USING CAUSE-AND-EFFECTS TO EXPLAIN BEHAVIORS IN ORDER TO UNDERSTAND AND SOLVE COMPLEX PROBLEMS

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ABSTRACT

Worldwide hyperconnectivity is leading to problems that have become too complex for us to understand and solve by our own unaided wits. This is causing people to use oversimplifications that can only result in frustrations, fear, and fights. Losing our connections with reality allows people to promote ridiculous policies and manipulate people with little fear of contradiction.

The Explainer computer program uses cause-and-effects to explain the causes of behaviors. A unique feature is its ability to handle cause-and-effect circuits that arise in many complex problems.

Logic is used to determine whether an effect is true, false, unknown, or conflicted by an inconsistency. Mechanisms are used here to determine whether a numerical value is increasing or decreasing.

The class of problems the Explainer can address is very broad. It includes finding the causes of faults in systems, medical diagnosis, crime analysis, and designing systems.

When the Explainer was used to find the causes of the economic crisis and widening wealth gap, it had to deal with more different aspects and levels of cause-and-effect reasoning than what people might be able to handle by their own wits alone.

1.0 What is the Explainer?

The Explainer is a method that allows people to use a computer to help them collaborate to solve problems that would otherwise be too complex for them to solve.

The collaborators discuss and develop cause-and-effect statements that govern the domain from which the problem arises. Given a behavior that arises from this domain, the Explainer uses logical abduction to find the various functions of assumptions, i.e. explanations, that would explain that behavior [13, 14, 21]. Then by logical deduction, it finds all the other behaviors that each explanation would also predict so these other behaviors can be tested to determine whether they actually occur [15]. If not, that explanation is ruled-out. This leaves only explanations that predict the desired behavior but do not also predict behaviors that do not occur.

This is a fundamental problem-solving principle. It is commonly used, but rarely explicitly described and taught as presented here. But a formal description of the method is required before a computer can be programed to use this method.

For example, when a physician is presented with a patient's symptoms, the physician first thinks of all the diagnoses that would cause those symptoms (abduction). Then the physician considers all the other symptoms that would also occur if that diagnosis were correct (deduction). He or she then examines the patient for these other symptoms, and rules out all the diagnoses that would predict symptoms that do not occur.

A physician could be assisted by access to a cause-and-effect knowledge base maintained by experts who keep up with the latest literature. A physician who subscribes to this knowledge base would present it with the patient's symptoms. The Explainer would reply with the various plausible diagnoses, i.e. explanations for those symptoms, and what other symptoms would result if that explanation were correct. The physician would then rule-out those explanations that would predict symptoms that do not occur.

2.0 Why is the World Becoming So Complex?

Because of improving technologies and globalization, many problems from around the world have become interwoven into problems that have become too complex to solve without the help of a computer.

When unable to solve complex problems, people tend to resort to oversimplifications. These oversimplifications do not solve the problems. But they can lead to frustrations, anger, hostilities, and political gamesmanship. It becomes easy to thwart the solution of problems or even to create problems in order to gain political advantage by blaming the problem on one's competitors. Anything goes, with little fear that anyone would be capable of using logic or reason to contradict them. This helps to explain our current state of chaos.

All over the world, we are seeing frustrations being acted out in the form of demonstrations, uprisings, and revolutions. This creates a great deal of worldwide turmoil leading to confusion and many unresolved difficulties.

The consequences of peoples' actions have become too complex to predict. But this has not prevented people from attempting to manipulate these systems for their financial gains, particularly when governments can be expected to allow them to keep their gains and bail out their losses with tax-payer dollars because they are too big to fail. This makes for a very unstable global financial system.

Simple-minded approaches to problems can cause us to escape the bounds of reality and enter personal fantasy worlds. Nothing can be pinned down. People can say whatever they want and pursue whatever policies they want with little fear of being contradicted by reality.

The problems become too complex for the voting population to understand. The media appeal to people's desire to take in the blow-by-blow fighting and avoid explaining the problems. Under these circumstances, people become too easily manipulated. This diminishes the capabilities of their governments to solve problems.

As the world becomes too crazy and too difficult to understand and control, disaster seems to lurk on the horizon.

In this day of the search engine, we have access to so much information that we are lulled into the belief that this information can be used to solve our problems.

But to solve problems, we need more than information. We also need the relations and logical facility to use these relations to connect this information in order to develop a picture of what is happening. Until we have that picture, we cannot solve the problem.

This is our motivation for finding a better way to solve complex social and other problems.

3.0 Why an Explainer is Needed

The world is in turmoil. It has become so hyper-connected that we face problems that are too complex to be understood and resolved by our wits alone. Frustration is occurring because of our inability to solve these problems.

This raises a question that we will try to answer here. Can the computer be used to help us solve these problems and better connect us to reality?

3.1 What distinguishes the Explainer from Rule-Based Expert Systems?

Expert systems are primarily used to debrief a single expert and replace his or her decision processes with a set of rules. An intermediate knowledge engineer reframes the decisions that the expert indicates he or she would make under various circumstances into the form of rules. Facts trigger the applications of the rules when the conditions for the rules to be fired are satisfied. However, at any time in the process there may be multiple rules ready to be triggered. The conclusions may depend on the order in which the rules are triggered. Various methods have been used to help to resolve these ambiguities. However, different methods to disambiguate may result in the process leading to different conclusions.

The appearance of rule-based expert systems is rather limited because of the difficulties encountered in the process of their development.

On the other hand, the Explainer is intended as a means for multiple experts with different points of view to collaborate in developing a set of cause-and-effect statements that govern the domain from which the problem arises. There is no need for an intermediating knowledge engineer to frame the cause-and-effect statements because this can be done directly by the collaborating experts themselves through the input to the Explainer. The input to the Explainer allows for several causes to be conjoined (ANDed) to have their effect, and for alternative conjoins to be separated by ORs.

The cause-and-effect statements are analogous to rules. However, using the Explainer there is no ambiguity about the order in which the rules are fired.

The experts using the Explainer can put together a system of cause-and-effect statements, test their implications for various problems, and then refine the statements. The Explainer provides a scenario to show the reasoning in reaching its explanations in order to assist in making these improvements. This improvement is a continuing process until people are satisfied with the results.

Rule based systems cannot deal with circuits in the rules. The Explainer can deal with circuits in the cause-and-effects. This capability is an important feature of the Explainer that plays a vital role in being able to solve many problems.

I have seen no indication that rule based expert systems have or could resolve the sort of complex social and political problems that the Explainer has demonstrated it can resolve.

3.2 What distinguishes the Explainer from Root Cause Analysis?

Root Cause Analysis starts with the behavior to be explained and develops step-by-step a series of causes such that each new cause added is the cause of a previous cause.

Whereas the Explainer begins with the cause-and-effect relations that define the domain from which the problem arises, Root Cause Analysis begins with the behavior and works backwards. The Explainer strings together the cause-and-effects from the assumptions that could explain a behavior to the behavior to be explained. This allows knowledge bases consisting of cause-and-effect statements that describe a domain to be used to explain various behaviors that can also arise from that same domain. These cause-and-effect knowledge bases can be shared, sold, or built upon by others for their own purposes.

The Explainer can use conjunctions of causes joined by ANDs and alternative conjunctions separated by ORs. A conjunction of assumptions is an explanation.

There are Root Cause Analysis tools available that can be used with the Explainer for diagramming the causes and their relations. But Root Cause Analysis diagrams are limited in their representations of ANDs and ORs.

3.3 The Difficulty of Finding Comparison Literature on a New Concept

Editors and reviewers feel more comfortable accepting a paper for publication if they can be assured the author is aware of the literature.

When building on an existing body of literature, it is easy to find the literature with which the article should be compared. But when an idea is new, most of the comparative literature may not yet exist.

The best one can do to indicate that such literature probably does not yet exist is to refer to other researchers who might be expected to know of such other literature if it did exist, and show that in what they have written where they would be expected to refer to such literature, they did not.

As an example, Judea Pearl probably would have referred to the handling of circuits in [11]. However, in a footnote on page 195 he says "Directed cycles, like those representing feedback in electronic circuits or econometric models, are not allowed in Bayesian networks and will not be discussed in this book." If he had been aware of the methods described in this paper, he may have noticed that the same method shown here might also be applied to handling circuits in Bayesian networks, so he could have considered them in his book.

Douglas Lenat has been working on Cyc for many years during which time he has accumulated over three million assertions [20]. But there is no indication that he has resolved the important social and political problems we are facing today and that the Explainer is able to address.

I have shown how the Explainer can shed light on the economic crisis and widening wealth gap problem and on many other complex social problems. To my knowledge, no one else has. If they had, I have not seen it. Nor have I seen any indication that the important problems we face today that the Explainer can deal with are being dealt with by any other method.

Vladimir Lifschitz, Leora Morgenstern, and David Plaisted in their Chapter 1 in *The Handbook of Knowledge Representation* [20] starting at page 67 and following refer to John McCarthy's work on using first order logic to deal with common sense facts. They then make several observations suggesting that to deal with this deductive reasoning would be too expensive and writing down all the knowledge would be infeasible. They quote Marvin Minsky as saying "The problem of finding suitable axioms – the problem of stating the facts in terms of always correct, logical, assumptions – is very much harder than is generally believed."

But they appear to be trying to deal with the very difficult problem of solving a wide variety of problems using one all-encompassing knowledge base. There is no mention that this can be done in practical circumstances by developing a domain of knowledge that is just sufficient for solving a specific problem.

But this article shows that for specific problems, it is possible to write down sufficient knowledge and do the deduction within a practical time-frame on a desktop computer to solve some very important problems.

Zhang and Nguyen in their article "A Tool for Knowledge Base Verification" [22] imply that circuits in knowledge bases are errors in the formulation of the problems. I don't believe these are necessarily errors. The weakness is that we had not been able to deal with them and so ignored them. Why did they not suggest how circuits could be handled if they were aware of methods for dealing with them, as this article shows?

4.0 A Non-Conventional Logic

The logic used here is closed and finite. It is closed in the sense that no cause outside the system can produce any effect within the system. Every effect within the system has either a cause within the system, or no cause. If it has no cause, it is an assumption.

It is finite in that every cause-and-effect in the system can be enumerated by a computer. This allows us to assume that if an effect is not caused to be true by a cause within the system, we can assume that that effect is either unknown, or is false under the default that everything is false unless it is caused to be true.

If as the causes are enumerated, there is a cause for a variable to be true and another cause for that same variable to be false, then that variable is said to be conflicted, i.e. it arises from a contradiction. If dealing with logic, a conflicted variable is an inconsistency that indicates that the problem has be incorrectly formulated. However, when we later consider mechanisms rather than logic, a conflicted variable just means that there are different mechanisms that produce different magnitudes of effect [16,17].

In logic we assume the variables can take on any one of the following four values.

T True
F False
U Unknown
C Conflicted:

5.0 Logic and Mechanisms

5.1 Properties of Cause-and-Effect Itself

We represent A causes B with a positive arc as A → B. A causes NOT B is represented by a negative arc as A ↛ B. Cause-and-effect represented by positive arcs is transitive, meaning that if A → B and B → C, we can say that A → C.

5.2 Using Logic to Represent Cause-and-effect

If we are interested in whether a variable is true or false, we represent cause-and-effect as logical implication. A → B would mean that if A were true then B is true, and A ↛ B would mean that if A were true then B is false. In either case, if A is false, there is no consequence on B [1, 3, 7, 10, 11, 12, 16, 17].

If there are multiple causes of C such as A → C and B ↛ C and both A and B are true, then there is a logical inconsistency. We say that C is conflicted.

A → B → C → A is a circuit. It is logically consistent. If there is an odd number of negative arcs in a circuit such as A → B → C ↛ A, the circuit is logically inconsistent so the problem has been improperly formulated. This is not a difficulty if we are dealing with mechanisms.

5.3 Using Mechanisms to Represent Cause-and-Effect

If we are interested in how a change in the magnitude of a cause A affects a change in the magnitude of effect B, then we use mechanisms.

A → B means that as the numerical value of A increases or decreases there is a corresponding increase or decrease in the numerical value of B. A ↛ B means that as the numerical value of A increases or decreases, the numerical value of B moves in the opposite direction.

If there are multiple causes of C such as A → C and B → C, then A and B are different mechanisms operating on C that may cause different numerical magnitudes of change in the numerical value of C. Each mechanism is treated separately.

We can also have multiple causes of a variable such as A → C and B ↛ C. By logic, if both A and B were true, this would be an inconsistency. As a mechanism, this is not inconsistent. It just indicates that they produce opposite magnitude changes in C.

The net magnitude change in an effect can be determined only later when the true magnitudes can be numerically computed and added together.

To accommodate both the logical and mechanisms interpretations, the variables are given the values of positive or negative. In the logical interpretation, a positive value corresponds to true and a negative value corresponds to false. In the mechanisms interpretation, a positive value indicates that the variable is stable or increasing. A negative value is interpreted as the variable is stable or decreasing.

5.4 The Process of Labeling the Nodes

There are either of two values that can be assigned to each node, and there are two types of arcs. The two possible values of the nodes are positive and negative. A positive arc means that the values at the head and tail of the arc are the same. A negative arc means that the values at the head and tail of the arc are opposite.

A labeling of the nodes begins with an arbitrary node first assigned a positive value. Later this same process is repeated beginning with the same initial node assigned a negative value.

For each assignment of the initial node, all the other nodes are assigned values according to the arcs connecting them. If any two arcs entering the same node would assign that same node different values, that node is considered to be conflicted.

If none of the nodes is conflicted in this process, then this provides the two homogeneous solutions for the block.

In the logic interpretation, a conflicted node means there is a logical contradiction and the labeling process stops and a report is made that the problem has not been properly formulated.

In the mechanism interpretation, a conflicted node means that there exists more than one mechanism. Then the labeling process must be repeated for all combinations of the conflicted nodes being labeled either positive or negative. If there are too many conflicted nodes, this combinatorial process can become onerous. Perhaps selecting a few of the combinations would be sufficient to develop some understanding of the problem and suggest enough proposals so that some might be worth considering.

6.0 Replacing Blocks With Equivalent Arcs

For simplicity, we will consider here only the case where there are no conflicted nodes and we are dealing with the mechanism approach. Then there are just two homogeneous solutions.

Each input to the block must align itself with and thus select one of the two homogeneous solutions. If an input would cause the corresponding valuable in the homogeneous solution to be positive, then the homogeneous solution that is selected is the solution that has a positive value of that variable. Similarly, if the input would cause the value of that variable to be negative, then the homogeneous solution chosen would be the solution that has a negative value for that variable.

Different inputs can select different homogeneous solutions. That is okay because they correspond to different mechanisms. Different mechanisms will cause different changes in the value of the variable. The amount of that change will not be resolved until the model is numerically computed.

There will be an arc from each input to each output of the block so as to replace the circuits in block with simple arcs. That arc will be a positive arc if the input and output variables in the selected homogeneous solution have the same value, and the arc will be a negative arc if the input and output variables in the selected homogeneous solution have opposite values.

The arcs within the block are constructed by creating arcs to each node in the block from an external cause that would cause the value of the node in the bock to correspond to that required by the selected homogeneous solution. A different homogeneous solution produces a different set of arcs representing different mechanisms.

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This will all be illustrated in section 8 when we consider the example of the cause of the economic crisis and widening wealth gap.

7.0 The Explainer

7.1 The Explainer Method

The situation from which a problem arises is described by a set of elementary cause-and-effect statements. Individually these statements may be quite simple. Strung together, they can become extremely complex. This is why we need a computer.

Let us assume that C is an effect. i.e. behavior, we wish to explain and that A is a primary cause. A primary cause is a cause that itself has no cause. We consider it to be an assumption. So by eliminating the intermediate causes, we can express the behavior C directly as a function of the assumptions that would cause that behavior C.

Thus, given a situation and a behavior that arises from that situation, we can use cause-and-effect statements to explain that behavior in terms of functions of the assumptions that if true would cause that behavior.

An explanation is a conjunction of variables with NOTs and ANDs. Different explanations are separated by ORs.

Usually, there are many plausible explanations for a given behavior. Each explanation is a function of assumptions

that may or not be true. We decide which explanation is appropriate by which assumptions are more likely to be true.

Two conditions must hold: One, the explanation must predict the intended behavior. Using the cause-and-effect statements to find an explanation that predicts the behavior to be explained is done by the logical process of abduction. Abduction is a form of backward chaining.

Two, the explanation must not predict behaviors that can be shown by their examination not to occur. To assure that the explanation does not predict behaviors that are not true, we must first find for each proposed explanation what behaviors it would predict. This is done by logical deduction. This is forward chaining.

Then the predictions that each explanation would predict must be examined to determine whether they actually do occur. Explanations that predict behaviors that do not occur must be ruled-out.

It is also possible to use this method to explain behaviors that one would desire to occur, and then turn the assumptions that would explain the behavior into actions to cause that behavior. This could have wide applications to solving our complex social problems.

This approach may also be used to design systems with desired requirements specifications using cause-and-effects to describe the possible components.

Although this is a very fundamental form of problem-solving, it is seldom described explicitly as it is here. Perhaps it would be valuable if it were taught this way.

But to program a computer to help us carry out this process requires that we must first make this process explicit.

7.2 The Explainer Program

The Explainer program first helps people to collaborate in discussing and arriving at some consensus to develop the cause-and-effect statements that describe the situation from which a behavior might arise.

The Explainer program then uses these causal relations to find causal explanations for behaviors that can arise from this situation. Thus, it helps us understand and frequently solve problems that otherwise we would be unable to deal with. Today we face and are baffled by many such problems.

The Explainer deals with a very broad class of problems. It can be widely applied to problems such as medical diagnosis, finding the cause of faults in systems, emergency management when things happen faster than people can keep track of them, accident analysis, solving crimes, analyzing how terrorism attacks can be committed and thus how they can be thwarted. A number of example applications appear in [24].

I hope to describe here the Explainer sufficiently for people to grasp why it works so they can be comfortable trying to use it to solve some of today's extremely difficult problems.

There is already a preliminary running Explainer program. As it stands as of this writing, it handles cause-and-effects provided there are no circuits. The methods for handling circuits are known and the program is currently being extended to be able to handle circuits without manual intervention.

In the meanwhile, it has been possible to demonstrate the solutions of problems involving circuits by supplementing the program with hand manipulations. One such problem is to find the causes of the economic crisis and widening wealth gap. This will be discussed later in section 8.

7.3 Partitioning to Find the Blocks That Contain the Circuits

This becomes more complicated when we consider that there can be cause-and-effect circuits, e.g. A → B → C → A. Handling circuits can be vital to understanding and solving many problems.

Given a matrix where marks in the cells show which effects depend on which others, a partition reorders the rows and columns in the same way so that there are square blocks on the diagonal and the remaining marks are all on the same side of the diagonal. Every circuit is in only one of these blocks. In a block there is a path from every node within the block to every other node within the same block, but this would not be true if we add any additional node from outside the block [18, 19].

Every effect that exits a block is a function of every cause that enters the block. By using these functions, the blocks can be bypassed so they can then be handled as though there were no circuits.

This same approach might be used for handling circuits in Bayesian analysis. But that is not considered here.

7.4 Two Homogeneous Solutions

Each block that has no conflicted variables has precisely two solutions, which may arbitrarily be called clockwise and counterclockwise. One homogeneous solution may cause the

numerical values of the items within the block to not change or to spiral downward, and the other homogeneous solution may cause the variables in the block not to change or to spiral upward.

In logic there is a third possibility; that there is an inconsistency. This is not a concern for mechanisms.

An entering cause will select one of the two homogeneous solutions such that the sign of the cause-and-effect arc head, positive or negative, matches the sign of the effect, positive or negative, as it appears in the appropriate homogeneous solution.

If the entering cause in the selected homogeneous solution is the same as the value of the homogeneous solution where it exits, the arc from the entering cause to the exiting effect that skips over the circuit is positive. If they are of opposite values, the arc is negative.

7.5 The Explanations

We usually will find multiple explanations for behaviors that arise from a situation. These explanations are functions of the assumptions that would explain, i.e. predict, that behavior.

7.6 Elimination of Intermediate Variables to Express a Behavior Directly as a Function of Assumptions

The abduction process may produce very long chains of cause-and-effects extending between the assumptions and the behavior. We wish to express the behavior directly in terms of the functions of assumptions that would explain that behavior. So we must eliminate the intermediate variables that appear in neither the behavior nor the assumptions. This is done by eliminating the intermediate variables by substitution.

If A → B → C → D, we can substitute A for B to get A → C → D, and substitute A for C to get A → D. Thus, we have eliminated the intermediate variables B and C.

This process of eliminating intermediate variables can produce many useless redundancies that make the process unnecessarily long and storage unnecessarily large. So to shorten the process and save storage, these redundancies should be eliminated as quickly as they occur.

We similarly eliminate intermediate variables when we solve a system of linear algebraic equations. For example:

X_1
$2\ X_1 + X_2 = 4$
$3\ X_1 + X_2 + X_3 = 6$

so

$X_2 = 4 - 2\ X_1$
$X_3 = 6 - (4 - 2\ X_1) - 3\ X_1$

then

$X_3 = 2 - X_1$

having eliminated the intermediate variable X_2

X_1 plays the role of the assumptions. X_3 plays the role of the behavior.

7.7 Replacing ORs with ANDs

Before we partition, we replace the ORs with ANDs to get everything in terms of ANDs by using De Morgan's rule. Thus, (A or B or C) becomes NOT D were D is (NOT A and NOT B and NOT C). This requires the introduction of a new variable D. Then we only have ANDs and NOTs when we do the partition.

7.8 The Explainer Solves a Common Type of Problem

Finding the explanations for behaviors is an extremely common type of problem. It is what allows us to understand and solve all the various types of problems mentioned above, as well as many others. See [24].

7.9 Improving the Capability to Find Explanations

Of course, the validity of the explanation is limited by the validity of the set of cause-and-effect statements. It is also limited by whether the behavior to be explained is accurately stated. The more familiar with the problem the people collaborating to do the analysis are, the more reliable the conclusions will be.

When the Explainer proposes an explanation, it also provides a scenario that shows step-by-step the reasoning the Explainer used to come to its conclusion. These scenarios can be of great help in finding and correcting faults in the cause-and-effects. Over time, the cause-and-effect statements become refined until they are able to provide satisfactory explanations over a sufficient domain of problems.

8.0 An Example

8.1 The Economic Crisis and Widening Wealth Gap Problem

Consider the economic crisis and widening wealth gap problem. To analyze the causes and possible solutions to this problem, the Explainer program had to deal with over thirty interrelated aspects of the problem and about twenty levels of

cause-and-effect reasoning. By human wits alone, we could be expected to deal with no more than about ten interconnected aspects and perhaps two or three levels of cause-and-effect reasoning at most.

It is no wonder that these problems have become too difficult for our comprehension. And when we cannot understand them, we cannot manage them. And not managing them can lead to chaos, blind decisions, and our ultimate decline. We need to find a way to understand these complex problems.

The analysis of the economic crisis and widening wealth gap problems has suggested at least two plausible causes and solutions that might deserve further consideration.

Finding the causes of a problem often provides the key to what is necessary to solve the problem.

Each behavior to be explained must be examined to determine whether it really occurs. And each plausible cause needs to be examined to see if it makes sense and deserves further consideration.

We will elaborate on two of the proposed causes.

8.2 Cause 1: Non-symmetry in the Information Available

The first plausible cause of the economic crisis and widening wealth gap can be traced to Adam Smith's hidden assumption. Adam Smith set the stage for understanding the capitalist system. He told us in 1776 in his book *The Wealth of Nations* that if everyone were to negotiate in his own self-interests, the result would be an efficient allocation of resources and an equable distribution of wealth based on people earning in proportion to what they contribute to the economy. (Today this would be called an emergent property.)

Adam Smith's hidden assumption was that everyone has the information he needs to negotiate in his own self-interests. But in the sub-prime mortgage crisis, the lenders had an advantage over the borrowers because they held knowledge about the complex investments and their risks that were not understood by the borrowers.

The borrower was promised a low initial interest rate. But the borrower did not understand that he might be unable to pay the mortgage payments when the rate was later increased, and that he should not gamble on the increase in the value of his home so he can refinance when the rate was increased.

This led to a home price inflation bubble as people were enticed into buying homes they really could not afford. And when the rates rose and the home prices had dropped so they could not refinance, their homes were foreclosed. Housing prices dropped and the bottom fell out of the market. And the lenders then possessed the house and all the mortgage payments the borrowers had paid, and retained the loan fees.

This might not have occurred if the Glass-Steagall Act had not been overturned in 1999.

The Consumer Financial Protection Bureau, had it been in place and enforced at the time, might have prevented this calamity. But it wasn't in place then. And it is now being emasculated by factions in Congress.

8.3 Cause 2: Big Businesses Will Not Lend to Small Businesses

The second plausible cause would be that businesses found they could automate. They accumulated large cashes of money by reducing their payrolls. Smaller businesses might have hired those who were laid off by bigger businesses because smaller businesses tend to do the more labor-intensive aspects of the work that automation cannot do.

But the bigger businesses may have been reluctant to invest their accumulated cash in the smaller businesses because they thought that small businesses were a poor investment because small businesses were not doing well. But small businesses may not have been doing well because they needed investments.

This is an example of a cause-and-effect circuit. By using mechanisms, it can be seen that this circuit selects the homogeneous solution that causes an endogenous spiraling down, to the detriment of both the bigger and smaller businesses.

One way to solve this dilemma may be to find a way to encourage those holding these large accumulations of wealth to invest it in smaller businesses.

This might be done by using the countervailing cycle provided by the other homogeneous solution, such as the government guaranteeing these loans. If the government guarantees the loans, both the large and small businesses would prosper, making the loans good investments. This might accomplish more at less cost to the taxpayers than if the government used other stimulus methods. And if the government received an insurance fee from the repayments, it might not cost the taxpayers anything. This may be worth a consideration. But it does not appear that it is being considered at this time.

Using the Explainer often leads to revealing plausible solutions that might not otherwise have been considered. Some of its proposals might appear to be obvious, but only after the Explainer had revealed them.

9.0 A Matrix Representation

Figure 1 is a matrix illustrating just part of a larger matrix that would help explain the causes of the economic crisis and widening wealth gap. It shows how these causes can be turned into actions to resolve the problem.

The matrix is displayed by the PSM32 program that is primarily intended to partition a matrix into lower diagonal form with square blocks on the diagonal that contain the circuits and the remaining marks on one or the other side of the diagonal [18, 19].

Each mark represents an arc. The even numbers in the matrix represent positive arcs, i.e. →. The negative numbers represent negative arcs, i.e. ↛.

In the following diagram, names of the effects are shown on the left with numbers. The same numbers that are associated with these names occur over the columns in the same order.

A mark in a cell indicates that the column of that mark is a cause of the row of that mark. Thus, each mark corresponds to an arc. Even numbers represent positive arcs. Odd numbers represent negative arcs.

The odd number appearing in the upper right corner of the big block corresponds to a negative arc, i.e. ↛ . It would imply an inconsistency if we were interpreting it as a logical operator.

The homogeneous solution selected here, Solution B, causes the values of the variables in the block to spiral down. Arbitrarily we may call this the counterclockwise solution.

By the logic interpretation, a circuit with an odd number of negative arcs results in an inconsistency. By the mechanism interpretation, a circuit with an odd number of negative arcs indicates that the numerical values associated with the variables in that block either remain stable or spiral down. No negative arcs or an even number of negative arcs results in the numerical values remaining stable or spiraling up.

If we are dealing with mechanisms, a positive arc indicates that the cause and effect are moving in the same direction. A negative arc indicates they are moving in opposite directions.

The selection of which homogeneous solution applies is made by the entering arc. The homogeneous solution selected is the one where the sign of the head of the entering arc is the same as the sign of the value for that same variable, i.e. the effect, as it appears in the appropriate homogeneous solution.

There may be multiple entering arcs. When using logic, if these entering arcs would select different homogeneous solutions, this indicates a logical inconsistency. When using mechanisms, these arcs would represent different mechanisms.

The variables that have no cause, as 1, 2, and 3 in the following matrix, are assumptions that can be used to explain the behavior.

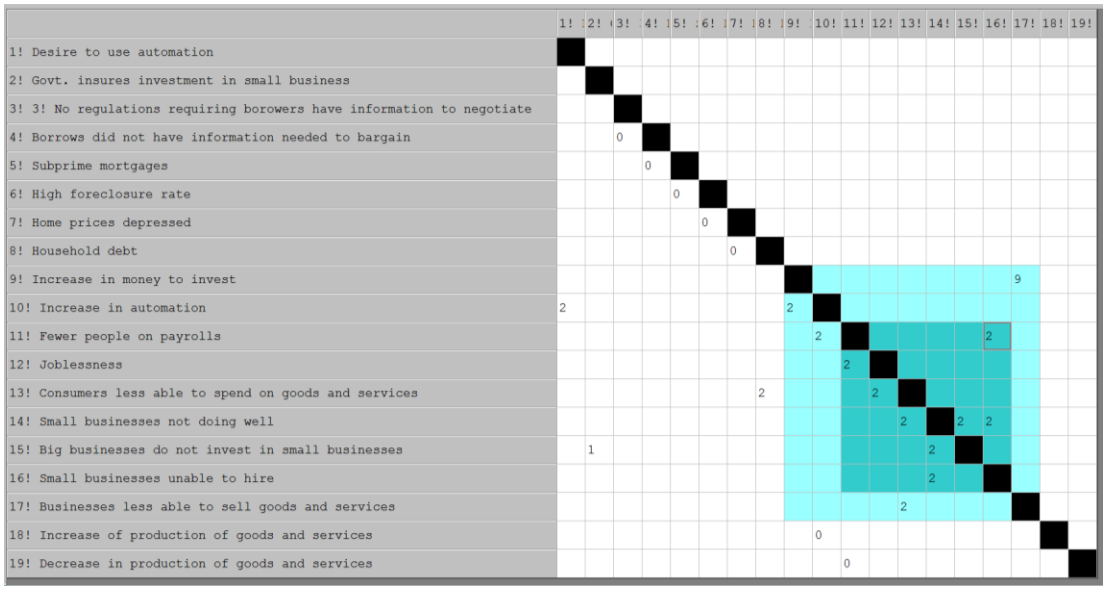

Figure 1 Matrix Showing Blocks and Cells Representing Arcs

The two homogeneous solutions, A and B obtained by applying all the causes, one homogeneous solution beginning with 9 as positive and the other beginning with 9 as negative, have values as follows:

Variable	Homogeneous Solution A	Homogeneous Solution B
9	Positive	Negative
10	Positive	Negative
11	Positive	Negative
12	Positive	Negative
13	Positive	Negative
14	Positive	Negative
15	Positive	Negative
16	Positive	Negative
17	Positive	Negative

So let us see what this matrix tells us.

Each arc leaving the block, i.e. marks underneath the block in the matrix, is a function of all the arcs entering the block, i.e. marks to the left of the block.

Looking at row 10, we see that there are two marks in that row, in columns 1 and 9. Since both marks are even, they each contribute to an increase in '10 Increase in automation'. Since they both have the same number, they are part of the same conjunction, i.e. they are joined by ANDs. So an increase in '10 Increase in automation' is caused by an increase in '1 Desire to use automation' and an increase in '9 Increase in money to invest'. They both correspond to positive arcs. They both elicit the same homogeneous solution B that causes a decrease in the values of the variables in the block.

Similarly, '13 Consumers less able to spend on goods and services' is caused to increase by 'Household debt' and 'Joblessness'. These are also positive arcs. They also elicit homogeneous solution B.

Looking at row 15 there is a 2 in column 14 implying that an increase in '15 Big businesses do not invest in smaller businesses' is caused by '14 Small businesses not doing well'.

In row 15 there is also a 1 in column 2. Being that this is an odd number in the cell, it implies that an increase in '2 Govt. insures investments in small businesses' causes a decrease in '15 Big businesses do not invest in small businesses', a negative arc. It elicits the other homogeneous solution, A, that causes an increase in the values of the variables in the block.

The two mechanisms work against each other, i.e. cause pressures to drive the variables in the block to move in opposite directions. If and when we later do the numerical calculations, we can add together the computed magnitudes of the effects to see the net magnitude of the effect.

Note that '18 Increase in production of goods and services', is a result due to automation, and '19. Decrease in productions of good and services', is another result but due to joblessness.

This matrix serves a dual function. It is also used to partition the matrix into a block lower triangular form.

If the government intervention involving the other homogeneous solution produces an upward spiral that is large enough, it can overcome the tendency of the initial homogeneous solution that would produce a downward spiral. Clockwise works against counterclockwise.

So without the government intervention, both big businesses and small businesses lose. But with the government intervention, if it is large enough, both big and small businesses and the overall economy will gain.

This analysis proposes a plausible solution to the problem that may merit further consideration. It is a proposal that to my knowledge has not been evident in the current discussions of the problem.

It is intended that the people who participate in this process 'play' with different ideas for the cause-and-effect statements and use the Explainer to reveal their implications. This might suggest some completely ridiculous ideas. But this may also reveal some ideas that had not previously been considered that now deserve consideration.

10.0 Cause-and-Effect Analysis

From the matrix we can read off the cause-and-effect statements and enter them into the Explainer program in the following form:

EFFECT A
CAUSED BY C
CAUSED BY B
OR CAUSED BY D

This would be interpreted as:
A is CAUSED BY (B AND C), OR is CAUSED BY D.

Using this notation, reading off the matrix, this is entered into the Explainer program as follows:

```
CAUSE~AND~EFFECT OF ECONOMIC CRISIS AND WIDENING WEALTH GAP
  1. Desire to use automation
  2. Govt. insures investment in small business
  3. No regulations requiring borrows have information to negotiate
  4. Borrowers did not have information needed to bargin
    Caused By
      +3. No regulations requiring borrows have information to negotiate
  5. Subprime mortgages
    Caused By
      +4. Borrowers did not have information needed to bargin
  6. High foreclosure rate
    Caused By
      +5. Subprime mortgages
  7. Home prices depressed
    Caused By
      +6. High foreclosure rate
  8. Household debt
    Caused By
      +7. Home prices depressed
  9. Increase in money to invest
    Caused By
      +13. Customers less able to spend on goods and services
  10. Increase in automation
    Caused By
      + 1. Desire to use automation
      + 9. Increase in money to invest
  11. Fewer people on payroles
    Caused By
      +13. Customers less able to spend on goods and services
  12. Joblessness
    Caused By
      + 10. Increase in automation
      + 13. Customers less able to spend on goods and services
  13. Customers less able to spend on goods and services
    Caused By
      +8. Household debt
  14. Small businesses not doing well
    Caused By
      +13. Customers less able to spend on goods and services
  15. Big businesses do not invest in small businesses
    Caused By
      +13. Customers less able to spend on goods and services
  16. Small businesses unable to hire
    Caused By
      +13. Customers less able to spend on goods and services
  17. Businesses less able to sell goods and services
    Caused By
      +13. Customers less able to spend on goods and services
  18. Increase in production of goods and services
    Caused By
      + 10. Increase in automation
  19. Decrease in production of goods and services
    Caused By
      + 11. Fewer people on payroles
```

Figure 2 – Input to the Explainer

When we ask the Explainer to explain the causes of joblessness in terms of the assumptions that would predict it, we get the following result:

EFFECT 12. Joblessness
CAUSED BY 1. Desire to use automation
AND 3. No regulations requiring borrows to have information to negotiate.

Thus, Joblessness is caused, i.e. predicted, by assumptions 1 and 3.

11.0 The Brainer – An Interesting Speculation

One conceivable application of the Explainer that would be very interesting, but has not yet been adequately studied, is to use it to produce a device that can use the Explainer method

to learn to understand and work with its environment. I call this device a Brainer. It would use its sensors to monitor its environment, looking for pairs of events that occur frequently within a reasonable interval of time, and always in the same order. These would be candidates for cause-and-effect relations and would be provisionally added to its cause-and-effect library.

By using its sensors and actuators, it could experiment on its environment to test the validity of what it observed as apparent cause-and-effects by producing causes to see if the hypothesized effects follow. By this means, it can both improve its knowledge and try to achieve its needs and desires.

Philosophical questions about epistemology and ontology might be seen in a new light in reference to such a simple model [4].

12.0 Conclusions

A method has been shown that can help us gain valuable insight into very complex problems.

The theory of mechanisms requires more work. But even in this primitive form, it can be very useful.

I hope that by this article I have convinced you or at least allayed your doubts, about the following:

1. The world has become more complex than we are able to handle.
2. Without better problem-solving methods, we are stumbling in the dark without a flashlight.
3. We are increasingly susceptible to being manipulated.
4. We now have the methods we need to resolve many of these complex problems and halt the progress toward our downfall.
5. Due to the newness of these methods, there is still a reluctance to believe in them.
6. Unless we look at these methods more closely and learn to use them to solve our problems, we are likely to fall into a serious decline.
7. Hopefully you can help get the news out to people who have the capability to look at these methods more carefully and pronounce them safe to use. Then perhaps this approval will get out to those who will use this method to solve some of our more vexing, complex social problems.

12.0 BIBLIOGRAPHY

[1] Brachman, Ronald & Hector Levesque (2004) *Knowledge Representation and Reasoning* (Morgan Kaufmann)

[2] Garey, Michael R. & David S. Johnson, (1979) *Computers and Intractability: A Guide to the Theory of NP-Completeness* (W. H. Freeman and Company)

[3] Glymour, Clark (2001) *The Mind's Arrows: Bayes Nets and Graphical Causal Models in Psychology* (The MIT Press)

[4] Gopnik, Alison, (2009) *The Philosophical Baby*, (Farrar, Straus and Giroux)

[5] Gore, Al (2007) *The Assault on Reason* (The Penguin Press, New York)

[6] Groopman, Jerome, (2007) *How Doctors Think* (Houghton Mifflin)

[7] Josephson, John R. & Susan G. Josephson (1996) *Abductive Inference: Computation, Philosophy, Technology* (Cambridge University Press)

[8] King, Ross D., Oliver Ray, Amanda Clare, Maria Liakata, Larisa Soldatova, Ken Whelan "Towards the automation of scientific method" *21st International Joint Conference on Artificial Intelligence IJCAI'09*

[9] King, Ross D. "Rise of the Robo Scientists" *Scientific American* January 17, 2011

[10] Mueller, Eric T. (2006) *Commonsense Reasoning* (Morgan Kaufmann Publishers)

[11] Pearl, Judea, (1988) Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference Revised 2nd Printing (Morgan Kaufmann, Publishers, Inc.), particularly pg. 195 footnote,

[12] Pearl, Judea, (2000) Causality: Models, Reasoning, and Inference (Cambridge University Press)

[13] Peirce, Charles Sanders, (1998) "Pragmatism as the Logic of Abduction" in The Essential Peirce, Volume 2: Selected Philosophical Writings, 1893-1913 (Indiana University Press)

[14] Peng, Yun & James A. Reggia, *Abductive_Inference Models for Diagnostic Problem-Solving* (1990) (Springer; 1st edition)

[15] Russell, Stuart. & Peter Norvig, (2003) 2nd ed., *Artificial Intelligence: A Modern Approach*, (Prentice-Hall of India)

[16] Salmon, Wesley C. (1998) *Causality and Explanation* (Oxford University Press)

[17] Sloman, Steven, (2005) *Causal Models: How People Think About the World and Its Alternatives*, (Oxford University Press)

[18] Steward, Donald V. (1981) "The Design Structure System: A Method for Managing the Design of Complex Systems" in IEEE Transactions on Engineering Management Vol. EM-28, Number 3, August 1981.

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

[20] Van Harmelen, Frank, & Vladimir Lifschitz, & Porter, Bruce (Editors) (2008) *Handbook of Knowledge Representation* (Elsevier)

[21] Walton, Douglas (2004) Abductive Reasoning (The University of Alabama Press)

[22] Zhang, Du & Doan Nguyen (1994) "PREPARE: A Tool for Knowledge Base Verification" *IEEE Trans. on Knowledge and Data Engineering*, vol. 6, No. 6, Dec 1994)

[23] http://problematics.com/ to get a more comprehensive view of the Explainer.

[24] http://problematics.com/readings.asp
then click on APPLICATIONS-E.doc to see demonstrations of how the Explainer has been used to deal with various types of problems.