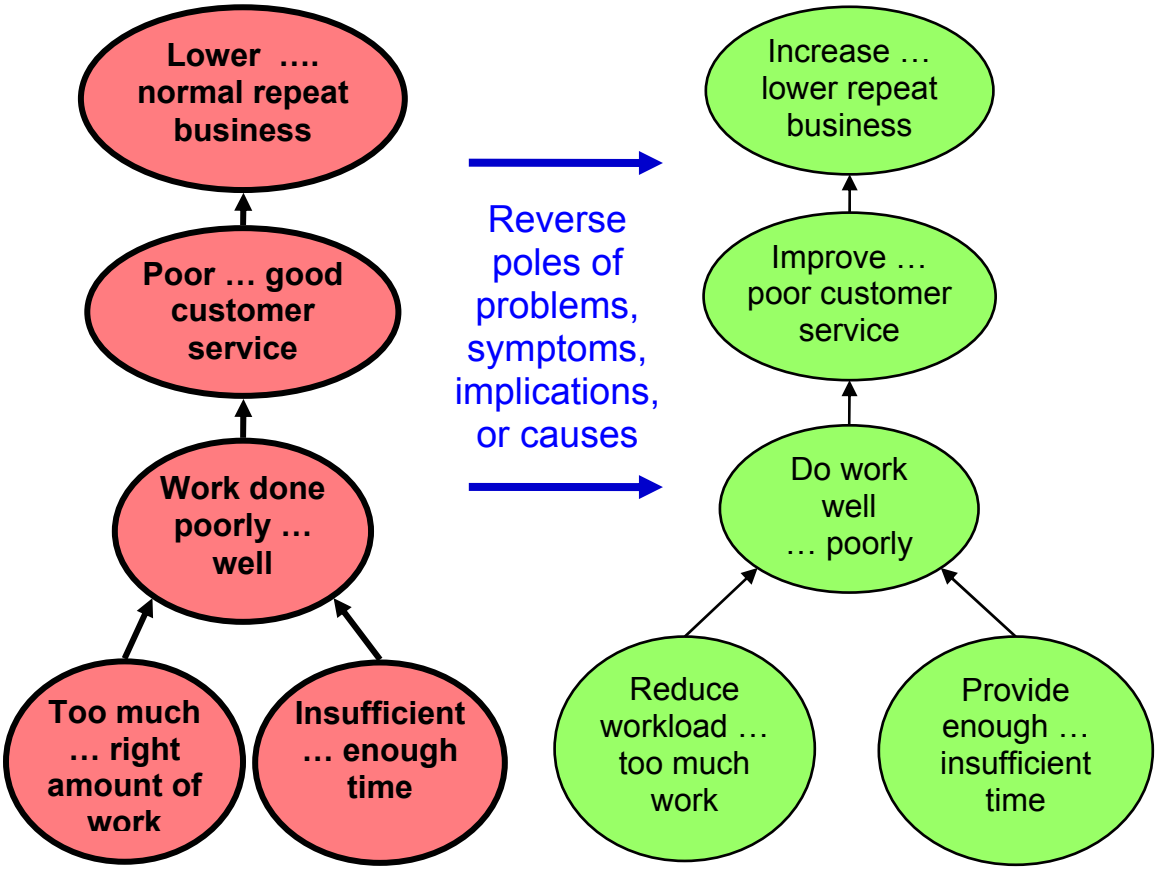


Figure 7: Example Conversion to an Initial Cognitive Map of a Problem as Solutions

Solution Derivation: Procedure to Analyse the Problem as Solutions

1. Add nodes toward bottom for solutions - how to achieve elimination or reduction of causes.
2. Add more nodes below for how to achieve the solutions.
3. Add nodes above for other consequences of solutions, possibly undesirable ones.
4. Review and make sure that all nodes' text is clear, unambiguous and begins with an imperative (command) verb, followed by an object noun.
5. Make sure the node connections are appropriate and that arrows connecting nodes are correct.

Figure 8 shows a general pattern for an augmented CM of solutions, i.e. one that adds potential solutions and consequences to the initial CM produced by the conversion described above. Figure 9 shows an example of an augmented CM (based on Figure 7 above), which adds some potential alternative solutions and considers undesirable consequences of the potential solutions. We can see that there are both desirable and undesirable consequences of the potential solutions. The resulting CM gives a good perspective for understanding the benefits and costs of the potential solutions and how they trade off against each other.

7. Status of Research

As noted in the introduction, this is research in progress. This section describes what has been done so far with coloured cognitive maps, open issues that have been identified, and planned future research.

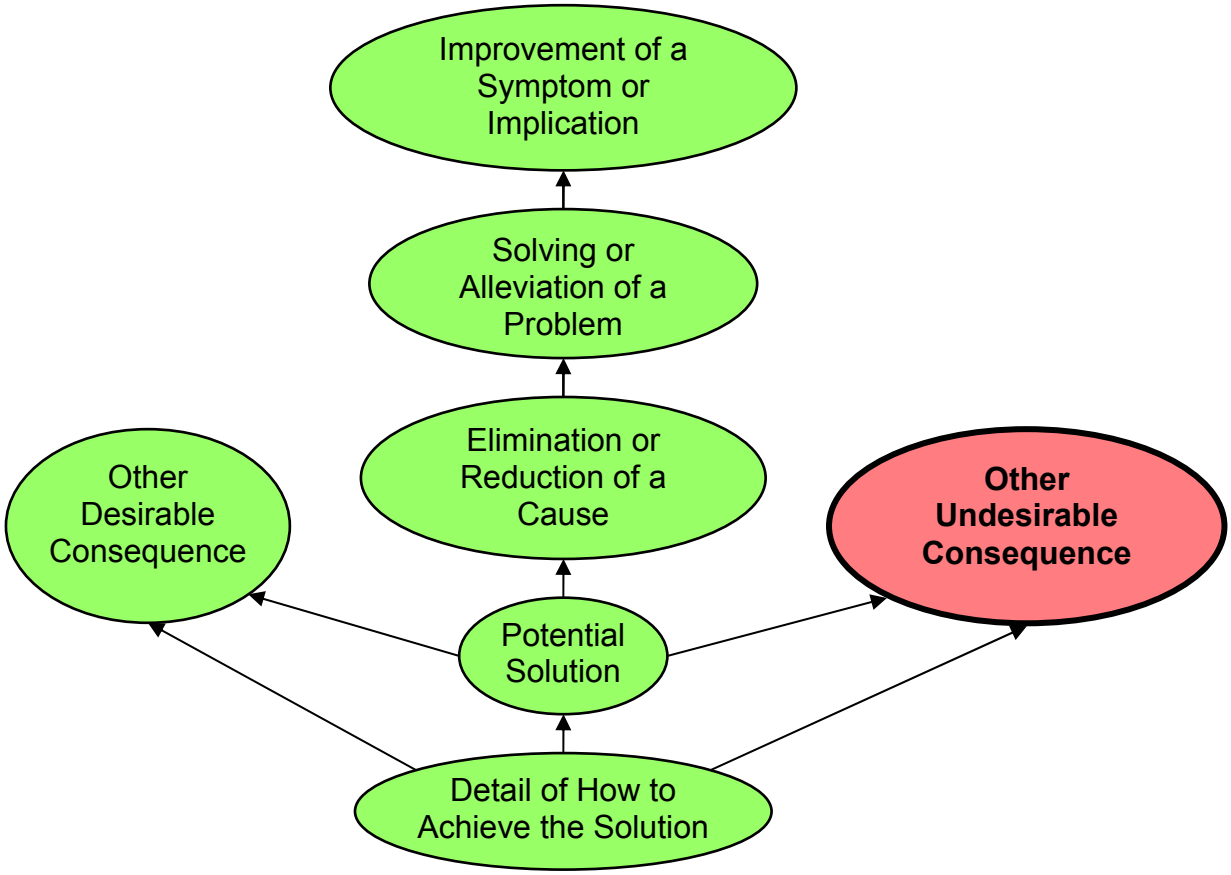


Figure 8: General Pattern for an Augmented Cognitive Map of a Problem as Solutions

7.1 Research Progress

So far, a notation and elementary procedures for using coloured cognitive maps have been developed and worked out. Testing and evaluation of the notation and procedures has been limited so far to its use by first year students in a unit titled "Problem Analysis". The context of the unit is in an Information Systems undergraduate degree program, as a follow-on unit to an Introduction to Information Systems and as a first unit in a stream of units relating to Systems Analysis. Students learn the technique (along with others in the unit curriculum), apply it individually in tutorials, and then apply it in groups on their major assignments (to produce an analysis report on some arbitrary, but complex problem.

Experience with the students thus far has been positive as many are able to come up with reasonably penetrating analyses of complex problems. Of course, expectations are fairly low for first year students. Additionally, they seem to be able to use the diagrams in group situations, i.e. either in sessions guided by tutors or within their assignment groups.

However, evaluation thus far can be characterised as informal and non-rigourous; more rigourous evaluation of the new method is needed. More careful gathering of data with student users is possible and could be very enlightening. More formal experimental evaluation is also possible, but evaluation in more naturalistic settings should be conducted.

7.2 Open Issues

Several sorts of issues remain open, including the form of the notation, the mode of employment of the notation (e.g. by individuals, by consultants in collaboration with individuals, or by groups of decision makers), and tool based support for the notation and method.

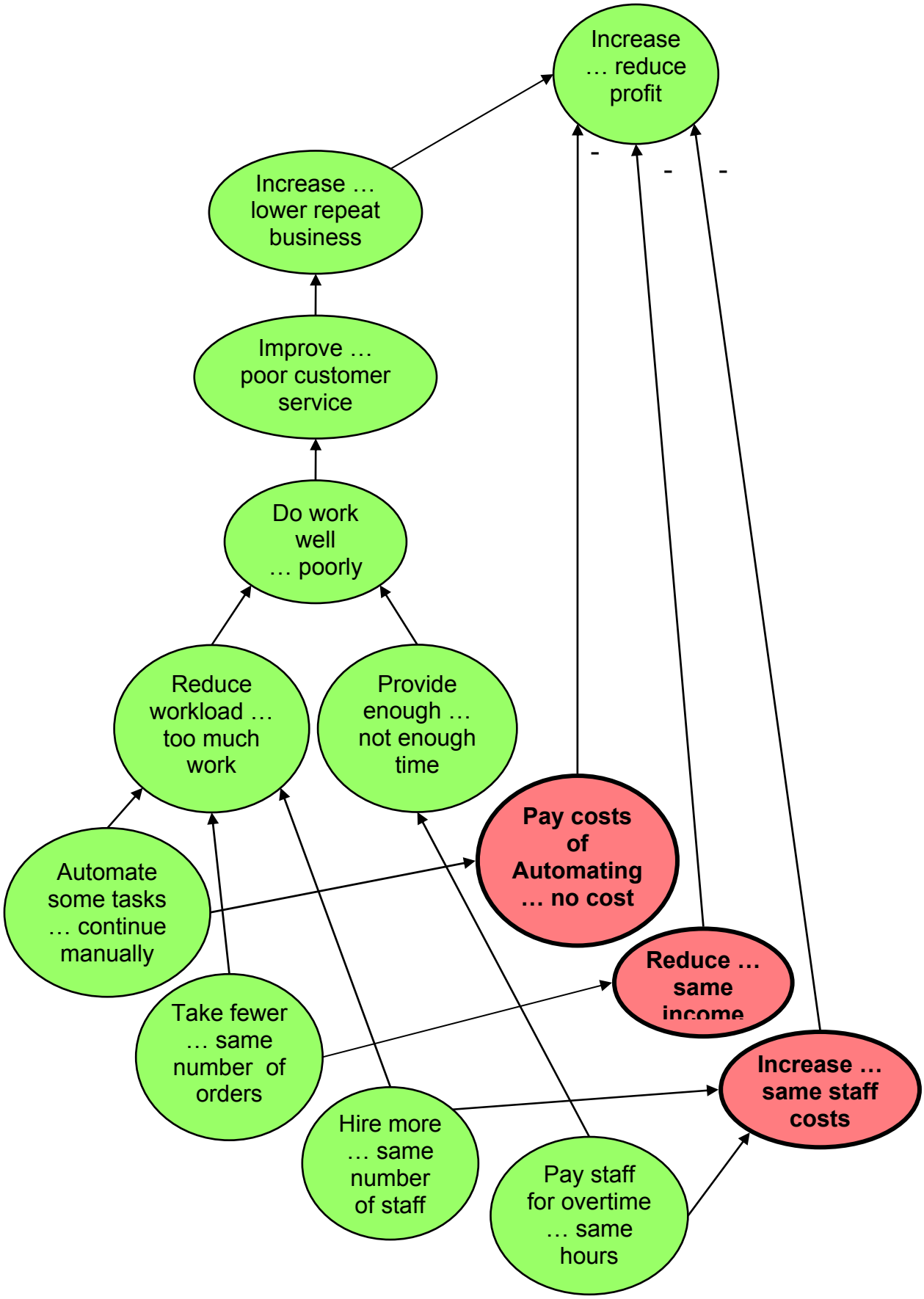


Figure 9: Example Augmented Cognitive Map of a Problem as Solutions

The form of the notation could be made somewhat more complex to yield finer gradations of perception of the problem and solution context. For example, rather than being just one shade of red or green, the notation could use darker shades of red or green to indicate nodes that are more desirable or undesirable and lighter shades of red or green for nodes that less desirable or undesirable (or even balanced/both). Similarly, the lighter shades of colours (or even white or other colours) could be used to indicate nodes where the desirability vs undesirability is unknown, unevaluated, or an open matter of group debate.

Another variation on the notation would be to use the width of the arrows to indicate the strength of the causality. Fat arrows could indicate very strong causality, either mandating or preventing (if there is a minus sign) the node at the head of the arrow. Thin arrows could indicate weak causality or influence.

Building on the levels of desirability or undesirability in the nodes and levels of causality in the arrows, one could try to formalise the diagrams and perform forms of automated analyses, which could be used to support comparison of different candidate solutions in a network of candidate solutions and outcomes in a CM of the problem as solutions. The groundwork for this could also be laid at the stage of analysing the CM of the problem as difficulties (before conversion).

Issues relating to the mode of use also have not been explored, such as how consultants or other experts might use the technique to interact with client(s) and how useful or well received that might be. Similarly, issues of group interaction using coloured cognitive maps have not been explored. However, Eden and Ackermann have already developed extensive experience and demonstrated value in these areas using regular (non-coloured) CMs. Nonetheless, coloured cognitive maps have not been used in these settings.

Tool support is another area that is not yet explored. Editors for coloured cognitive maps could be built, similar to Decision Explorer (available from banxia.com), which provides extensive tool support for regular cognitive maps, including editing, navigation, and analysis. Group Explorer also provides support for co-located groups. Automation of analysis with such tools as described above would also need to be tried out and evaluated.

7.3 Planned Research

More formal evaluation of the technique in classroom settings is planned. Initially this will be an evaluation of the elementary (unshaded) form of coloured cognitive maps.

The author also plans to work together with other researchers to try the technique out in consulting environments, through a programme of action research.

The author is also collaborating with a different researcher to build and evaluate a collaborative tool to support student groups in creating, discussing, editing, and using coloured cognitive maps. For the moment, this is planned to be in their elementary (unshaded) form. Such a tool would have not only the purpose of supporting the use of CMs in decision making, but also of supporting learning of the coloured cognitive mapping technique and also being able to aid instructors in supporting and assessing student learning.

8. Summary

Cognitive mapping is a graphical technique that can be used to model parts of a decision context and to analyse problems from problem diagnosis through solution derivation and comparison. This paper has proposed a simple and straightforward way to analyse problems using the coloured cognitive mapping technique. In particular, it has discussed four extensions to cognitive mapping from the existing literature – a conceptualisation of two

kinds of problems (problems as difficulties and problems as solutions), the use of coloured nodes to indicate desirability or undesirability of the node, a simple procedure to convert cognitive maps from problems as difficulties into problems as solutions, as well as an overall process encompassing the above three extensions for using cognitive maps to support and facilitate analysis of problem situations. Additionally, the technique supports generation of potential solutions to the problem based on the understanding of the problem situation (context) and analysis and comparison of the potential (candidate) solutions.

While a basic approach has been defined, several areas of open research issues remain, some of which are identified in the paper.

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