A Method for Solving Complex Problems Using Computer Interaction

Donald V Steward
Steward@Problematics.Com
© Donald V Steward 2009
Draft for Comment Only – Version B Revision 4

ABSTRACT

Many significant problems are not being properly solved today because of the inabilities of humans to handle the reasoning and the large number of considerations involved. These failures are often costly and sometimes tragic.

The Explainer is an interactive method for logically describing the context of a problem so that the causes of its behavior or how to change its behavior can be explained. It offers a logical language to discipline discussions about how to solve large, complex problems.

The Explainer or something equivalent is not being used today probably because skeptics can point out there can be circumstances when there are cause-and-effect circuits where the method will not yield solutions within reasonable computing times. But optimists point out that many significant problems don't involve cause-and-effect circuits and these problems can be solved very quickly. When there are circuits, subject to certain reasonable but not yet proven assumptions, most of these problems can also be solved in reasonable computing times. This makes it possible to solve many important problems that today would remain unsolved or incorrectly solved.

The key is to represent the circumstances of a problem in terms of assertions and cause-and-effect statements.

The Explainer has been used to solve problems as diverse as explaining the causes of medical symptoms, or finding a solution to the financial liquidity crisis.

1.0 The Explainer Problem

Every day our society is confronted with incorrectly solved problems, often with disastrous consequences. People are very limited in their ability to use logic and deal with all the considerations required to solve complex problems properly. This leaves room for ambiguities that become filled by unidentified assumptions, unintended or self-interested distortions of the problem, or various irrationalities that can lead to poor decisions, misunderstandings, and unnecessary conflict.

The issue of concern here is to determine whether these problem solving discussions can be framed in such a way that better logic can be brought to bear and the computer used to handle more considerations, thus resulting in better solutions to many important problems that presently are not being properly solved.

2.0 Cause-and-Effect Language for Problem Solving

It will be shown that by phrasing the situation from which a problem arises in terms of assertions, i.e. propositions, and cause-and-effect relations, better logic can be used to solve complex problems. And because the process can be formalized, the computer can be used to deal with more concerns than otherwise could be considered.

This reduction of the problem situation to assertions and cause-and-effect relations can be done if as each thought is presented, questions are continually asked as to why this should be believed, and then why that should be believed, and so forth until the thought has been reduced to simple assertions and cause-and-effect relations. Once in this form, it becomes possible to obtain a logical description of the situation from which to solve the Explainer Problem.

The Explainer Problem is: Given a situation and a behavior, infer the most likely causes that would explain that behavior. This is sometimes called abduction. That behavior may be behavior that is observed or new behavior that can be obtained by taking certain actions.

Solving the Explanation Problem will be shown to be fundamental to solving many types of problems that might previously not have been thought of as explanation problems.

3.0 The Skeptic and the Optimist

The skeptic would be quick to point out that there can be explainer problems that could not be solved within reasonable computing times because they fall into the classification of NP-Complete problems. Thus the skeptic would look no further. But the optimist would note that although there are limits, there are still many important problems that can still be solved in very reasonable computing times. This article pursues the optimistic approach and contends that this approach leads to better solutions of complex problems than otherwise possible.

Too many skeptics and not enough optimists may account for why we don't see such a method being widely used today to solve many serious problems, among them many social problems that if not solved properly can lead to conflict and violence.

The cause-and-effect relations for many significant problems do not contain circuits. These problems do not confront the NP-Complete difficulties that might make their computing times impractical. They can be solved very quickly. But those problems that do involve cause-and-effect circuits can involve the NP-Complete characteristics. But many and perhaps most of these problems can still be solved in reasonable computing times by using an efficient search process and several reasonable but not yet fully proven assumptions to reduce the number of remaining free variables that must otherwise be determined be exhaustive combinatorial analysis.

The method will be explained using the most elementary propositional logic so that it can be understood without the need to be familiar with more sophisticated techniques such as Horn clauses, resolution, or forward or backwards chaining.

4.0 Cause-and-Effect

Cause-and-effect will be interpreted as implication. A is caused by B is represented as A ← B, i.e. A is implied by B. Note that implication allows A to be true even though B may be false. This provides for the possibility that A may be true because it has another cause from outside the system under consideration.

If A is caused by B, and B is caused by C, it can be concluded that A is caused by C, thus eliminating the intermediate effect B. As long as there are no circuits in the cause-and-effect relations, this can be used to eliminate intermediate effects to state the behavior as a Boolean expression of certain primary causes, i.e. propositions. These Boolean expressions will be made up of terms involving ANDs and NOTs, with the terms separated by ORs. Each term represents an explanation.

5.0 How We Explain

When we normally try to explain a behavior, we first think of all the plausible explanations, i.e. hypotheses. A plausible explanation is one that would lead to the behavior to be explained. Generally for any behavior there will be a number of plausible explanations. But most of them will not be reasonable for the circumstances of the problem.

Then we look at each plausible explanation and consider what assumptions are required by that explanation and the consequences if that explanation were correct. The consequences can be obtained by the use of simple deduction. If the explanation involves assumptions or would have consequences that are not likely to be valid, that explanation is rejected and other plausible explanations are considered until hopefully a most likely explanation remains.

6. Explaining the Cause of a House on Fire

For example, if it is observed that a house is on fire, one may wish to explain what caused it. First a number of plausible explanations may be considered. The house fire might have been started by a burning ember blown from a neighboring house on fire. If that were the explanation, a consequence to be expected would be that a neighboring house would be observed on fire. If no neighboring house were on fire, another explanation may be proposed. Arson? Its consequence would be that a fire accelerant may have been used. Is there any sign of a fire accelerant present? How about children playing with matches? Were there children present when the house caught on fire?

In this example, the plausible explanations are already recognized by experience. But often, as in the medical diagnostic example below, the plausible explanations must be built up from more primitive pieces of knowledge through the use of cause-and-effect reasoning.

7.0 Describing the Prevailing Situation

Once the prevailing situation can be formalized as assertions and cause-and-effect relations, a computer can help the user do the proper reasoning. But in the process it may ask the user for further information to establish whether or not the assumptions and consequences of an explanation are likely to be valid. This added information can lead to a better solution.

8.0 Circuits and the NP-Complete Difficulty

If there are no circuits in the cause-and-effect statements, the solution to the Explainer Problem is quite straight-forward. A great many problems do not involve circuits, and thus can be solved quite simply.

As will be seen later, when there are circuits, the process can become more difficult and conceivably in some instances impossible to handle within practical computing times. But there is reason to believe that those instances where a problem cannot be solved in a reasonable computing time are rare when solving realistic problems.

9.0 The Explainer Can Solve Many Different Types of Problems

Being able to solve the explainer problem is the key to solving a great many apparently different types of problems. For example, it can be used to develop diagnostic tools for medical symptoms or for explaining the faults in various mechanical systems or processes. It can also use evidence to obtain the best explanations for what happened in the past such as in solving crimes or interpreting historical or archeological evidence.

Much less obvious is how it can be used to design something by using the cause-and-effect properties of the available components to explain the requirements specifications of what is being designed. This will produce a number of plausible designs with the best design chosen by using criteria such as cost, manufacturability and so on.

And it is also interesting to note that this method can be used to develop systems that can learn by being able to explain what happens to them and then turning these explanations into cause-and-effect statements that can be added to the existing repertoire of cause-and-effect statements, thus making the Explainer recursive.

And very importantly, it is a language that can be used to discipline the discussions people have while trying to solve complex problems. By asking that each contributed thought be stated precisely by reducing it to assertions and cause-and-effect relations, it becomes possible to assemble these thoughts into a more precise and comprehensive picture of the situation than can be obtained from the usual forms of discussion. Once in this form formal rules of logic can be applied so the computer can be used to handle the logical reasoning and more considerations than could be handled otherwise.

A scenario for an explanation can be derived by simple deduction using the cause-and-effect relations. The scenario describes how the Explainer arrived at the proposed explanation. It can also be very useful in diagnosing difficulties with the cause-and-effect knowledge.

The Explainer has been used to analyze the sub-prime mortgage and liquidity crisis. It traced the cause back to the fundamental principle that a free market can only operate properly if the government can guarantee that parties to a financial transaction have equal access to the information they need to evaluate their risks. Such regulations could prevent the sale of sick cows to unsuspecting buyers.

Apparently the problem has not been solved because too many people have a vested interest in the cause of the problem not being understood. If understood, people could insist that Congress pass the appropriate regulation that would put an end to their game rather than reward them with further profits using taxpayer money. Properly solving the problem might save taxpayers hundreds of billions of dollars. This proposed solution deserves further consideration.

The Explainer is also being used to analyze the situation in Iraq to propose approaches to reducing the violence there. However, it still requires people better acquainted with the situation than I to judge the likely validity of the assumptions and side-effects for each of the proposed actions.

The Iraq problem shows how quickly the Explainer can solve a rather large problem where there are no circuits in the cause-and-effect statements. This problem involves 46 effects of which 13 are primaries and produces 11 proposals for how to decrease the violence with a computing time of less than a tenth of a second on a desktop computer.

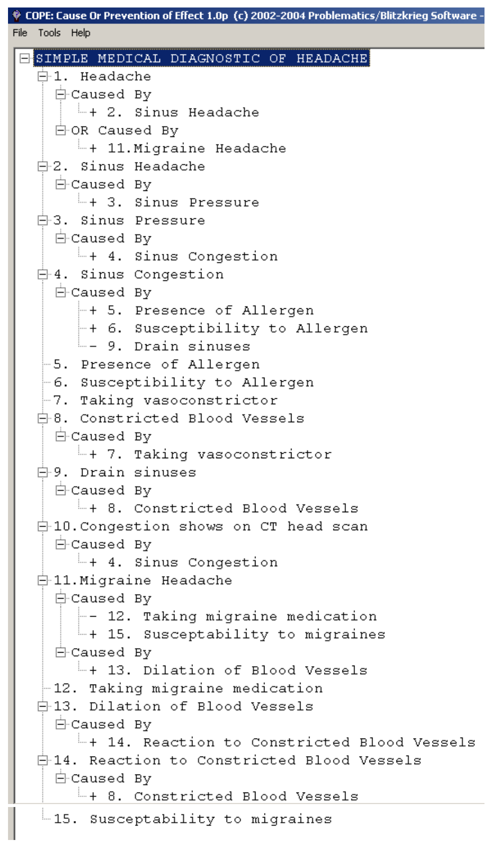
These and other examples can be found at: http://problematics.com/articles/APPLICATIONS-E.doc

10. Medical Diagnostic Example

This method can be illustrated by the following simple medical diagnostic problem, which like many other problems does not contain any cause-and-effect circuits. Assume that a physician is presented by a patient claiming to be having severe headaches. On the previous visit the physician had assumed that the headaches were due to sinus pressure and had prescribed that the patient take pseudoephedrine, a vasoconstrictor. Now the headaches have become more severe.

Assume also that the physician subscribes to a web medical diagnostic service where medical professionals who keep up with the literature continually update the diagnostic model.

This problem is greatly simplified as presented here. But let’s consider that those supplying the service had made up the following model, shown here as a screen shot of the input to the existing Explainer program:



The input is entered in the form:

□ a

□Caused By

+ b

- c

□OR Caused By

+ d

Means a ← (b AND NOT c) OR d

The input is modular. It can be entered in any order. The model developers can easily add, delete, or change the cause-and-effect statements as new knowledge becomes available. The Explainer provides a scenario for each explanation showing the steps by which the explanation was reached. These scenarios can be very helpful in finding and fixing faults and weaknesses with the model.

Part of the output of the program is a printed rearrangement of the input such that each effect appears only after the effects it depends on have been shown, which can be done if there are no circuits in the cause-and-effect statements. This printout makes it easier to understand the model. So it is included as follows:

MODEL

PROPOSITION 5. Presence of Allergen
PROPOSITION 6. Susceptibility to Allergen
PROPOSITION 7. Taking vasoconstrictor
PROPOSITION 12. Taking migraine medication
PROPOSITION 15. Susceptibility to migraines
EFFECT 8. Constricted Blood Vessels
CAUSED BY 7. Taking vasoconstrictor
EFFECT 9. Drain sinuses
CAUSED BY 8. Constricted Blood Vessels
EFFECT 14. Reaction to Constricted Blood Vessels
CAUSED BY 8. Constricted Blood Vessels
EFFECT 4. Sinus Congestion
CAUSED BY 5. Presence of Allergen
AND 6. Susceptibility to Allergen
AND NOT 9. Drain sinuses
EFFECT 10.Congestion shows on CT head scan
CAUSED BY 4. Sinus Congestion
EFFECT 13. Dilation of Blood Vessels
CAUSED BY 14. Reaction to Constricted Blood Vessels
EFFECT 3. Sinus Pressure
CAUSED BY 4. Sinus Congestion
EFFECT 11.Migraine Headache
CAUSED BY NOT 12. Taking migraine medication
AND 15. Susceptibility to migraines
OR
CAUSED BY 13. Dilation of Blood Vessels
EFFECT 2. Sinus Headache
CAUSED BY 3. Sinus Pressure
EFFECT 1. Headache
CAUSED BY 2. Sinus Headache
OR
CAUSED BY 11.Migraine Headache

Now the physician asks the Explainer for the plausible explanations for a headache that can be found using the cause-and-effect statements in the model. The result is printed out as follows:

EXPLAIN:
1. Headache

EFFECT 1. Headache
CAUSED BY 5. Presence of Allergen
AND 6. Susceptibility to Allergen
AND NOT 7. Taking vasoconstrictor
OR
CAUSED BY NOT 12. Taking migraine medication
AND 15. Susceptibility to migraines
OR
CAUSED BY 7. Taking vasoconstrictor

Now that the Explainer has produced these three plausible explanations, the physician then can ask the Explainer questions about each of these explanations. This will produce scenarios describing how each explanation was arrived at.

To understand these scenarios and how they were produced, we will need to be aware of several rules: (A term is set of variables, i.e. effects, joined by ANDs.)

Table 2 - Rules

- A term is True if all its effects are True
- A term is False if any of its effects are False
- A term is unknown if at least one of its effects is unknown and none of its effects are False
- An effect is True if any term is True
- An effect is False if any term is False and no term is True or Unknown
- An effect is Unknown if no term is either True or False

Noting that the patient had taken a vasoconstrictor and the headaches worsened, the physician may wish to understand how this could be. So he asks the Explainer how it came to the conclusion that taking a vasoconstrictor may have caused the headaches to worsen. He gets the following scenario.

IF THE ACTIONS OR ASSUMPTIONS ARE:
7. Taking vasoconstrictor IS TRUE
THEN THE CONSEQUENCES ARE:
5. Presence of Allergen IS UNKNOWN
6. Susceptibility to Allergen IS UNKNOWN
7. Taking vasoconstrictor IS TRUE
12. Taking migraine medication IS UNKNOWN
15. Susceptibility to migraines IS UNKNOWN
8. Constricted Blood Vessels IS TRUE
Term 1 IS TRUE
7. Taking vasoconstrictor IS TRUE
9. Drain sinuses IS TRUE
Term 1 IS TRUE
8. Constricted Blood Vessels IS TRUE
14. Reaction to Constricted Blood Vessels IS TRUE
Term 1 IS TRUE
8. Constricted Blood Vessels

IS TRUE
4. Sinus Congestion IS FALSE
Term 1 IS FALSE
5. Presence of Allergen IS UNKNOWN
6. Susceptibility to Allergen IS UNKNOWN
NOT 9. Drain sinuses IS FALSE
10.Congestion shows on CT head scan IS FALSE
Term 1 IS FALSE
4. Sinus Congestion IS FALSE
13. Dilation of Blood Vessels IS TRUE
Term 1 IS TRUE
14. Reaction to Constricted Blood Vessels IS TRUE
3. Sinus Pressure IS FALSE
Term 1 IS FALSE
4. Sinus Congestion IS FALSE
11.Migraine Headache IS TRUE
Term 1 IS UNKNOWN
NOT 12. Taking migraine medication IS UNKNOWN
15. Susceptibility to migraines IS UNKNOWN
OR Term 2 IS TRUE
13. Dilation of Blood Vessels IS TRUE
2. Sinus Headache IS FALSE
Term 1 IS FALSE
3. Sinus Pressure IS FALSE
1. Headache IS TRUE
Term 1 IS FALSE
2. Sinus Headache IS FALSE
Term 2 IS TRUE
11.Migraine Headache IS TRUE

This would tell the physician what is still unknown and how what is known would lead to this conclusion. The output could be made simpler by not showing what is unknown.

This confirms the explanation that under the conditions observed, **2. Sinus Headache IS FALSE** and **11. Migraine Headache IS TRUE**.

Appendix I provides a mathematical description of how explainer problems can be solved. It even shows the rules of the propositional logic that are sufficient to solve the Explainer problem. It demonstrates why the solution of explainer problems that do not contain circuits is so simple and why it can be expected that most explainer problems that do contain circuits can very likely be solved in reasonable computing times.

Appendix II shows an analysis for explaining the cause and ultimate solution to the current economic crisis. Note that it explains why house prices rose and then sank, why the foreclosures occurred, why market liquidity froze and why more targeted regulation will be required before the problem is resolved.

This problem involves a small circuit. The explanation of how this is handled appears in Appendix I.

As of this moment, most of the attention has been focused on resolving the symptoms rather then on solving the problem. Resolving the symptoms is turning out to be vastly more expensive than it would be to solve the problem.

APPENDIX I

1.0 Simple rules of logic

We only need to work with the following simple rules of Propositional Logic. More sophisticated techniques are not necessary.

T means True

F means False

$a \cdot b$ means a AND b

$T \cdot T = T$

$T \cdot F = F$

a, b, c, ... are propositions meaning assertions of facts that may be T or F

A, B, C, ... are primary propositions meaning that they are not caused by anything else and can be used to construct the explanations.

Y represents the behavior to be explained

$\overline{a}$ means NOT a

$a \cdot b = b \cdot a$

a+b means a OR b, either a or b or both are true

$a + b = b + a$

$a \cdot (b+c) = a \cdot b + a \cdot c$

$a + (a \cdot b) = a$

$a \leftarrow b$ means a is implied by b, or equivalently a is caused by b

$(a \leftarrow b) \cdot (b \leftarrow c) = a \leftarrow c$, which allows us to eliminate the intermediate proposition b

NOT $(a \cdot b)$ = NOT a + NOT b

NOT (a+b) = NOT a $\cdot$ NOT b

2.0 How it is solved when there are no circuits

A matrix is used to represent the expressions. Each row represents the expression providing the immediate cause for an effect. The variables in each term are shown in a row by using the same number for all the variables in that same term, and using different numbers for different terms. More than one number may appear in a cell if that effect appears in more than one term.

Once all the intermediate variables have been eliminated by substitution, the explanation will be presented to the user as a disjunctive Boolean expression of the primaries. Each term of the Boolean expression corresponds to an alternative explanation.

In the following matrix, the variable to be explained is denoted by Y.

The example of Figure 1 has been ordered to be lower-diagonal, which can always be done when there are no circuits, or as will be seen later, after the circuits have been resolved.

	A	B	C	a	b	c	Y
A	X						
B		X					
C			X				
a	1			X			
b		1		1	X		
c			1		-1	X	
	1	1			1	-1	X

Figure 1: Matrix with no circuits

This matrix says the following: A, B, and C are primary propositions. They are not caused by anything else and can be used in the explanation.

Then:

1. $a \leftarrow A$
2. $b \leftarrow B \cdot a$
3. $c \leftarrow C \cdot \overline{b}$
4. $Y \leftarrow A \cdot B \cdot b \cdot \overline{c}$

By substitution the intermediate variables a, b, and c are eliminated to express Y, the behavior to be explained, directly in terms of the primaries A, B, and C as follows.

1. $a \leftarrow A$
2. $b \leftarrow B \cdot a$
   $\leftarrow A \cdot B$
3. $c \leftarrow C \cdot \overline{b}$
   $\leftarrow C \cdot (\overline{A} + \overline{B})$
4. $Y \leftarrow A \cdot B \cdot b \cdot \overline{c}$
   $\leftarrow A \cdot B \cdot A \cdot B \cdot (\overline{C} + A \cdot B)$
   $\leftarrow A \cdot B \cdot (\overline{C} + A \cdot B)$
   $\leftarrow A \cdot B \cdot \overline{C} + A \cdot B = A \cdot B$

Thus,

5. $Y \leftarrow A \cdot B$

Note that all redundancies have been eliminated.

The behavior to be explained is required to be true. So the hypothesis $A \cdot B$ is a proposed explanation for the behavior Y.

The Explainer program for solving the case where there are no circuits is currently running and being used to solve example problems.

3.0 How it is solved when there are circuits

3.1 Using Blocks

To minimize the difficulties due to circuits, it is appropriate first to partition the problem into a block triangular form so that the circuits are confined to within the smallest possible square blocks on the diagonal, as in Figure 2. [1] What is called the input to the block will appear as the occurrence of variables to the left of the block, shown within a dotted box on the left.

	A	B	a	b	c	d	e	f	Y
A	X								
B		X							
a			X			1			
b	1		1	X					
c		1		-1	X		1		
d				-1	1	X			
e			1			1	X		
f				1				X	
Y					1			1	X

Figure 2: Matrix with circuits

This matrix represents the following expressions:

6. $a = d$
7. $b = A \cdot a$
8. $c = B \cdot \overline{b} \cdot e$
9. $d = \overline{b} \cdot c$
10. $e = a \cdot d$
11. $f \leftarrow b$
12. $Y \leftarrow c \cdot f$

3.2 Assumption 1

When dealing with circuits we make an assumption. We assume that within blocks we can use equivalence rather than implication. A←B implies that if B is true then A must be true. But if B is false, A may still be true due to another cause originating from outside the systems under consideration. But for the relations between variables within the same block and its input, we will assume there are no causes outside the block that are not explicitly stated, so we can use A=B, meaning that if A is true then B must also be true and if B is false then A is false. We use ← when appropriate and = when we use this assumption. Notice that we have already used this notation above.

This assumption is equivalent to saying we are dealing with a closed system where there are no causes arising from outside the system.

3.3 Resolving blocks by using templates

We will 'resolve' blocks by producing the same consequences as the circuits within the block by modifying the inputs to the block and leaving just the diagonal within the block. Then we can treat the resolved block the same as if were there no circuits.

First we need to show how we make the changes in the block input. For this we will use templates.

We use a table showing the sequence of operations to use the expressions within the block and its inputs to bind as many of the unknown variables as possible, leaving fewer remaining variables to be bound by combinatorially trying all possible assignments, which otherwise might require the computing time to become greatly increased.

The first row of Table 1a shows the variables within the block and in the input to the block. The second row shows the values assigned to these variables at the end of each step. The third row shows an up arrow to indicate the choice for the first variable to be assumed in order to start the search. The other entries in that row show the numbers of the expressions or previously assigned variables used to assign that variable. The forth row shows the order of the steps in which the values of the variables are assigned. A repeated step number indicates that more than one variable is assigned in the same step.

The search shown here is started by assuming that $d = T$, as shown by the up arrow in step 0. (It will be necessary to do another search later starting with $d = F$.) In step 1 $d = T$ is substituted into expression 6 to show that $a = T$. In step 2 a is substituted into expression 7 with the result that $b = A$. In step 3 expression 10 shows that $e = T$. In step 4 using expression 8 shows that $c = \bar{A} \cdot B$. In step 5 using expression 9 shows that $d = \bar{A} \cdot B$.

Using these two expressions for d shows that $T = \bar{A} \cdot B$.

Table 1a: Starting search with $d = T$

Var	$\bar{A} \cdot B$	a	b	c	d	e
Val	T	T	A	$\bar{A} \cdot B$	$T, \bar{A} \cdot B$	T
Exp	d	6	7	8	↑, 9	10
Stp	6	1	2	4	0, 5	3
	Input	Block				

The first two rows of this table represent what we call a template. Templates are used to define the variables within the block to be consistent with the values of variables in the input of the block.

Satisfying the conditions on the input part of the template implies the values assigned by the template to the variables within the block part of the template.

Thus, if we can infer that if $\bar{A} \cdot B = T$ in the input of the block, then we can infer by assumption 2 (see 3.3 below) that the variables within the block have the values that appear in that template.

Note that in step 2 we have inferred that $b = A$, but from the above argument we also infer that if $A = F$ and $B = T$, then $b = A$. Thus, we may conclude that there are two paths by which we can infer that $b = A$. Since $b = A + \bar{A} \cdot B = A$, we conclude that this is consistent, thus. $b = A$ irrespective of which path is taken.

The results of substituting the template into the matrix are shown in Figure 3.

	A	B	a	b	c	d	e	C	Y
A	X								
B		X							
a	-1	1	X						
b	1			X					
c	-1	1			X				
d	-1	1				X			
e	-1	1					X		
C				1				X	
Y					1				X

Figure 3: Matrix with blocks resolved

3.3 Assumption 2

Assumption 2 is that templates such as this do show how the input variables to a block define the variables within the block such that these input variables can be considered as causes for the variables within the block. This allows a problem to be converted to a corresponding problem with the same solutions that no longer has circuits and can be solved as we previously showed how to solve problems without circuits.

3.4 The other alternative starting with $d = F$

Now let's consider that other alternative of starting with $d = F$. Here again we use the assumption that we can use equivalence within the block.

Table 1b: Starting with $d = F$

Var	A	B	a	b	c	d	e
Val	**?**	**?**	F	F	F	F	F
Exp			6	7	8	↑	10
Step			1	2	2	0	1
	Input		Block				

In general there will be several valid templates. And often we must consider all combinations of these templates, which can run up the computing time.

3.5 Assumption 3

It will be assumed that a false variable in a block is caused by a dummy proposition which might be called FALSE. If this proposition appears in an explanation, that explanation is rejected because that explanation depends on something being true that is really false.

3.6 Other circumstances that may be encountered in the search

For each variable with which we begin the search, we must do a search beginning with that variable being T and again with that variable being F .

The search may lead to a contradiction. For example, if in expression 9, $d = b \cdot c$ rather than $d = \bar{b} \cdot c$, then we would get Table 2.

Table 2: Showing an inconsistency

Var	A	B	a	b	c	d	e
Val	F	T	T	A	$\bar{A} \cdot B$	T , $A \cdot \bar{A} \cdot B$	T
Exp	d	d	6	7	8	↑, 9	10
Step	5	5	1	2	3	0, 4	2
	Input		Block				

This leads in step 4 to $A \cdot \bar{A} \cdot B = T$, which is a contradiction.

The search may come to an end without all the variables being assigned values. Then the search must be restarted twice beginning with one of the unassigned variables set first as T and then set as F . If this happens often, it could lead to excessive computing times.

3.7 Incrementally resolving blocks

It is also possible first to resolve the small block within the larger one, and then use that resolution to resolve the larger block. This provides the same result as though we resolved the two blocks in one operation as we did above. The purpose of showing is to indicate that blocks can be resolved incrementally.

For example, again using the equivalence assumption:

Table 3a: Template to bind variables just within the smaller block, beginning with $d = T$

Var	B	a	b	c	d	e
Val	T	T	F	T	T	T
Exp.	8	10	9	9	↑	8
Step	2	3	1	1	0	2
	Input			Block		

This gives us Figure 4 where the inner block has been resolved but the larger block has not yet been resolved.

	A	B	a	b	c	d	e	C	Y
A	X								
B		X							
a			X			1			
b	1		1	X					
c		1	1	-1	X				
d		1	1	-1		X			
e		1	1	-1			X		
C				1				X	
Y					1				X

Figure 4: Matrix with smaller block resolved

The expressions now seen after the inner block has been resolved are:

6. $a = d$

7. $b = A \cdot a$

9a. $d = B \cdot a \cdot \bar{b}$

Then to resolve the larger block using the resolution of the inner block, we get Table 3b.

Table 3b: Template to bind variables within the larger block, beginning with $d = T$

Var	$\bar{A} \cdot B$	a	b	d
Val	T	T	A	T, $\bar{A} \cdot B$
Exp	d	6	7	↑, 9a
Step	4	1	2	0, 3
Input	Block			

Putting these templates together and for c noting that $\bar{A} \cdot B = T$ and for b noting that $b = A = F$ shows that resolving the blocks by pieces gives the same result as resolving the whole system including both blocks. This gives us some confidence that blocks can be resolved incrementally; thus extending the range of problems that we could expect to solve within reasonable execution times.

4. COMMENTARY

It is expected from the author's experience that a large fraction of problems will not contain circuits. The solutions to those problems do not depend on any of the assumptions 1, 2 or 3.

When there are circuits, it may be necessary to rely on one or more of these assumptions. These assumptions are reasonable, but have not been proven. Proving or disproving these assumptions is an area requiring further work.

Many explanations are oblivious before the fact but obvious after this analysis. The acceptance of explanations that invoke these assumptions used in the case of circuits may have to depend on whether the solutions appear obvious after the fact rather than only on an acceptance of the validity of these assumptions. In the case of circuits the user can easily be told which proposed explanations depend on which of these assumptions.

To prove or disprove these assumptions will require further work. .

In the meanwhile, the user is advised to look at the proposed solutions that depend on these assumptions to decide whether the solutions make sense and are useful. This judgment should be made in the light of whether these solutions are better than those that might otherwise be obtained without the discipline of this method.

5. SUMMARY

Many problems don't involve circuits, and these can be solved quite quickly. If we accept the appropriate assumptions needed to resolve the blocks, many other problems involving circuits can also be solved in reasonable computing times. This means that many problems that today are not properly solved now can be.

6. REFERENCE

[1] Steward, D. V., *Systems Analysis and Management: Structure, Strategy and Design,* Petrocelli Books Inc. (now McGraw-Hill), 1981.