Towards Consistency-Based Reliability Assessment (Extended Abstract)

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1. MOTIVATION

Merging information provided by several sources is an important issue and merging techniques have been extensively studied. When the reliability of the sources is not known, one can apply merging techniques such as majority or arbitration merging or distance-based merging for solving conflicts between information. At the opposite, if the reliability of the sources is known, either represented in a quantitative or in a qualitative way, then it can be used to manage contradictions: information provided by a source is generally weakened or ignored if it contradicts information provided by a more reliable source [1, 4, 6]. Assessing the reliability of information sources is thus crucial. The present paper addresses this key question. We adopt a qualitative point of view for reliability representation by assuming that the relative reliability of information sources is represented by a total preorder. This works considers that we have no information about the sources and in particular, we do not know if they are correct (i.e they provide true information) or not. We focus on a preliminary stage of observation and assessment of sources. We claim that during that stage the key issue is a consistency analysis of information provided by sources, whether it is the consistency of single reports or consistency w.r.t trusted knowledge or the consistency of different reports together. We adopt an axiomatic approach: first we give some postulates which characterize what this reliability preorder should be, then we define a generic operator for building this preorder in agreement with the postulates.

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2. PRELIMINARIES

Let A be a finite set of agents; let L be a propositional logic defined over the finite set of propositional letters and propositional constants $\top$ and $\bot$. An interpretation m is a mapping from the set of formulas of L to the set of truth values $\{0, 1\}$ so that $m(\top) = 1$ and $m(\bot) = 0$. Interpretation m is *a model* of formula F iff $m(F) = 1$. The set of F models is denoted $M(F)$. *Tautologies* are formulas which are interpreted by 1 in any interpretation. We write $\models F$ when F is a tautology. *Consistent* formulas are interpreted by 1 in at least one interpretation. A formula is *consistent* iff it is has one model.

Let $\leq$ be a total preorder on A representing the relative reliability of agents: $a \leq b$ stands for b is at least as reliable as a. $a = b$ stands for $a \leq b$ and $b \leq a$. $GT(a, \leq) = \{x \in A \setminus \{a\} : a \leq x\}$ is the set of agents which are as least as reliable as a. Let $a \in A$, $\leq_1$ be a total preorder on A and $\leq_2$ a total preorder on $A \setminus \{a\}$; $\leq_1$ *is compatible with* $\leq_2$ iff $\forall x \forall y \;\; x \leq_2 y \Longrightarrow x \leq_1 y$.

A communication set on A, Ψ, is a set of pairs $< a, \varphi >$ where $a \in A$ and φ is a formula reported by a. We define $Ag(\Psi) = \{a \in A, \exists \varphi \; < a, \varphi > \in \Psi\}$, $\Psi_a = \{< a, \varphi > | < a, \varphi > \in \Psi\}$ and $\Psi(C) = \bigcup_{a \in C} \Psi_a$, if C is a set of agents. Finally we define $\mathsf{Report}(\Psi)$ by $\bigwedge_{< a, \varphi > \in \Psi} \varphi$ if $\Psi \neq \emptyset$ and by $\top$ otherwise.

Let Ψ and Ψ' be two communication sets on A. Ψ and Ψ' are *equivalent* (denoted $\Psi \equiv \Psi'$) iff $\forall a \in A \;\; \models \mathsf{Report}(\Psi_a) \leftrightarrow \mathsf{Report}(\Psi'_a)$. Ψ and Ψ' are *weakly equivalent* (denoted $\Psi \rightleftarrows \Psi'$) iff $\forall a \in A, \exists b \in A, \exists c \in A \;\; \models \mathsf{Report}(\Psi_a) \leftrightarrow \mathsf{Report}(\Psi'_b)$ and $\models \mathsf{Report}(\Psi'_a) \leftrightarrow \mathsf{Report}(\Psi_c)$.

Consistency of communication sets is evaluated with respect to some integrity constraint IC, which is a consistent formula of L. IC has to be viewed as information taken for granted or certain. Let Ψ be a communication set on A. Ψ is IC*-contradictory* iff $\mathsf{Report}(\Psi) \wedge IC$ is inconsistent; otherwise Ψ is IC-consistent. Ψ is *minimal* IC*-contradictory* iff Ψ is IC*-contradictory* and no strict subset of Ψ is IC*-contradictory*. The set of *minimal* IC*-contradictory* subsets of Ψ is denoted $\Psi \perp IC$.

$A^{\perp} = \cup_{F \in \Psi \perp IC} Ag(F)$ is the set of agents which have reported a piece of information which belongs to some *minimal* IC*-contradictory* communication set. Notice that $A^{\perp} \neq \emptyset$ iff Ψ is IC*-contradictory*.

Finally consider $C \subseteq A$. C is IC*-conflicting* iff $\mathsf{Report}(\Psi(C)) \wedge IC$ is inconsistent. C is *minimal* IC*-conflicting* iff it is IC*-conflicting* and no strict subset of C is IC*-conflicting*.

3. RELIABILITY ASSESSMENT

Given a set of agents A, an integrity constraint IC and a communication set Ψ, the total preorder representing the relative reliability of agents in A is denoted $\Gamma^{IC,A}(\Psi)$. The operator Γ, which defines this relative reliability preorder is characterized by the following postulates:

P1 $\Gamma^{IC,A}(\Psi)$ is a total preorder on A.

P2 If $\Psi \equiv \Psi'$ then $\Gamma^{IC,A}(\Psi) = \Gamma^{IC,A}(\Psi')$.

P3 If $\models IC \leftrightarrow IC'$ then $\Gamma^{IC,A}(\Psi) = \Gamma^{IC',A}(\Psi)$.

P4 If $\models \mathsf{Report}(\Psi_a)$ then $\Gamma^{IC,A}(\Psi)$ is compatible with $\Gamma^{IC,A\setminus\{a\}}(\Psi \setminus \Psi_a)$.

P5 If A is not *IC-conflicting* then $\Gamma^{IC,A}(\Psi)$ is the equality preorder.

P6 If A is *IC-conflicting* then $A \setminus A^{\perp} \subseteq GT(a, \Gamma^{IC,A}(\Psi))$ for any $a \in A^{\perp}$.

P7 If $\{a_1, ..., a_k\}$ ($k \geq 2$) is a *minimal IC-conflicting* subset of agents then $\exists i\, \forall j \neq i$, $GT(a_j, \Gamma^{IC,A}(\Psi)) \subset GT(a_i, \Gamma^{IC,A}(\Psi))$.

Postulate **P1** specifies that the expected result is a total preorder. **P2** and **P3** deal with syntax independence. **P4** states that an agent which reports a tautology or which reports no information has no influence on the relative reliability of other agents. **P5**, **P6** and **P7** focus on consistency of information provided by agents in A. **P5** considers the case *when A is not IC-conflicting.* In such a case, the sources are considered as equally reliable. **P6** and **P7** consider the cases *when A is IC-conflicting.* According to **P6**, any agent reporting a piece of information belonging to some *minimal IC-contradictory* communication set is considered as less reliable than any other agent which have not. According to **P7**, if some agents are *minimally IC-conflicting,* then at least one of these agents is strictly less reliable than the others. This is inline with our understanding of reliability: if some agents are at the same level of reliability, then we will believe, with the same strength, information they will provide. But, it is generally admitted ([2, 5]) that it is impossible to believe with the same strength, several pieces of information which are contradictory. Consequently, agents who are *IC-conflicting* should not be at the same levels of reliability.

4. A GENERIC OPERATOR

We start by introducing a measure to quantify the inconsistency degree of communication sets. This measure is adapted from the Shapley inconsistency measure proposed in [3] for measuring inconsistency of sets of formulas.

DEFINITION 1. *A weak-independent IC-inconsistency measure is a function I_{IC} which associates any communication set Ψ with a positive real number $I_{IC}(\Psi)$ so that:*

Consistency: *$I_{IC}(\Psi) = 0$ iff Ψ is IC-consistent.*

Monotony: *$I_{IC}(\Psi \cup \Psi') \geqslant I_{IC}(\Psi)$*

Dominance: *for all ϕ and ψ, if $IC \wedge \phi \models \psi$ and $IC \wedge \phi$ is consistent, then $I_{IC}(\Psi \cup \{< a, \phi >\}) \geqslant I_{IC}(\Psi \cup \{< b, \psi >\})$ for any $a, b \in A$.*

Free formula independence: *If $< a, \phi >$ is free (it does not belong to any minimal IC-contradictory subset of $\Psi \perp IC$), then $I_{IC}(\Psi) = I_{IC}(\Psi \setminus \{< a, \phi >\})$.*

Syntax weak-independence: *$\forall IC'$ if $\models IC \leftrightarrow IC'$ then $I_{IC}(\Psi) = I_{IC'}(\Psi)$ and $\forall \Psi'$ if $\Psi \rightleftarrows \Psi'$ then $I_{IC}(\Psi) = I_{IC}(\Psi')$*

For instance, the two following measures are syntax weak-independent IC-inconsistency measures.

$I^{IC}_{drastic}(\Psi) = 0$ if Ψ is IC-consistent; 1 otherwise.

$I^{IC}_{MI}(\Psi)$ = size of $(\bigcup_{a \in Ag(\Psi)} < a, \mathsf{Report}(\Psi_a) > \perp IC)$

Then we introduce a function for measuring how much an agent contributes to the *IC-inconsistency* of a communication set. According to this definition, the contribution of an agent to the fact that Ψ is *IC-contradictory* is the importance of this agent in a coalitional game defined by function I_{IC}.

DEFINITION 2. *Consider a set of agents A, a communication set Ψ on A, an integrity constraint IC and a syntax weak-independent IC-inconsistency measure I_{IC}. Function $Cont^{I_{IC}}_{\Psi}$ associates any agent a with a positive real number $Cont^{I_{IC}}_{\Psi}(a)$ =*
$\sum_{\substack{C \subseteq A \\ C \neq \emptyset}} \frac{(|C|-1)!(|A|-|C|)!}{|A|!} (I_{IC}(\Psi(C)) - I_{IC}(\Psi(C \setminus \{a\})))$

Function $Cont^{I_{IC}}_{\Psi}$ obviously induces a total preorder among agents. But this preorder does not satisfy **P7**. This is why we propose the following generic operator for ranking agents, $\Gamma^{I_{IC}}$, which agrees with postulates.

DEFINITION 3. *$\Gamma^{I_{IC}}$ is defined by:*

1. $X \leftarrow A$
2. $E \leftarrow \Psi \perp IC$
3. $\leq \leftarrow \{a \leq b \mid a, b \in A\}$
4. **While** $E \neq \emptyset$ **do**
  (a) Deterministically choose $a \in Ag(\cup_{F \in E} F)$ which maximizes $Cont^{I_{IC}}_{\Psi}(a)$
  (b) $X \leftarrow X \setminus \{a\}$
  (c) $E \leftarrow E \setminus \{F \in E \mid a \in Ag(F)\}$
  (d) $\leq \leftarrow \leq \setminus \{b \leq a \mid b \in X\}$
5. **Return** $\leq$

THEOREM 1. *$\Gamma^{I_{IC}}$ operator satisfies postulates* **P1-P7**.

5. CONCLUSION

This work proposes to assess the relative reliability of some information sources by analysing the consistency of information they report, whether it be the consistency of each single report, or the consistency of a report as regard to some trusted knowledge or the consistency of different reports together. We have given some postulates stating what the relative reliability preorder should be. Then we have introduced a generic operator for building such preorder which is parametrized by a function for measuring the inconsistency of the information reported. We prove that this generic operator agrees with the postulates.

Notice that if one has already some partial information about the reliability of the agents (for instance, one knows that a is more reliable than b but has no idea about c reliability) then this process is not applicable as is. In that case, reliability assessment consists of combining the different preorders. For future work, we plan to study these agregation operators.

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