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Conflict management in Dempster–Shafer theory using the degree of falsity ☆

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ABSTRACT

In this article we develop a method for conflict management within Dempster–Shafer theory. The idea is that each piece of evidence is discounted in proportion to the degree that it contributes to the conflict. This way the contributors of conflict are managed on a case-by-case basis in relation to the problem they cause. Discounting is performed in a sequence of incremental steps, with conflict updated at each step, until the overall conflict is brought down exactly to a predefined acceptable level.

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1. Introduction

In this article we develop a method for conflict management within Dempster–Shafer theory [2–8] where it is assumed that all belief functions are referring to the same problem or alternatively that they are false.

In general a high degree of conflict is seen as if there is a representation error in the frame of discernment, while a small conflict may be the result of measuring errors.

One type of representation error resulting in high conflict is when belief functions concerning different subproblems that should be handled independently are erroneously combined [9,10]. When this is the case the assumption that all belief functions combined must refer to the same problem (*not* different subproblems) is violated.

We may interpret the conflict as metalevel evidence stating that at least one piece of evidence in the combination should not be part of that combination. By temporarily removing (and replacing) each belief function from the combination, one at a time, we induce a drop in conflict. This is used to derive metalevel evidence regarding each individual belief function indicating that this particular belief function does not belong to the problem in question.

When assuming that there is only one problem at hand, such metalevel evidence must be interpreted as a proposition about the falsity of this belief function. A normalization of the drop in conflict will be shown to be the degree of falsity of that belief function.

However, instead of directly discounting each piece of evidence to its individual degree of falsity we take an incremental step in that direction for all belief functions. Based on these initial discounts we recalculate conflict and update all degrees of

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falsities. The process is performed sequentially until a predefined level of maximal acceptable conflict is reached. With this sequential approach we obtain a smooth discounting process (compared to if we would have fully discounted each belief function to its degree of falsity) and we are able to exactly match any level of acceptable conflict without risk of overshooting.

An alternative way to manage the conflict is to assume that there are different subproblems where the set of basic belief assignments (bbas) may be distributed to different clusters that should be handled separately [9–18].

Another approach also using meta-knowledge regarding the reliability of the source is *contextual discounting* [19]. It is also possible to develop alternative distance measures between bodies of evidence [21,22]. In [22] Jousselme and Maupin compare several different distance measures. It is important to observe that different measures may measure different types of distances. Some distance measures measure the degree to which two bodies of evidence are different, while others such as conflict, measure the degree to which they are incompatible. For example, two propositions (corresponding to two focal elements) "a red car" and "a fast car" are different, but may be fully compatible if there is a red fast car in the frame of discernment.

A recent paper [23] also uses the idea of sequential discount to manage the conflict when combining belief functions. However, they use a distance measure by Jousselme et al. [20] that measures dissimilarity.

A recent overview of different alternatives for conflict management when combining conflicting belief functions was given by Smets, see [24].

In Section 2 we investigate the degree of falsity of a piece of evidence. In Section 3 we develop a method of sequential incremental discounting using the degree of falsity. We perform an experiment to investigate the behavior of an algorithm for conflict management in Section 4. Finally, conclusions are drawn in Section 5.

2. Degree of falsity

Let us recapitulate the interpretation of conflict as if there is at least one piece of evidence that violates the representation given by the frame of discernment, and thus can be said *not* to belong to the set of bbas that refer to this problem χ [10].

A conflict in χ is thus interpreted as a piece of metalevel evidence that there is at least one piece of evidence that does not belong to the subset

$$\begin{aligned} &m_\chi(\exists j.\, e_j \notin \chi) = c^{(0,0)}, \\ &m_\chi(\Theta) = 1 - c^{(0,0)}, \end{aligned} \tag{1}$$

where $c^{(0,0)}$ is the initial conflict in χ.

Let us observe one piece of evidence e_q in χ. If e_q is taken out from χ the conflict $c^{(0,0)}$ in χ decreases to $c^{(0,q)}$. This decrease in conflict can be interpreted as follows: there exists some metalevel evidence indicating that e_q does not belong to χ

$$\begin{aligned} &m_{\Delta\chi}(e_q \notin \chi), \\ &m_{\Delta\chi}(\Theta), \end{aligned} \tag{2}$$

and the remainder of the conflict $c^{(0,q)}$ after e_q has been taken out from χ is metalevel evidence that there is at least one other piece of evidence e_j, $j \neq q$, that does not belong to $\chi - \{e_q\}$

$$\begin{aligned} &m_{\chi-\{e_q\}}\big(\exists j \neq q.\, e_j \notin (\chi - \{e_q\})\big) = c^{(0,q)}, \\ &m_\chi(\Theta) = 1 - c^{(0,q)}, \end{aligned} \tag{3}$$

We will derive the basic belief number (bbn) $m_{\Delta\chi}(e_q \notin \chi)$ by stating that the belief in the proposition that there is at least one piece of evidence that does not belong to χ, $\exists j.\, e_j \notin \chi$, should be equal no matter whether we base that belief on the original piece of metalevel evidence, before e_q is taken out from χ, or on a combination of the other two pieces of metalevel evidence $m_{\Delta\chi}(e_q \notin \chi)$ and $m_{\chi-\{e_q\}}\big(\exists j \neq q.\, e_j \notin (\chi - \{e_q\})\big)$, after e_q is taken out from χ, i.e.:

$$\mathrm{Bel}_\chi(\exists j.\, e_j \notin \chi) = Bel_{\Delta\chi \oplus (\chi-\{e_q\})}(\exists j.\, e_j \notin \chi). \tag{4}$$

We have, on the left hand side (LHS)

$$\mathrm{Bel}_\chi(\exists j.\, e_j \notin \chi) = m_\chi(\exists j.\, e_j \notin \chi) = c^{(0,0)}, \tag{5}$$

and, on the right hand side (RHS)

$$\begin{aligned} \mathrm{Bel}_{\Delta\chi\oplus(\chi-\{e_q\})}(\exists j.\, e_j \notin \chi) &= m_{\Delta\chi\oplus(\chi-\{e_q\})}\big((e_q \notin \chi) \wedge \big(\exists_j \neq q.\, e_j \notin (\chi - \{e_q\})\big)\big) \\ &\quad + m_{\Delta\chi\oplus(\chi-\{e_q\})}\big(\exists j \neq q.\, e_j \notin (\chi - \{e_q\})\big) + m_{\Delta\chi\oplus(\chi-\{e_q\})}(e_q \notin \chi) \\ &= m_{\Delta\chi}(e_q \notin \chi) m_{(\chi-\{e_q\})}\big(\exists j \neq q.\, e_j \notin (\chi - \{e_q\})\big) + m_{\Delta\chi}(\Theta) m_{(\chi-\{e_q\})}\big(\exists j \neq q.\, e_j \notin (\chi - \{e_q\})\big) \\ &\quad + m_{\Delta\chi}(e_q \notin \chi) m_{(\chi-\{e_q\})}(\Theta) \\ &= m_{\Delta\chi}(e_q \notin \chi) c^{(0,q)} + \big[1 - m_{\Delta\chi}(e_q \notin \chi)\big] c^{(0,q)} + m_{\Delta\chi}(e_q \notin \chi)\big(1 - c^{(0,q)}\big) \\ &= c^{(0,q)} + m_{\Delta\chi}(e_q \notin \chi)\big(1 - c^{(0,q)}\big). \end{aligned} \tag{6}$$

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