On Explanatory Belief revision systems: Initiation Grant Proposal

A. V. Ravishankar Sarma
Lecturer, HSS department
IIT Kanpur, Kanpur
Email: *avrs@iitk.ac.in*

October 9, 2007

Abstract

In this project, a new model for belief revision based on abduction will be elaborated within the framework of AGM belief revision. We construe "abduction" as the process of reasoning in which explanatory (causal) hypothesis are formed and evaluated. Our basic hypothesis is that agent seeks *explanation*, before she accepts and integate the new evidential information with the old. As a result, it generates heirarchies of explanation and out of which causal explanations are considered to be most plaussible explanations. Here, not all explanations are acceptable for abduction, but only the best or atleast good ones [41]. The dynamics of belief based on plaussibility of explanations would give us a reasonable mechanism whether or not to give priority to the incomming information. In this proposed research, we will (1) extend AGM framework with abductive revision operators (2) we characterize such revision with an ordering called *causal epistemic entrenchment ordering*. We provide this ordering for generating the adequate explanation out of a set of plaussible explanations.

Keywords: Belief Revision, Abduction, Entrenchment, explanation, Core and Periphery of beliefs

1 Background and Research

If I have seen further than other men, it is because
I stood on the shoulders of giants... Issac Newton

People since antiquity are worried about how to perform a radical change in their body(set) of beliefs. There appears to be a big fence between religious beliefs on the one hand and the the scientific (observational) beliefs on the other hand, based on reasons. The progress of science and growth of scientific knowledge as we see today took its shape as a resistance to the acceptance of the authority of religion. The scientific beliefs when compared to religious beliefs are based on systematic "inquiry" based on solid foundations of reason than mere superstitions.

One of the major problems faced by the people is determining the appropriate reaction when faced with *evidence* contradicting some of the existent beliefs. If scientists are asked the question about his/her aims, we get an answer that his inquiry is directed towards some observed phenomena. For instance, scientist might wonder what needs to be done when the laws of conservation of mass[1] fails to hold for the nuclear processes. A scientist might find it difficult to abandon it. It follows that some beliefs are more entrenched than the other, and entrenchment is dependent on the information value it carries.

The purpose of science is to discover reality or to predict things correctly. [59]. The theory that explains better survives; and a successful explanation is one that yields many predictions. For example Newtons theory of gravitation has greater explanatory power than that of Kepler theory. Belief revision (theory change) is an active area which interests both philosophy [29, 39, 19, 22] and AI community [13, 45]. For applications of belief revision in various areas, we refer to [63]. The problem has originated in philosophical logic, where the problem of accepting conditional beliefs has been considered to be difficult in the standard framework [17, 18]. Philosophers (logicians) goal has been to provide a mechanism for fixing the inconsistent belief state resulting from accepting the new evidential information. Here, the sources of information can be single or multiple and the out put revised belief state contains part of the old and part of new information. On the other hand, AI community is interested to explore belief revision such as building reason maintenance systems and use it to understand basic behavior of intelligent systems. AI researchers are interested in designing automated agents which interact with the environment while revising beliefs. [2]

Abductive reasoning is quite ordinary and common sensical. The term *Abduction* deals with whole field of growth of scientific knowledge. [3]. For instance, if we see broken horizontal glass on the floor, we might explain this fact by postulating the effect of wind shortly before it. This is not a deductive consequence of the glass being broken (A cat may well have been responsible for it). Abduction is the process of reasoning in which explanatory hypotheses are formed and evaluated.

[1] states that the mass of a system of substances is constant, regardless of the processes acting inside the system.

[2] Jaime Simao Sichman and Yves Demazeau. A model for the decision phase of autonomous belief revision in open multi-agent systems. Journal of the Brazilian Computer Society, 3(1):40–50, Jul 1996.

[3] Abduction is a kind of theory forming or interpretive inference. The philosopher and logician Charles Sanders Peirce(1839-1914) contended that there occurs in science and everyday life a distinctive pattern of reasoning wherein explanatory hypotheses are formed and accepted. He calls it as *Abduction*

For instance, when Leverrier postulated the existence of Neptune from the discrepancy between the predicted and the observed trajectory of Uranus. The abduction here, operates from facts to facts (which is a simple case), where as for instance, when Newton's theory was conjectured from Kepler's laws and falling bodies law, it is said to have operated from Laws to theory.

Abduction was first introduced in the epistemological context of scientific discovery [2]. Abduction is the process of inferring certain facts and laws that render some sentence plausible, that explain some phenomena and observation. Hence the goal of abduction is to find a set of assumptions that, together with the background knowledge, entail or explain the observations. Originally proposed by the philosopher C. S. Peirce [4], and latter gained few logical improvements, including Rescher(1978), and Levi(1971) [5]. Abduction has been used a reasoning mechanism for number of applications from building explanations for natural language text to device diagnosis [11]. The intimate connection between causation and abduction has become vividly clear in the cox's paper on causal approach to diagnosis. The most basic and, in some idealized sense, the the compelling form of abduction is presented by Hempel's deductive nomological explanations [30]. For example, the observation that Eagle flies can be explained by the fact that the Eagle is a bird and and "all birds fly". Since such definition can be shown to be unsatisfactory, a richer approach first consists in considering non-monotonic reasoning [49, 50, 51]. Latter, Abduction is viewed as inference to the best explanation(see Harman [28], Thagard [6], Lipton 1991). However, the notion of "best"" explanation is too demanding since abduction may select several candidates to belief.

Abduction and belief revision are closely related to each other and they are two sides of the same coin [4, 7]. For instance, an abductive logics has been proposed with in the AGM [1] framework [61]. An abductive framework for belief revision has been proposed by [32]. Abduction is the process of finding plausible explanations for some observed event. If the reasoner becomes more experiences, i.e., more facts becomes known, it is possible that previously assumed explanations have to be rejected. Thus non-monotonic mechanism is needed to keep track of the "plausible hypotheses".

When multiple explanations are possible for retaining the beliefs, abduction can be viewed as a search in a space of explanations. One alternative is to maintain fewer explanations and to alter them using belief revision if they become inconsistent. Thus belief revision can be seen as a technique for improving the abduction. On the other hand, in the process of giving up beliefs we need o generate explanations and order them in the relative importance of epistemic value. Beliefs carrying most plausible explanations with respect to the new information to be given more information value which is qualitatively known by the epistemic entrenchment ordering.

In general, the purpose of an explanation is to render facts intelligible to a mind seeking to understand. The adequate explication of the notion of explanation is still a topic of discussion and dispute in philosophy. Different notions of explanations have been studied quite extensively, see

[4]Peirce, C.S. 1931-58. The Collected Papers of Charles Sanders Peirce, eds. C. Hartshorne, P. Weiss (Vols. 1-6) and A. Burks (Vols. 7-8). (Cambridge MA: Harvard University Press).

[5]"Probability and Evidence," Induction, Acceptance and Rational Belief, ed. by M.Swain, Dordrecht: Reidel, pp.134-56.

[6]Thagard, P. and Shelley, C. P. (1997). Abductive reasoning: Logic, visual thinking, and coherence. In M.-L. Dalla Chiara et al. (Eds.), Logic and scientific methods. Dordrecht: Kluwer, 413-427. HTML

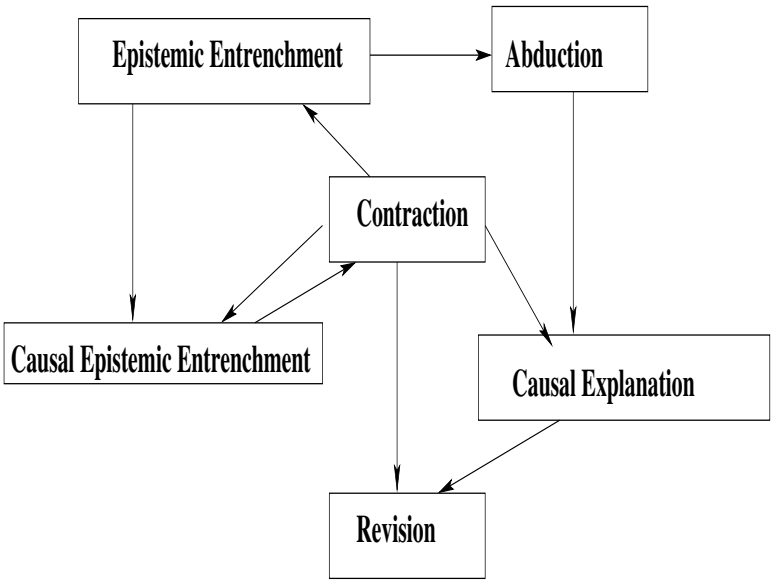

Figure 1: Abduction, causal explanation and Entrenchment

especially [31, 21, 56, 60] for philosophical work, and [57, 9, 25]for work in AI that is related to Bayesian networks. There is no consensus among AI researchers or Philosohers about the criteria of ranking explanations. Researchers have identified *simplicity, coherence, certainty, specificity, Consilience, ability to provide alternative explanations as the important criteria for explanation.* A critical examination of such approaches from the viewpoint of explanations in probabilistic systems is given in [8]. Notions related to explanation have emerged in theories of belief change in AI [2]. One does not just want to incorporate new beliefs, but often also, to justify them. The main motivation of these theories is to develop logical and computational mechanisms to incorporate new information to a scientific theory, data base or set of beliefs.

In the context of belief revision, Falappa and Kern-Isberner [14], presented a new kind of non-prioritized revision operator based on the use of explanations. The idea is that an agent, before incorporating information which is inconsistent with its knowledge, sees an explanation supporting it. They explored explanations within the deductive framework. Boutilier views belief revision as an adductive inference process. In [7] abduction is treated as belief revision process in which they proposed a model of abduction based on the revision of epistemic state of an agent.

Causality plays an important role in the generation of explanations, which are of crucial importance in areas like planning, diagnosis, natural language processing, and probabilistic inference. Causal considerations play an important role in abduction. They determine, in particular, the very choice of abducibles, as well as the right forms of descriptions and constraints [5]. As has been shown by Pearl [47, 12], system descriptions that do not respect the natural causal order of things can produce inadequate predictions and explanations. The link between causality and dynamics of belief revision via contraction is discussed in [20].

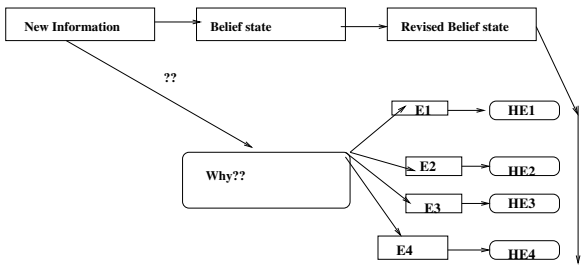

Figure 2: Problem of Belief revision based on Abduction

2 Description of Problem:

There are two ways of viewing the problem with respect to the revision of beliefs. As shown in the diagram 2, an agent may generate different explanations before accepting the new information. Some are related to readjusting old beliefs and others may be with abandoning some of the beliefs in the periphery, and other are concerned with abandoning new information altogether. Corresponding to each expansion he generalizes an hypotheses. Then we evaluate the hypotheses using the tools of abduction. The best hypotheses can be generated out out by invoking causal explanation. Such a causal explanation is embedded on causal explanations.

Existing belief revision model deal with how belief revision should take place with a set of rationality postulates and an ordering over beliefs to know the relative importance of information value. They are based on reasoning in which the reasonable conclusions are always reached by considering the logical consequences of some known facts. A common pattern of inference that fails to confirm to this picture is *abduction*. These postulates are syntactic and does not give us adequate explanations as to why we need to revise the beliefs the way it is defined in the standard frame work and 2. it does not allow for the role of explanation agent should revise beliefs.

The problem of ordering explanations is similar to the ordering of beliefs in two respects. (1) both are epistemic and (2) the ordering is dependent on external constraints for its understanding. The existing entrenchment ordering of beliefs in giving up beliefs in the belief revision is not sufficient in situations such as 1. beliefs are causally dependent on the other. If we give up any belief from the causal beliefs in the belief set, then some of the beliefs that are causally dependent on it will also needs to be given up, leading to problem of information economy. 2. choosing relevant beliefs which participate in the belief revision. 3. We believe that not much progress took place in the direction where for instance causal structure influences agent belief revision mechanism.

The objective of the proposal is to study belief revision in the context of abductive explanation. The aim of our project is propose appropriate semantics for belief revision based on causal explanation. When the new information contradicting the old information then the usual strategy followed is the one adopted by many belief revision frameworks including the popular AGM framework. The strategy is to withdraw some of the beliefs from the existent beliefs by imposing an ordering over beliefs, called epistemic entrenchment ordering of beliefs.

A more natural strategy would be for the agent to first seek an explanation or justification for the new information. Then the explanation together with the new information leads to appropriate change of beliefs. In order to achieve this end, we propose logic of belief change based on abductive reasoning. It extends the standard framework of belief revision with an additional structure called *causal structure*. Causal explanation is constituted by at least one of the semantic features such as causal mechanism, causal process, causal properties and intervention.

3 AGM paradigm

Alscourron, Gärdenfors and Makinson (AGM) [1] have advanced a set of postulates that have become standard(paradigm) against which proposals for belief revision are examined. The AGM postulates models beliefs (deductively closed sets of sentences) and constrain how rational agent should change its belief set K when the new information arrives. The guiding principle behind the AGM postulates is that of *minimal change*, i.e., the new belief state $K^1 = K * \phi$ should not differ from K by more than the evidence requires.

There are two ways to characterize belief revision satisfying AGM rationality postulates. One is based on the concept of *epistemic entrenchment* [23], a total ordering(connected, transitive and reflexive) over sentences of a language. The other uses the notion of *faithful per orders* due to Mendelzon [**?**], operated over interpretations of finitely propositional language.

The semantics of AGM postulates is based on the structure and dynamics of possible worlds. They are worked out in detail and widely elaborated in the works of Grove [24], Spohn (Ranking functions) [58] and Williams(Transmutations) [64]. We begin with fairly standard definition of abduction. Similar definitions are found in [51, 52, 34, 35] and Jack [7],and [8]
Definition 3.1 (Abduction)**.** *An abduction of a formula ϕ with respect to a domain theory Γ (a set of formulas) is a set of formulae E such that :*

1. $\Gamma \cup E \models \phi$.

2. $\Gamma \cup E$ *is consistent (i.e.,* $\Gamma \cup E \not\models \bot$*.) We also say that E is abduced from Γ and ϕ.*

Observation 3.2. *If an abduction E of a formula ϕ with respect to a domain theory Γ exists then a finite abduction $E^1 \subseteq E$ (Where E^1 is understood to be finite) of ϕ with respect to Γ exists.*
Lemma 3.3. *If a finite abduction E of ϕ with respect to Γ exists it can be represented by by a single formula Ψ ($\Gamma \cup \{\psi\} \models \phi$, $\Gamma \cup \{\Psi\} \not\models \bot$)*

Given a formula ϕ and domain theory Γ w can usually derive a number of abductions. Following Paggnucco, we are interested in *minimal Abductions*, which are defined as follows:
Definition 3.4 (minimal abduction: [46])**.** *An abduction Ψ of ϕ with respect to Γ is a minimal abduction iff for any Ψ^1, if $\Psi \models \Psi^1$ is also an abduction of ϕ with respect to Γ then $\models \Psi \leftrightarrow \Psi^1$ (Where Ψ, Ψ^1, ϕ are*

[7] P. Jackson. Propositional Abductive Logic. 7th AISB, 1989, 89–94
[8] H J. Levesque. A knowledge level account of abduction, 11th IJCAI, 1989, 1061-1067

all single formulae)

4 Related Work

There are various approaches in which new information can be added to the old [16]. As beliefs are inferentially related, revision affects belief sets, not just single beliefs but whole webs of related beliefs. The new belief may allow inferences affecting several other beliefs and may mean there is more or less support for other beliefs. However, in all the approaches based on AGM, the revised belief state is uniquely determined by the input and the existing beliefs. This need not be the case in the indeterministic settings. Whereas in the AGM theory of belief revision is seen as a function from belief state and a sentence to a new belief state,

Lindstrom and Rabinowicz [40] propose to view the revision process as a relation, allowing for many other equally reasonable revisions of a theory with given proposition. They provide an axiomatic system for relational belief and showed how this system can be related to axioms of epistemic entrenchment. For this we refer to Rabinowicz and Lindstrom [9] and [10]. This relational belief revision arise out of the incomparability of beliefs. Issac Levi proposed a more compelling defense of entrenchment incomparability. According to Levi, the incomparability is not because of we are comparing propositions that are different content-wise, but "due to conflict or indeterminacy in the agent's values and goals". [11]

However, acceptance of new information need not be necessary all the time. It need not always be subjected to to the principle of minimal change where we accept the best possible pieces of information. A wide treatment of non-prioritized revision operators on belief sets can be found in [26].In an recent work, Nayak et. al [44, 43] have advocated the adoption of the principle of rejecting the worst in lieu of the principle of selecting the best in the context of AGM belief revision. The aim of this work is to extend this idea of abductive reasoning- in particular to explore the consequences of discarding the *chose the best* principle in favour of of *reject the worst* principle in the context of abductive belief change [12]. Belief revision can be prioritized or non prioritized based on whether or not we give emphasis to the new information seeking explanations for justifying such an acceptance. For instance, in the *non prioritized belief revision* one need not give priority to the new information(acceptance is not necessary) and an explanation may be called for before accepting the new information.

Boutilier proposed a model to abduction on the revision of epistemic state of an agent. There, explanations must be sufficient to induce belief in the sentence to be explained, or ensure its consis-

[9] Lindstrm, S., and Rabinowicz, W.(1991), Epistemic entrenchment with incomparabilities and relational belief revision, in The Logic of Theory Change,Fuhrmann, A, and Morreau, M. (eds.): 93-126.

[10] Rabinowicz, W. and Lindstrm, S. (1994), How to model relational belief revision, in D Prawitz and D. Westersthl (eds.), Logic and Philosophy of Science in Uppsala, Kluwer, 69-84.

[11] Levi, I. (2004), Mild contraction: evaluating loss of information due to loss of belief, Clarendon Press: Oxford.

[12] Maurice Pagnucco. The Role of Abductive Reasoning within the Process of Belief revision. PhD thesis, University of Sydney, 1996.

tency with other beliefs. They suggested a mechanism with which one can generate explanations that *nonmonotoncically predict* an observation, generalizing the the received view of explanations, which requires some deductive relationship between explanation and observation. They also provided a natural preference ordering on explanations, defined in terms of normality and plausibility. See [7] for details. Their notion explanation is restricted to propositional case. Inspired by the Spohn's ranking functions based on the dynamics o possible worlds, Williams extended this to a conditional case and introduces the notion of transmutations on knowledge bases. Williams introduced the the notion of *adjustment* which is a transmutation that involves *absolute minimal change* [64, 62]. This led to our notion of entrenchment ranking which explores the relevance of competing explanations and the strength of competing explanations using the quantitative information encoded in Entrenchment ranking.

Ordering explanations

If an agent has to choose among competing explanations, there must exist some criteria for this choice. An obvious preference criterion on explanations is based on the likelihood of the explanations themselves. An agent should choose the most probable explanation relative to a given context. The idea of choosing most probable explanations was discussed by Pearl. [13]

There have been proposals to address these issues in a more qualitative manner using logic-based frameworks also. Peirce [48] discusses the plausibility of explanations, as do Quine and Ullian [53]. Consistency-based diagnosis [14] uses abnormality assumptions to capture the context-dependence of explanations; and preferred explanations are those that minimize abnormalities. Pooles [49, 50] assumption-based framework captures some of these ideas by explicitly introducing a set of default assumptions to account for the nonmonotonicity of explanations.

5 Novelty of Project

Our work is different from other in the following respects:

1. We provide new entrenchment ordering called *Causal entrenchment ordering* for explaining revision of causal and conditional beliefs. It is different from standard entrenchment ordering and entrenchment ordering due to Gardenfors and Nayak respectively. CEE is constrained by the constraints o causal relevance. One difference is that the ordering relation is non linear and and need not hold the connective property(which talks about the comparability of beliefs). Moreover, maximal entrenched beliefs need not be tautologies all the time. Beliefs are structured in terms of core and periphery. The resultant theory of belief revision is closer

[13] Judea Pearl. Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference. Morgan Kaufmann, San Mateo, 1988.

[14] Raymond Reiter. A theory of diagnosis from rst principles. Articial Intelligence, 32:5795, 1987.

to some of the important works on belief revision, such as [15, 27, 6, 10]

2. Our approach insists on preserving the *core*, which is motivated by the examples from history of science. Our notion of abduction is close to some of the approaches by Aliseda [2, 3], but the difference lies in the constraints on the possibilities of explanations. Inference to the best explanation (when it is causal) might come close to our definition of abduction provided, we understand causal explanation in terms of some semantic properties.

3. The idea of explanatory belief revision systems (as far as we believe) is new and we expect the study to lead to an automated self explanatory belief revision system(AEBRS).

6 Project Time line

The time period for the project since it gets the approval is three semesters (1.5 years) and it is divided into three phases.

1. **Phase-1:**An appropriate theory of *Abduction* suitable for the given belief revision situation is explored. An analogy between scientific theory change and belief change based on abduction will be provided.

2. **Phase2:** We extend the AGM frame work to account for belief changes based on abductive explanations. We extend the standard entrenchment ordering with a new entrenchment ordering(different on properties). The abductive belief change operators and rationality postulates are studied in AGM belief revision framework.

3. **Phase-3:** Some consequences of resulting theory will be discussed. Two important problems are (1) the problem of success and recovery postulate 2. Mechanism of ordering explanations based on epistemic entrenchment. Our work also has a consequence to scientific theory change(core and periphery of beliefs) and provide some insights when we connect Epistemic Entrenchment to social choice theory.

7 Project Outcomes

In the history and philosophy of science *belief* has been tremendously systematic. Beliefs have been discarded in a consistent manner, maintained or created with an eye toward compatibility with the generative *hard core* of dominant belief systems.

We see that the work described above has the following outcomes. First in the scientific theory

change, where it attempts to answer:

- How do we characterize hard core? and Periphery?
- What role abduction play in the scientific theory change? How do we chose the best hypotheses when there is a conflict?

7.1 Consequences to Philosophy of Science: Scientific theory change

In his famous book *The structure of scientific revolution*, Thomas Kuhn [36] proposed that science evolves according to highly discontinuous process, which consists of (1) long periods of *normal science*, in which the prevailing scientific belief revision system remains unchanged, and new beliefs are accepted or rejected largely on the basis of their compatibility with this belief revision system. (2) rare sudden *paradigm change*, in which the old belief system is replaced with new one.

One of the classic example of scientific revolution is the switch from Newtonian mechanics to relativity and quantum theory. Kuhn never talked much about how belief systems work. Rather, he placed the burden of explanation on sociology. Lakatos [38, 37] was more specific. He hypothesized that science is organized into belief systems called *research programmes*, each of which consists of *hard core* of essential beliefs and a *periphery* of beliefs which serves as a medium between hard core and the context.

Example 7.1. *In the Ptolemaic research program, the analysis of the motions of heavenly bodies are explained in terms of circular paths. One could argue that hard core here contains the belief that circle is the basic unit of heavenly motion, and o the beliefs that earth is the center of universe. Whereas initially the periphery contained among other things, the belief that the heavenly bodies resolve around the earth in circular orbits.*

When testing refuted the latter belief, it was rejected and replaced with another belief that was compatible with the hard core; the belief that the heavenly bodies move in *epicycles*, circles around the earth. The data was accommodated, but hard core remained untouched.

Example 7.2. *Consider next the Copernican theory, that planets revolve in circles around the Sun. This retains part but not ll of the hard core of the Ptolemaic belief system, and it generates a new periphery. In Copernicus's time, it was not clear* why, *if the earth is moved, everything on its surface didn't fly off. Explanation given to this phenomena are not adequate until around the time of Newton, there was a convincing explanation. In other words, the persuasiveness of Newton's theory of gravitation was enhanced by its ability to explain not only the motion of planets, but also the occurrence of the tides. These vague dilemma ridden theories before Newton epitomize Lakatos's concept of Periphery.*

Philosophers of science have number of explanations of the transition from Ptolemaic to Copernican Cosmology. It was not that Copernican belief system explained the data much better than its predecessor; in fact, it has been argued that, when the two are restricted to the same number of parameters, their explanatory power is approximately the same.

In a similar way when the general theory of relativity could accurately predict the exact amount of precession of Mercury's orbit, it is seen as a result of the way mass curves space- a notion which is entirely foreign to Newton. The other work that connects epistemic entrenchment and scientific change and scientific discovery are [33, 42, 54]

7.2 Social Choice

Belief revision(Entrenchment) and social choice are intertwined to each other. Both are concerned with a decision concerned with preferences and choice. Rott [55] showed that all operations of belief change (or nonmonotonic logic) that are generated by rational choice functions, with the choices satisfying certain coherence constraints, satisfy corresp onding rationality postulates for belief change (soundness).

The process of voting can be seen as the aggregation of individual preferences (i.e., that of the voters for candidates) to produce a collectively preferred alternative (the result of the election). This problem is extensively studied by social choice theory. On the other hand, belief revision as we have seen above, investigates the dynamics of the process of belief change: when an agent is faced with new information which contradicts his/her current beliefs, he/she will have to retract some of the old beliefs in order to accommodate the new belief consistently. The main concern here is how to make a fair decision on what old beliefs to retract. Although there are clear connections and sharing of principles between the areas, the investigation of the similarities between the three of them is quite new.

8 Concluding Remarks

The role of abduction in the ordering beliefs is critical for explanatory belief revision system. This project provides a novel approach for belief revision by examining the hierarchy of explanations generated before accepting the new information. It provides an agent with a decision of which beliefs to abandon based on minimal change. a mechanism when to accept the evidential new information. Any proper theory of belief revision must involve three things: a way of characterizing beliefs (2) a set of criteria for preferring some revisions to others (3) a mechanism for applying these criteria to identify the preferred set of beliefs. What we believe or reasons for holding a belief is associated with its underlying causal structure. In this work, we elaborate the missing link between epistemic entrenchment and the causal explanation. The resulting framework of belief revision based on explanation, which we call as explanatory belief revision system (EBRS). The semantics of such belief revision system is based on extensions of Grove's system of spheres based on an understanding of the dynamics of possible worlds. The way people actually revise beliefs is shown to be different from what the formal models suggested in the logic and AI literature. The standard frame work is suitable for belief changes satisfying principle of minimal

change. In an interesting empirical work, Clare Walsh [15] showed that when people are asked to create explanations to remove inconsistencies, they make more than minimal changes.

Dissemination

We aim to present the findings at major conferences, such as the Knowledge Representation. Publication will be in the format of 2 articles in good national and international journals [16] such as Journal of Philosophical Logic, Thinking and Reasoning, JICPR, and some of the important on line peer reviewed on line philosophy journals [17].

Word Count

- Words: 4700 Project2.tex
- Characters:32946

[15] Byrne, R. M. J. Walsh C.R. (2005). Resolving Contradictions. In V. Girotto P.N. Johnson-Laird, (Eds.). The shape of reason: essays in honour of Paolo Legrenzi. Hove: Psychology Press.

[16] http://www.philosophylists.info/Journals.html

[17] http://philsci-archive.pitt.edu/

Table 1: Financial Proposal

S. No	Type	Price in Rs
1	Cost of Equipment(PC, Printer, Scanner, UPS etc.)	Rs. 85,000
2	Cost of Logic Softwares (Hugin)	Rs. 65,000
3	Cost on Travel (visiting IIIT, Library consultation etc.)	Rs.45,000
4	Contingency (Stationary items etc)	40,000
5	Books (Hand books of Logic and phiosophy of logic etc)	Rs. 65,000
6	Total cost envisaged for the entire study (Approx)	Rs. 3, 00, 000

Budget Justification

1. Equipment: A good working Laptop or LCD monitor desktop is important for the research. It will serve as the dedicated computational tool which we will use to demonstrate the logic software and run the logic software. We also will require an additional 300GB external hard disk, in order to make periodic backups of our data. We are requesting a 2GB pen Drive for carrying the presentation(ppt) files.

2. Logic Software: We would like to buy Hyperproof, Aristotle to demonstrate applications of logic(Therem proving, deduction). This we will use it in the course curriculam and popularizing *Logic education* in schools. Other important softwares used in teaching logic are mentioned in the website *http://www.cs.otago.ac.nz/staffpriv/hans/logiccourseware.html*. Hugin is another software which is very useful for our research. [18]. It roughly costs Rs 49,000 for educational licence. This package would be useful for others working in the area of causal bayesian networks. It is used in the construction an use of Bayesian networks, the construction and use of influence diagrams, methods for analysing results, and programming with the different programming interfaces for the Hugin Decision Engine.

3. Contingency: We will be preparing some tools (mainly posters and purchasing some puzzle solving tools to teach logic. Contingency also include CD box, Tea maker, note books etc.

4. Travel: Travelling to Hyderabad(IIIT) twice or thrice is absolutely essential to my project. I will be jointly collaborating with IIIT and Hyderabad central University.

5. Books: Some of the source books are essential for our project. They include handbooks of philosophical logic, which are available in our library.

[18](http://www.hugin.com)

References

[1] Carlos E. Alchourrón, Peter Gärdenfors, and David Makinson, 'On the logic of theory change: Partial meet contraction and revision functions', *J. Symb. Log.*, **50**(2), 510–530, (1985).

[2] Atocha Aliseda, 'Abduction, reason, and science: A review', *AI Magazine*, **23**(1), 113–114, (2002).

[3] Atocha Aliseda, *Logical Investigations into Discovery and Explanation*, Series: Synthese Library , Vol. 330, The Hague, 2006.

[4] Chandrabrose Aravindan and Phan Minh Dung, 'Belief dynamics, abduction, and databases', in *Logics in Artificial Intelligence*, eds., Craig MacNish, Luís Moniz Pereira, and David Pearce, 66–85, Springer-Verlag, Berlin, (1994).

[5] Alexander Bochman, 'Production inference, nonmonotonicity and abduction', in *AMAI*, (2004).

[6] Richard Booth, Thomas Meyer, and Ka shu Wong, 'A bad day surfing is better than a good day working: How to revise a total preorder', in *KR*, eds., Patrick Doherty, John Mylopoulos, and Christopher A. Welty, pp. 230–238. AAAI Press, (2006).

[7] Craig Boutilier and Verónica Becher, 'Abduction as belief revision.', *Artificial Intelligence*, **77**(1), 43–94, (1995).

[8] Urszula Chajewska and Joseph Y. Halpern, 'Defining explanation in probabilistic systems', in *UAI*, pp. 62–71, (1997).

[9] Eugene Charniak, 'Logic and explanation', *Computational Intelligence*, **3**, 172–174, (1987).

[10] Samir Chopra, Aditya Ghose, and Thomas Meyer, 'Non-prioritized ranked belief change', *Journal of Philosophical Logic*, **32**(3), 417–443, (2003).

[11] Philip T. Cox and Tomasz Pietrzykowski, 'General diagnosis by abductive inference', in *SLP*, pp. 183–189, (1987).

[12] Adnan Darwiche and Judea Pearl, 'Symbolic causal networks', in *AAAI*, pp. 238–244, (1994).

[13] Jon Doyle, 'Truth maintenance systems for problem solving', in *IJCAI*, p. 247, (1977).

[14] Marcelo A. Falappa, Gabriele Kern-Isberner, and Guillermo Ricardo Simari, 'Explanations, belief revision and defeasible reasoning', *Artif. Intell.*, **141**(1/2), 1–28, (2002).

[15] Eduardo L. Fermé and Sven Ove Hansson, 'Selective revision', *Studia Logica*, **63**(1), 331–342, (1999).

[16] André Fuhrmann and Michael Morreau, eds. *The Logic of Theory Change, Workshop, Konstanz, FRG, October 13-15, 1989, Proceedings*, volume 465 of *Lecture Notes in Computer Science*. Springer, 1991.

[17] P. Gärdenfors, 'Conditionals and changes of belief', *Acta Philos. Fennica*, **30**, 381–404, (1978).

[18] Peter Gärdenfors, 'An epistemic approach to conditionals', *American Philosophical Quarterly*, **18**(3), 203–211, (1981).

[19] Peter Gärdenfors, 'Propositional logic based on the dynamics of belief', *J. Symb. Log.*, **50**(2), 390–394, (1985).

[20] Peter Gärdenfors, 'Causation and the dynamics of belief', in *Causation in Decision, Belief Change, and Statistics, Vol. 2*, eds., William L. Harper and Brian Skyrms, 85–104, Kluwer Academic Publishers, (1988).

[21] Peter Gärdenfors, *Knowledge in Flux: Modeling the Dynamics of Epistemic States*, MIT Press, Bradford Books, Cambridge, MA, 1988.

[22] Peter Gärdenfors, 'Belief revision and knowledge representation', in *TARK*, p. 117, (1996).

[23] Peter Gärdenfors and David Makinson, 'Revisions of knowledge systems using epistemic entrenchment', in *TARK*, pp. 83–95, (1988).

[24] Adam J. Grove, 'Two modellings for theory change', *Journal of Philosophical Logic*, **17**, 157–170, (1988).

[25] Joseph Y. Halpern and Judea Pearl, 'Causes and explanations: A structural-model approach. part II: Explanations', *CoRR*, **cs.AI/0208034**, (2002).

[26] Sven Ove Hansson, Eduardo Leopoldo Fermé, John Cantwell, and Marcello Alejandro Falappa, 'Credibility limited revision', *Journal of Symbolic Logic*, **66**(4), 1581–1596, (2001).

[27] Sven Ove Hansson, Eduardo Leopoldo Fermé, John Cantwell, and Marcello Alejandro Falappa, 'Credibility limited revision', *Journal of Symbolic Logic*, **66**(4), 1581–1596, (2001).

[28] Gilbert Harman, *Change of View*, MIT PRESS, 1986.

[29] William L. Harper, 'Ramsey test conditionals and iterated belief change', in *Foundations of Probability Theory, Statistical Inference, and Statistical Theories of Science, Volume 1*, eds., William L. Harper and Clifford A. Hooker, 117–136, D. Reidel Publishing Co., Dordrecht, (1976).

[30] C. G. Hempel, *Aspects of Scientific Explanation*, The Free Press, New York, NY, 1965.

[31] Carl G. Hempel, 'The covering law analysis of scientific explanation', *Philosophy of Science*, **15**(2), 135–146,157–157,172–174, (1948).

[32] Katsumi Inoue and Chiaki Sakama, 'Abductive framework for theory change', in *Proceedings of the Fourteenth International Joint Conference on Artificial Intelligence*, ed., Chris Mellish, pp. 204–210, San Francisco, (1995). Morgan Kaufmann.

[33] Robert Klee, 'Problems with formal models of epistemic entrenchment as applied to scientific theories', *Synthese*, **122**(3), 313–320, (2004).

[34] K. Konolige, 'A general theory of abduction', in *Working Notes of the 1990 Spring Symposium on Automated Abduction*, ed., P. O'Rorke. AAAI, (1990). Technical Report 90-32, Department of Information and Computer Science, University of California, Irvine.

[35] Kurt Konolige, 'Abduction versus closure in causal theories.', *Artificial Intelligence*, **53**(1), 255–272, (1992).

[36] Thomas Kuhn, *The Structure of Scientific Revolutions*, The University of Chicago Press, Chicago, IL, 1970.

[37] I. Lakatos and A. (eds.) Musgrave, *The Methodology of Scientific Research Programmes, in Lakatos and Musgrave (ed)*, MIT PRESS, 1970.

[38] I. Lakatos and A. (eds.) Musgrave, *Criticism and the Growth of Knowledge*, MIT PRESS, 1986.

[39] Isaac Levi, 'The iteration of conditionals and the Ramsey test', *Synthése*, **76**(1), 49–81, (1988).

[40] Sten Lindström and Wlodzimierz Rabinowicz, 'Epistemic entrenchment with incomparabilities and relational belief revision', in *The Logic of Theory Change*, pp. 93–126, (1989).

[41] Peter Lipton, *Inference to the Best Explanation*, Routledge, London, 1991.

[42] Eric Martin and Daniel N. Osherson, 'Scientific discovery based on belief revision', *The Journal of Symbolic Logic*, **62**(4), 1352–1370, (December 1997).

[43] Abhaya C. Nayak, 'Acceptance without minimality', in *JELIA*, pp. 163–178, (2000).

[44] Abhaya C. Nayak and Norman Y. Foo, 'Abduction without minimality', in *Australian Joint Conference on Artificial Intelligence*, pp. 365–377, (1999).

[45] Bernhard Nebel, 'A knowledge level analysis of belief revision', in *KR*, pp. 301–311, (1989).

[46] Maurice Pagnucco, Abhaya C. Nayak, and Norman Y. Foo, 'Abductive reasoning, belief expansion and nonmonotonic cesequence.', in *Deductive Databases / Abduction in Deductive Databases*, pp. 143–158, (1995).

[47] Judea Pearl, *Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference*, morgan, 1988.

[48] C. Peirce, 'Abduction and induction', in *The Philosophy of Peirce: Selected Writings*, ed., J. Buchler, chapter 11, Harcourt, Brace and Company, New York, (1948).

[49] David Poole, 'On the comparison of theories: Preferring the most specific explanation', in *IJCAI*, pp. 144–147, (1985).

[50] David Poole, 'Representing knowledge for logic-based diagnosis', in *FGCS*, pp. 1282–1290, (1988).

[51] David Poole, 'Explanation, prediction: an architecture for default, abductive reasoning', *Computational Intelligence*, **5**, 97–110, (1989).

[52] Stathis Psillos, 'Simply the best: A case for abduction', in *Computational Logic: Logic Programming and Beyond*, pp. 605–626, (2002).

[53] W. V. Quine and J. S. Ullian, *The Web of Belief*, Random House, New York, NY, 1978.

[54] D. Rose and P. Langley, 'Belief revision in scientific discovery', in *Proc. of AAAI-86*, pp. 528–532, Philadelphia, PA, (1986).

[55] Hans Rott, *Change, Choice, and Inference*, Oxford University Press, Oxford, 2002.

[56] Wesley C. Salmon, *Scientific explanation and the causal structure of the world*, Princeton University Press, 1984.

[57] Murray Shanahan, 'Prediction is deduction but explanation is abduction', in *IJCAI*, pp. 1055–1060, (1989).

[58] W. Spohn, 'Ordinal conditional functions: A dynamic theory of epistemic states', **volume 2**, 105–134, (1988).

[59] Stephen Toulmin, *Foresight and Understanding: An Enquiry Into the Aims of Science.*, Bloomington: Indiana University Press, 1961.

[60] Bas C. van Fraassen, 'The pragmatics of explanation', *American Philosophical Quarterly*, **14**(2), 143–150, (1977).

[61] Bernard Walliser, Denis Zwirn, and Hervé Zwirn, 'Abductive logics in a belief revision framework', *Journal of Logic, Language, and Information*, **14**(1), 87–117, (2005).

[62] Mary-Anne Williams, 'Anytime belief revision', in *IJCAI (1)*, pp. 74–81, (1997).

[63] Mary-Anne Williams, 'Applications of belief revision', in *Transactions and Change in Logic Databases*, pp. 287–316, (1998).

[64] Mary-Anne Williams, Maurice Pagnucco, Norman Y. Foo, and Brailey Sims, 'Determining explanations using transmutations', in *IJCAI (1)*, pp. 822–829, (1995).