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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.

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 ⊤ and ⊥. An interpretation m is a mapping from the set of formulas of L to the set of truth values {0, 1} so that m(⊤) = 1 and m(⊥) = 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 |= F when F is a tautology. Consistent formulas are interpreted by 1 in at least one interpretation. A formula is consistent iff it has one model.

Let ≤ be a total preorder on A representing the relative reliability of agents: a ≤ b stands for b is at least as reliable as a. a = b stands for a ≤ b and b ≤ a. GT(a, ≤) = {x ∈ A \ {a} : a ≤ x} is the set of agents which are as least as reliable as a. Let a ∈ A, ≤_{IC} be a total preorder on A and ≤_{A} a total preorder on A \ {a}; ≤_{IC} is compatible with ≤_{A} iff ∀x∀y x ≤_{I} y ⇒ x ≤_{A} y.

A communication set on A, Ψ, is a set of pairs < a, ϕ > where a ∈ A and ϕ is a formula reported by a. We define Ag(Ψ) = {a ∈ A, ∃ϕ < a, ϕ >∈ Ψ}. Ψ_{a} = {< a, ϕ >| < a, ϕ >∈ Ψ} and Ψ(C) = ∪_{a∈C}Ψ_{a}, if C is a set of agents. Finally we define Report(Ψ) by ∨_{<a,ϕ>∈Ψ}ϕ if Ψ ≠ ∅ and by ⊤ otherwise.

Let Ψ and Ψ’ be two communication sets on A. Ψ and Ψ’ are equivalent (denoted Ψ ≡ Ψ’) iff ∀a ∈ A ⇒ Report(Ψ_{a}) ↔ Report(Ψ’_{a}). Ψ and Ψ’ are weakly equivalent (denoted Ψ ⊲⊳ Ψ’) iff ∀a ∈ A, ∃ϕ ∈ Ψ, ∃c ∈ Ψ \ A ⇒ Report(Ψ_{a}) ↔ Report(Ψ’_{a}) and |= Report(Ψ) ↔ Report(Ψ’).

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 Report(Ψ) ∨ 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 Ψ ⊥ IC.

A^+ = U_{Ψ∈Ψ ⊥ 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^+ ≠ ∅ iff Ψ is IC-contradictory.

Finally consider C ⊆ A. C is IC-contradicting iff Report(Ψ(C)) ∨ IC is inconsistent. C is minimal IC-contradicting iff it is IC-contradicting and no strict subset of C is IC-contradicting.
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 Γ^{IC,A}(Ψ). The operator IΓ, which defines this relative reliability preorder is characterized by the following postulates:

P1: IΓ^{IC,A}(Ψ) is a total preorder on A.

P2: If Ψ ≡ ≡ Ψ then IΓ^{IC,A}(Ψ) ≡ IΓ^{IC,A}(Ψ).

P3: If |= IC ↔ IC then IΓ^{IC,A}(Ψ) ≡ IΓ^{IC,A}(Ψ).

P4: If Report(Ψω) then IΓ^{IC,A}(Ψ) is compatible with IΓ^{IC,A}(Ψ) (Ψω).

P5: If A is not IC-conflicting then IΓ^{IC,A}(Ψ) is the equality preorder.

P6: If A is IC-conflicting then A \ A^− \subseteq GT(a, IΓ^{IC,A}(Ψ)) for any a ∈ A^−.

P7: If {a_1, ..., a_k} (k ≥ 2) is a minimal IC-conflicting subset of agents then \exists \forall j \neq i, GT(a_i, IΓ^{IC,A}(Ψ)) ⊊ GT(a_i, IΓ^{IC,A}(Ψ)).

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 has 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}(Ψ) so that:

Consistency: I_{IC}(Ψ) = 0 if Ψ is IC-consistent.

Monotony: If I_{IC}(Ψ ∪ φ) ≥ I_{IC}(Ψ) for all φ and ψ, if IC ∧ φ |= ψ and IC ∧ φ is consistent, then I_{IC}(Ψ ∪ {< a, φ >}) ≥ I_{IC}(Ψ ∪ {< b, ψ >}) for any a, b ∈ A.

Free formula independence: If < a, φ > is free (it does not belong to any minimal IC-contradictory set of Ψ ⊥ IC), then I_{IC}(Ψ) = I_{IC}(Ψ \ {< a, φ >})

Syntax-weak independence: If IC′ then I_{IC}(Ψ) = I_{IC}(Ψ) and ∀Ψ if Ψ ⊨ ψ then I_{IC}(Ψ) = I_{IC}(Ψ)

For instance, the two following measures are syntax-weak-independent 1IC-inconsistency measures.

I_{IC}^{IC, A}(Ψ) = 0 if Ψ is IC-consistent; 1 otherwise.

I_{IC}^{IC}(Ψ) = size of (\{\,(a > b) \} < a, \ Report(Ψ_a) \ ⊥ 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_{IC}^{Ψ} associates any agent a with a positive real number Cont_{IC}^{Ψ}(a) = \sum_{a \in A}^{\{IC\}_{\neq [IC]} \{IC(A|C) \} - I_{IC}(Ψ(C \setminus \{a\}))}

Function Cont_{IC}^{Ψ} 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, Γ_{IC}, which agrees with postulates.

DEFINITION 3. Γ_{IC} is defined by:

1. X ← A
2. E ← Ψ ⊨ IC
3. (a ≤ b | a, b ∈ A)
4. While E ≠ Ψ do:
   (a) Deterministically choose a ∈ Ag(∪_{F ∈ E} F) which maximizes Cont_{IC}^{Ψ}(a)
   (b) X ← X \ {a}
   (c) E ← E \ {F ∈ E | a ∈ Ag(F)}
   (d) ≤ ← ≤ \{b ≤ a | b ∈ X\}
5. Return ≤

THEOREM 1. Γ_{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 is 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 aggregation operators.

REFERENCES