Enthymemetic Conditionals: Topoi as a guide for acceptability

Eimear Maguire
Laboratoire Linguistique Formelle (UMR 7110), Université de Paris
eimear.maguire@etu.univ-paris-diderot.fr

Abstract

To model conditionals in a way that reflects their acceptability, we must include some means of making judgements about whether antecedent and consequent are meaningfully related or not. Enthymemes are non-logical arguments which do not hold up by themselves, but are acceptable through their relation to a topos, an already-known general principle or pattern for reasoning. This paper uses enthymemes and topoi as a way to model the world-knowledge behind these judgements. In doing so, it provides a reformalisation (in TTR) of enthymemes and topoi as networks rather than functions, and information state update rules for conditionals.

1 Introduction

The content of the antecedent and consequent of a conditional, not just their truth or falsity, makes a difference to whether we find the conditional acceptable or not, generally rejecting those that seem disconnected (Douven, 2008). If we are to model conditionals in a way that reflects their acceptability, we must include some means of making those judgements. Enthymemes are non-logical arguments which are nevertheless treated as acceptable through their relation to a topos, a general principle or pattern for reasoning. Apart from the evidence from their own acceptability conditions, which correlate strongly with judgements of high conditional probability, conditional structures are also associated with 'that kind of thinking', being used as plain-language explanations of particular topoi (e.g. "if something is a bird, then it flies" in Breitholtz, 2014b), or used as materials on reasoning in any number of experiments (e.g. Pijnacker et al., 2009). If we are going to explicitly recognise the use of such 'rule' type objects in discourse, then conditionals are one place where they show up, at least sometimes.

This paper has two aims. First, to propose a formalisation of enthymemes and topoi that is geared towards relating them to more complex rule-based world knowledge, including a distinction between knowledge about causality, non-causality, and ambiguity about causality. Second, to account for the acceptability (or not) of conditionals by proposing an enthymeme-like structure as associated with *if*-conditionals, such that topoi can enhance their content and are used in judging whether a given conditional is acceptable or not. The acceptability of conditionals is linked to perceived relationships between the antecedent and consequent cases: with enthymemes and topoi, we can incorporate this non-arbitrarily into the dialogue state.

The rest of this section will provide some background. Section 2 is focused on enthymemes, topoi, and specification of the alternative formalism, while Section 3 uses this in a proposal of update rules associated with conditionals. Lastly, Section 4 provides a conclusion. This paper draws on work on enthymemes and topoi elsewhere in Breitholtz (2014a,b) etc, and will likewise use TTR (Cooper, 2012) for formalisation.

1.1 Enthymemes and Topoi

Enthymemes are incomplete non-logical arguments that get treated as complete ones. They are 'incomplete' in that to be accepted, they must be identified as a specific instance of a more general pattern that is already in the agent's resources – a topos. Topoi encode world knowledge that comes as a 'rule of

Proceedings of the IWCS 2019 Workshop on Computing Semantics with Types, Frames and Related Structures, pages 65–74
Gothenburg, Sweden, May 24, 2019. ©2019 Association for Computational Linguistics

thumb', such as characteristics typical of groups, and a speaker may hold contradictory topoi as equally valid in different scenarios, with no clash experienced unless both are used at the same time. Speakers make enthymemetic arguments by linking what on the surface might technically be non-sequiturs, but are easily identified as an argument using accepted principles. For example, a speaker might say "Let's go left here, it's a shortcut". This argument invokes the assumption that shorter routes are better, and that therefore the left turn being a shortcut is a good reason to take it – but they might equally say "it's longer", invoking an assumption that a longer route is preferable.

Topoi have been proposed to be a resource available to speakers, and consequently a means to address non-monotonic reasoning (Breitholtz, 2014b), the treatment of non-logical rules as expressing necessity, and contradictory claims being equally assertable, as in the route-taking example above Breitholtz (2014a).

To these ends, they have been formalised in TTR for use in dialogue (Breitholtz and Cooper, 2011), as functions from records to record types, as in this example (Breitholtz, 2014a):

(1) a. *Topos:*

$$\lambda \text{r} : \begin{bmatrix} x & : \textit{Ind} \\ \text{c}_{bird} & : \text{bird}(x) \end{bmatrix} \left(\begin{bmatrix} \text{c}_{fly} & : \text{fly(r.}x) \end{bmatrix} \right)$$

b. *Enthymeme:*

$$\lambda \text{r} : \begin{bmatrix} x = \text{Tweety} & : \textit{Ind} \\ \text{c}_{bird} & : \text{bird(x)} \end{bmatrix} \left(\begin{bmatrix} \text{c}_{fly} & : \text{fly(Tweety)} \end{bmatrix} \right)$$

Both are of type *Rec* → *RecType*, and the fields of the specified record types match, but fields of the enthymeme have been restricted to specific values. A function to a record type does not by itself indicate what happens once we have access to that type, such as gaining a belief that some instance of it exists (e.g. that there really some case where the bird flies). For these functions to be useful, they are additionally governed by a theory of action, which will license various actions that can be performed with the type, e.g. judging that the original situation is additionally of that type, judging that there exists some situation of the type described, or creating something of that type (Cooper, in prep).

1.2 Conditionals

The assumption that conditionals express a proposition is fundamental to most linguistic work on the topic, both that which follows the commonly accepted restrictor theory of conditional semantics based on the work of Lewis (1975), Kratzer (1986) and Heim (1982), and that which does not (e.g. Gillies, 2010).

As mentioned at the beginning, the acceptability of conditionals correlates strongly with their conditional probability, with Stalnaker (1970) proposing that the probability of a conditional and the conditional probability of the consequent on the antecedent are one and the same, in what is usually referred to as *the Equation*. A subsequent proof by Lewis (1976) found that there is no single proposition based on the antecedent and consequent such that its probability will consistently match the conditional probability. Therefore one could have a propositional theory of conditionals, or validate the Equation – but not both.

However, conditional probability seems so important to the meaning of conditionals that in the view of some non-linguists, (e.g. Edgington, 1995; Bennett, 2003) conditionals should properly be considered be probabilistic, directly expressing the conditional probability of the consequent on the antecedent, P(*cons*|*ant*). Subsequent empirical work overwhelmingly supports the intuition behind the original Equation, and shows that conditional probability does indeed tend to correlate with acceptability (e.g. Evans et al., 2003; Oaksford and Chater, 2003). Conditional probability thus needs to be taken seriously, whether one believes it is the core content of a conditional or not: indeed, figuring out how propositional theories can accommodate its relationship to acceptability is an important issue (e.g. Douven and Verbrugge, 2013). Conditional probability is also not the only factor in acceptability: it is further moderated by whether there appears to be a connection between antecedent and consequent (Skovgaard-Olsen et al., 2016). To make these judgements, we need to know about the relationships between the antecedent and consequent states.

2 Enthymemes, Topoi and Other Knowledge

Given that their presence in an agent's resources has already been motivated, topoi are a natural way to account for the required knowledge about some 'dependence' between antecedent and consequent. Enthymemes and topoi are snippets of reasoning, rather than complex networks, but they should also be related explicitly to other rule-like world knowledge, which includes the possibility of multiple relationships between more than two cases, and knowledge of explicitly causal relations. If we are going to use topoi to express the kind of knowledge that also forms such networks (i.e. informative about causality or related probabilities in more complex systems), then they should be in the same form as that knowledge. The alternative, to keep succinct rule-like topoi apart from larger rule-based(ish) systems, is counter-intuitive.

Bayesian networks (a combination of directed acyclic graphs and probability distributions) are a common way to encode causal relations. They have two components, the first of which is a directed acyclic graph, with the various variables as nodes, and directed edges describing any direct relationships. Graphs and networks are a useful way to describe relationships, and express a more complex set of relationships than a linear chain of functions. The graph structure is in accordance with constraints about what direct parenthood in the graph can mean – that the parent is part of the minimal set of preceding nodes whose value determines the probability distribution of the child.

The second component to a Bayesian Network is a set of probability functions for determining the values of variables given the values of their parents – their conditional probabilities. Associated probabilities are also a natural means of modelling learning, by adjusting the confidence in a given rule on the basis of evidence and experience, allow us to make explicit the level of confidence in a judgement beyond a binary. For unreliable rules, a high (but below 1) probability can be used to express that they are likely to be correct in a given case, but not certain.

2.1 Graphical Topoi

The proposal is as follows. Topoi and enthymemes are of the same type as any other 'relational' knowledge, by which I mean knowledge about causal and correlational relations. This knowledge can be encoded as a graph. The direction(s) of the links between connected nodes, along with additional constraints, indicate either causal or non-causal relations via directed or bi-directed links respectively. The variable at each node is a $RecType$, representing a situation, with the probability of a $RecType$ being across whether it is true or false (for type *T*, whether $\exists a : T$). Topoi and enthymemes as usually discussed are minimal examples, containing only two nodes.

Let *RecType*$_i$ be a *RecType* associated with an index, and *ProbInfo* be a constraint on some probability. The supertype of enthymemes and topoi, rather than a function *Rec→RecType*, is the type *Network*:

$$(2)\quad \textit{Network} =_{def} \begin{bmatrix} \text{nodes} : \left\{\textit{RecType}_i\right\} \\ \text{links} : \left\{\langle \textit{RecType}_i, \textit{RecType}_i\rangle\right\} \\ \text{probs} : \left\{\text{ProbInfo}\right\} \\ \text{c}_{index} : \exists\langle x'_j, y_p\rangle, \langle x''_k, z_q\rangle \in \text{links}, x'_j, x''_k \sqsubseteq_r x_i \in \text{nodes}, \\ \qquad i = j = k. \text{ Likewise for } \langle y_p, x'_j\rangle, \langle z_q, x''_k\rangle \in \text{links} \\ \qquad \text{and } \langle x'_j, y_p\rangle, \langle z_q, x''_k\rangle \in \textit{links}. \\ \text{c}_{links} : \forall\langle x'_i, y'_p\rangle \in \text{links}, \exists x_i, y_p \in \text{nodes}, x'_i \sqsubseteq_r x_i, y'_p \sqsubseteq_r y_p \end{bmatrix}$$

Let $\sqsubseteq_r$ indicate a subtype relation where subtyping is through restriction of one or more fields i.e. not through the specification of extra fields. The first constraint c$_{index}$ enforces co-indexing, that if subtypes of a node are included in *links*, they all share its index. The second constraint c$_{links}$ specifies that any members of *links* are between (potentially restricted subtypes of) members of $nodes$. For ease of reading and the sake of space, the constraints will not be repeated in further examples. In a link $\langle x_i, x_j\rangle$, the specification of member x_i may use j to indicate some $r : x_j$, and vice versa, e.g. where a is some field in x_i and b is some field in x_j, specifying that $a = j.b$.

Causality, non-causal correlation and independence are interpreted on the basis of the members of *links*. Where a path is a sequence of indices $\langle 1, \ldots, k \rangle$ such that for each $i, i+1$ there is $\langle x_i, x_{i+1} \rangle \in$ *links*, the node indexed i is a predecessor of the node indexed j (shorthand: *predecessor*$(i, j,$ *links*$)$) if there is a path from i to j, given the contents of *links*. Where there is a bi-directional link e.g. $\langle x_i, x_j \rangle, \langle x_j, x_i \rangle \in$ *links*, the relationship is non-causal. Where there is an absence of any path, the relationship may be treated as potential independence. Where there is a link in one direction only, the relationship may be treated as potentially causal. However, neither this potential independence or causality is locked in: there is a distinction between merely lacking information, and having information about a confirmed absence. Certainty about independence or causality is expressed via constraints preventing the addition of any link that would violate them. For n : *Network* containing nodes x_i and x_j, independence, causality and non-causality can be expressed in updated n' as follows, where $a \wedge b$ indicates the merge of two records, a record containing all fields from both, and $a \boxed{\wedge} b$ indicates their asymmetric merge (see Cooper and Ginzburg (2015)), where in event of a field appearing in both records, the field from b is the one found in the merge, effectively overwriting the field of a.

(3) *Independence of* i *and* j*:*

$$n' = n \wedge \left[\mathrm{c}_{ind_{ij}} : \neg \textit{predecessor}(i, j, \textit{links}) \wedge \neg \textit{predecessor}(j, i, \textit{links}) \right]$$

(4) *Direct causality from* i *to* j*:*

$$n' = n \wedge \left[\mathrm{c}_{cause_{ij}} : \langle i, j \rangle \in \textit{n.links} \wedge \neg \textit{predecessor}(j, i, \textit{links}) \right]$$

(5) *Non-causality between* i *and* j*, where* $\langle x_i, x_j \rangle \in$ *n.links:*

$$n' = n \boxed{\wedge} \left[\text{links} = \text{n.links} \cup \langle x_j, x_i \rangle : \left\{ \langle \textit{RecType}_i, \textit{RecType}_i \rangle \right\} \right]$$

The choice of bi-directed rather than undirected edges to express non-causality is motivated by a desire for the difference in belief from potentially causal to non-causal to be something that changes easily (i.e. with the addition of information, not replacement of one thing with another of a different type), and for creation of a 'casual' (not a typo) middle-ground, where only one direction is of relevance and there is no strong commitment either way.

All this is meant to allow for a more complex set of relationships than expressed in your average topos which, as stated earlier, is a minimal case with just two nodes. The original example can now be rewritten as follows:

(6) *Topos:*

$$\begin{bmatrix} \text{nodes} = \left\{ \begin{bmatrix} \text{x : Ind} \\ \mathrm{c}_{bird} : \text{bird(x)} \end{bmatrix}_1, \begin{bmatrix} \text{x : Ind} \\ \mathrm{c}_{fly} : \text{fly(x)} \end{bmatrix}_2 \right\} : \left\{ \textit{RecType}_i \right\} \\ \text{links} = \left\{ \left\langle \begin{bmatrix} \text{x : Ind} \\ \mathrm{c}_{bird} : \text{bird(x)} \end{bmatrix}_1, \begin{bmatrix} \mathbf{x = 1.x} : \text{Ind} \\ \mathrm{c}_{fly} : \text{fly(x)} \end{bmatrix}_2 \right\rangle \right\} : \left\{ \langle \textit{RecType}_i, \textit{RecType}_i \rangle \right\} \\ \text{probs} = \left\{ \text{P} \left(\begin{bmatrix} \mathbf{x = r.x} : \text{Ind} \\ \mathrm{c}_{fly} : \text{fly(x)} \end{bmatrix}_2 \mid \text{r} : \begin{bmatrix} \text{x : Ind} \\ \mathrm{c}_{bird} : \text{bird(x)} \end{bmatrix}_1 \right) = 0.95 \right\} : \left\{ \text{ProbInfo} \right\} \end{bmatrix}$$

(7) *Enthymeme:* as the topos, but all variants indexed with i are replaced with

$$\begin{bmatrix} \mathbf{x = Tweety} : \text{Ind} \\ \mathrm{c}_{bird} : \text{bird(x)} \end{bmatrix}_1$$

The confidence rating of 0.95 has been somewhat arbitrarily set here for topoi to imply high confidence without certainty. Enthymemes are distinguished from other arguments by the fact they don't hold up by themselves, but are instead accepted on the basis of identification with a topos – this doesn't include arguments that are accepted despite being unsupported. However, the terms enthymeme and topoi will continue to be used here: this is partly for convenience, but also because once the context indicates that an enthymemetic argument is being made (such as a recognisable suggestion+motivation pattern), an unsupported 'enthymeme', once accepted, can be used to establish a potential new topos (Breitholtz, 2015). An *Enth* is defined as a *Network* containing a node that has at least one field restricted to a specific object, removing its generality. A *Topos* is a *Network* in which no fields are restricted to a specific object.

An enthymeme e may be identified with a topos t if its nodes and links have equivalents in t, that is if for every node $x_i \in e.nodes$, $\exists y_p \in t.nodes$ such that $x_i \sqsubseteq y_p$ and for any links $\langle x'_i, x'_j \rangle \in e.links$, $\exists \langle y'_p, y'_q \rangle \in t.links$ such that $x'_i \sqsubseteq y'_p$ and $x'_j \sqsubseteq y'_q$. This may be by a clear match for the topos fields, but may also include the types of fields in the enthymeme as subtypes of fields in the topos[1].

[1] as in the example "Give a coin to the porter, he carried the bags all the way here" from Breitholtz (2014b), where carrying

3 Conditionals and Reasoning

Having reformalised topoi and enthymemes as an object intended for more general correlational and causal knowledge, we turn back to conditionals.

Firstly, and as mentioned at the beginning, expressing this kind of relational knowledge is (both intuitively and according to empirical evidence) strongly associated with conditionals, and existence of a dependence relation and high conditional probability usually determine their acceptability. Van Rooij and Schulz (2019) suggest a way to combine these two features into a single measure, the relative difference the state of the parent in a relation makes to the likelihood of the child. Pleasingly, with some independence assumptions this measure works not only for the 'causal' direction typically expressed by conditionals (*if there's fire, there's smoke*), but for the reverse as expressed by evidential conditionals (*if there's smoke, there's fire*). However, for it to do so, the direction of the relationship still has to be recognised even when the 'usual' roles of antecedent as parent and consequent as child have flipped. This kind of structural knowledge is topoic.

Secondly, and while it feels almost trivial to point out, we use conditionals to tell each other new things. When we are informed of something through the use of a conditional, we don't necessarily know beforehand that they lie in such a relation: otherwise they would only be useful to draw attention to connections we haven't made, not to tell each other things that are entirely new. Indeed, Skovgaard-Olsen et al. (2016) found evidence that when faced with a conditional, people assume that there is a positive connection between antecedent and consequent unless they have reason to believe otherwise. It is not so much that an acceptable conditional has to be backed up by pre-existing knowledge about the relation between the antecedent and consequent cases, but at the very least it should not *clash* with any.

Breitholtz (2014a) mentions how an enthymemetic argument can be recognised on the basis of the current conversational game/expected rules (with the specific example of knowledge that a suggestion may be followed by the speaker providing a motivation), or by an explicit lexical cue. With the above in mind, I will suggest that use of an *if*-conditional is one such linguistic cue.

3.1 Enthymemetic Conditionals

The overall suggestion is as follows. *If*-conditionals are associated with the making of enthymeme-like arguments. Note that I say "enthymeme-*like* arguments", not "enthymemetic arguments". Enthymemes depend on identification with a previously-known topos, while conditionals can be used to teach new relations, rather than just make statements that rely on existing knowledge to make sense. Although they are structured like the characterisation of enthymemes and topoi above, they are not all strictly speaking 'enthymemetic'. The content of a conditional can be checked against the topoi in the agent's resources. Given a match with a topos, an enhanced version can be added to the agent's knowledge if a link is found between the two relevant nodes. If no supporting topos is found, a more minimal version can be added without the benefit of any extra details a topos might have provided. If there only exists a match for the nodes in a topos that specifies there is definitely no link between them, or that there is a conflicting link, then the conditional should be rejected. The following subsections describe dialogue state update rules associated with conditionals.

3.2 Use of a conditional

To begin with, the type of an information state is minimally given as (8), broadly following the decisions for the place of enthymemes and topoi in Breitholtz (2014a) etc.

(8) *InfoState* $=_{def}$

$$\begin{bmatrix} \text{priv} & : \begin{bmatrix} \text{Topoi} & : \left\{\text{Topos}\right\} \end{bmatrix} \\ \text{dgb} & : \begin{bmatrix} \text{enths} & : \left\{\text{Enth}\right\} \\ \text{Topoi} & : \left\{\text{Topos}\right\} \\ \text{Moves} & : \text{list(LocProp)} \end{bmatrix} \end{bmatrix}$$

someone else's bags is recognised as a subtype of work, and the enthymemetic argument is on the basis of a topos like *work should be rewarded*

(9) *Prop* $=_{def}$

$$\begin{bmatrix} \text{sit} & : \textit{Rec} \\ \text{sit-type} & : \textit{RecType} \end{bmatrix}$$

(10) *Update rule* $=_{def}$

$$\begin{bmatrix} \text{pre} & : \text{InfoState} \\ \text{effects} & : \text{Infostate} \end{bmatrix}$$

The information state has two parts: the agent's private resources, and their representation of the shared context. The *private* resources include propositions[2] and specific relations about which they have beliefs, and a set of general topoi which they can use as resources. Fields for beliefs about propositions and for private beliefs about specific enthymemes have been omitted from the above as we will not need to reference them, although propositions themselves will appear in example (14) later. A public *Topoi* field tracks which topoi have been introduced onto the dialogue gameboard. The general form for update rules is given in (10): *pre* describes the preconditions for states to which the rule can be applied, and *effects* the changes.

Next we will add a few useful functions on the basis of some of the content of Section 2.1: a means to describe whether there is a successful match between an enthymeme and a topos, and a means to reference the result of an enthymeme that has been enriched by the content of a topos.

(11) *enthMatch*(e : Enth, t : Topos) : Bool, **true** iff all of the following hold

(i) All e's nodes are subtypes of t's nodes:
$\forall x_i \in e.\textit{nodes}, \exists y_p \in t.\textit{nodes}$ such that $x_i \sqsubseteq y_p$,

(ii) All e's links are subtypes of t's links:
$\forall \langle x'_i, x'_j \rangle \in e.\textit{links}, \exists \langle y'_p, y'_q \rangle \in t.\textit{links}$ such that $x'_i \sqsubseteq y'_p$ and $x'_j \sqsubseteq y'_q$,

(iii) For any constraints on links in e, the same constraints hold for the equivalent links in t:
$\forall c_{ind_{ij}} \in e, \exists c_{ind_{pq}} \in t$ or $c_{ind_{qp}} \in t$,
$x_i \in e.\textit{nodes}, y_p \in t.\textit{nodes}, x_i \sqsubseteq y_p$ and $x_j \in e.\textit{nodes}, y_q \in t.\textit{nodes}, x_j \sqsubseteq y_q$.
Likewise for all $c_{cause_{ij}} \in e$, there is an equivalent $c_{cause_{pq}} \in t$.

(12) *enhanceEnth*(e : Enth, t : Topos) : Enth, e' such that e' is an asymmetric merge of t and e, where the sets in *nodes*, *links* and *probs* undergo asymmetric union such that for any nodes $x_i \in e.\textit{nodes}, y_p \in t.\textit{nodes}, x_i \sqsubseteq y_p$, the corresponding node $z_u \in e'.\textit{nodes} = y_p \boxed{\wedge} x_i$.
Likewise for any subtypes x'_i and y'_p, $x'_i \sqsubseteq y'_p$ in members of $e.\textit{links}$, $t.\textit{links}$, $e.\textit{probs}$ and $t.\textit{probs}$.

The update rules for each case are given in the subsections below. These are rules for 'specific' conditionals, not those expressing general rules such as *if there's fire, there's smoke*. There should be an equivalent to each rule below for a conditional that expresses a general topos, on the basis of whether any fields in the conditional's content are tied to a specific object. These should lead to an update of *Topoi* only, not of *enths*. They are not included here, and the rules below don't include explicit constraints for steering the update into *enths* only where a check for a restricted field is successful. There are three rules given: where there is a supporting topos in the 'default' direction, where there is not but there is a supporting topos in the reverse direction, and where there is neither support nor a clash.

3.2.1 Recognising a supporting topos

First are the update rules for when the agent has a topos linking the two parts of the conditional: either in the direction with the antecedent as the parent in the link, or in the opposite direction with consequent as parent (though only if no topos with the default direction is known). The direction of antecedent as parent is 'default' in the sense that it should be preferred if distinct topoi in both directions are available, and is the direction assumed in case neither a supporting topos nor a conflicting one is found. The update in case of a supporting topos in the antecedent-consequent direction is given in (13):

[2] defined in (9) as Austinian propositions as per Ginzburg (2012)

(13) *default direction, ant→cons:*

$$\left[\begin{array}{ll} \text{pre}: & \left[\begin{array}{ll} \text{priv}: & \left[\begin{array}{ll} \text{Topoi} & :\left\{\text{Topos}\right\} \\ t & : \text{Topos} \\ c_{member} & : t \in \text{Topoi} \\ c_{def} & : \textit{enthMatch}(x:X, t) \end{array}\right] \\ \text{dgb}: & \left[\text{Moves[0]} = \text{Assert(if(a, b))} \quad : \text{LocProp}\right] \end{array}\right] \\ \text{effects}: & \left[\text{dgb}: \left[\begin{array}{l} \text{enths} = \text{pre.dgb.enths} \\ \qquad \cup\, \textit{enhanceEnth}(x:X,t) : \left\{\text{Enth}\right\} \\ \text{Topoi} = \text{pre.dgb.Topoi} \cup \text{pre.priv.}t : \left\{\text{Topos}\right\} \end{array}\right]\right] \end{array}\right]$$

where X is the type

$$\left[\begin{array}{l} \text{nodes} = \\ \quad \left\{\text{a.sit-type}_1, \text{b.sit-type}_2\right\} : RT_i \\ \text{links} = \\ \quad \left\{\langle \text{a.sit-type}_1, \text{b.sit-type}_2\rangle\right\} : \langle RT_i, RT_i\rangle \\ \text{probs} = \\ \quad \left\{\text{P(b.sit-type}_2 | \text{ r : a.sit-type}_1) = 0.95\right\} : \text{PI} \end{array}\right]$$

This rule may be applied following assertion of a conditional, where an agent knows a topos t that matches an enthymeme based on the content of the conditional, with a link from antecedent to consequent. In this case, the agent may add such an enthymeme enhanced with the topos to their *enths*, and add the underlying topos to the set of currently active topoi in the conversation.

Where such an option does not exist, a topos with only a link from consequent to antecedent can be used. The enthymeme added to *enths* in this case will contain a link only in the *ant←cons* direction. In practice, this means that any topoi supporting a link from antecedent to consequent take precedence over topoi which only reflect a link from consequent to antecedent. Relative to (13), the update rule for this case has constraints in its preconditions that (i) there are no topoi with a link in the *ant→cons* direction, but (ii) there is a known topos that supports an enthymeme in the alternative order. This topos is used to enhance such an enthymeme in *effects*.

The following is a simplified example using this second 'alternative order' rule for evidential conditionals. For space, members of *links* and *probs* are referenced by their index in *nodes* bolded.

(14) "If the glass fell, the cat pushed it."

a. Type of i : *InfoState*, a candidate for the second update rule

$$\left[\begin{array}{ll} \text{priv}: & \left[\text{Topoi} = \left\{\left(\left[\begin{array}{l} \text{nodes} = \left\{\left[\begin{array}{l} x : \text{Ind} \\ y : \text{Ind} \\ \text{c}_{push} : \text{push}(x,y) \end{array}\right]_1, \left[\begin{array}{l} x = 1.y : \text{Ind} \\ \text{c}_{fall} : \text{fall}(x) \end{array}\right]_2\right\} \\ \text{links} = \langle \mathbf{1}, \mathbf{2}\rangle \\ \text{probs} = \left\{\text{P}(\mathbf{2}|r:\mathbf{1}) = 0.95\right\} \end{array}\right]\right), \ldots\right\}\right] \\ \text{dgb}: & \left[\text{Moves[0]} = \text{Assert}\left(\text{if}\left(\left[\begin{array}{l} \text{sit} = \left[\begin{array}{l} x = \text{obj}_3 \\ \text{c}_{glass} = \text{glass(obj}_3) \\ \text{c}_{fall} = \text{fall(obj}_3) \end{array}\right] \\ \text{sit-type} = \left[\begin{array}{ll} x & : \text{Ind} \\ \text{c}_{glass} & : \text{glass}(x) \\ \text{c}_{fall} & : \text{fall}(x) \end{array}\right] \end{array}\right], \left[\begin{array}{l} \text{sit} = \left[\begin{array}{l} x = \text{obj}_4 \\ y = \text{obj}_3 \\ \text{c}_{cat} = \text{cat(obj}_4) \\ \text{c}_{push} = \text{push(obj}_4, \text{obj}_3) \end{array}\right] \\ \text{sit-type} = \left[\begin{array}{ll} x & : \text{Ind} \\ y & : \text{Ind} \\ \text{c}_{cat} & : \text{cat}(x) \\ \text{c}_{push} & : \text{push}(x,y) \end{array}\right] \end{array}\right]\right)\right)\right] \end{array}\right]$$

b. Type of i' : *InfoState*, the result of applying the update rule to i

$$\left[\text{dgb}: \left[\begin{array}{ll} \text{enths} = i\text{.dgb.enths} \cup \left[\begin{array}{l} \text{nodes} = \left\{\left[\begin{array}{l} x = \text{obj}_4 : \text{Ind} \\ y = \text{obj}_3 : \text{Ind} \\ \text{c}_{cat} : \text{cat}(x) \\ \text{c}_{push} : \text{push}(x,y) \end{array}\right]_1, \left[\begin{array}{l} x = \text{obj}_3 : \text{Ind} \\ \text{c}_{glass} : \text{glass}(x) \\ \text{c}_{fall} : \text{fall}(x) \end{array}\right]_2\right\} \\ \text{links} = \langle \mathbf{1}, \mathbf{2}\rangle \\ \text{probs} = \left\{\text{P}(\mathbf{2}|r:\mathbf{1}) = 0.95\right\} \end{array}\right] & : \left\{\text{Enth}\right\} \\ \text{Topoi} = i\text{.dgb.Topoi} \cup t & : \left\{\text{Topos}\right\} \end{array}\right]\right]$$

where t is the topos specified in *priv.Topoi* in (14a)

3.2.2 New information

Even without a guiding topos, conditionals allow us to express or learn information via an assumption that there is a positive connection between antecedent and consequent – provided we do not already know that the two are independent, or that the consequent shouldn't follow from the antecedent.

The last rule describes this case, where the agent's known topoi have neither evidence about a link between the antecedent or consequent, about the definite absence of one, or about a conflicting link. In this case, an 'enthymeme' with a link in the *ant→cons* direction may be added to *enths* solely on the basis of the conditional content. No additional topos is added to the list of active topoi – the process for generalising an acceptable enthymeme to a re-usable topos is not addressed here.

Recall that the topoi in an agent's resources may conflict with each other, and by necessity one of them was learned first: despite this, a conditional does not lead to formation of an acceptable enthymeme when such a clashing topos is already present. The shorthand for presence of a clashing topos is given in (15) as *enthClash*. An enthymeme clashes with a topos where the equivalent parent nodes lead to mutually exclusive child nodes, i.e. child nodes where a true type cannot be formed from their meet.

(15) *enthClash*(e : Enth, t : Topos) : Bool, **true** iff
$\exists x_i, y_j \in e.nodes, p_i, q_j \in b.nodes, x_i \sqsubseteq p_i$
$\exists \langle x'_i, y'_j \rangle \in e.links, x'_i \sqsubseteq x_i, y'_j \sqsubseteq y_j, \exists \langle p'_i, q'_j \rangle \in t.links, p'_i \sqsubseteq p_i, q'_j \sqsubseteq q_j,$
and $\neg T$, where $T = y'_j \wedge q'_j$

Relative to the previous two update rules, the preconditions in this rule specify that *priv.Topoi* has no topos supporting an enthymeme with a link between the antecedent and consequent in either direction, or a link which clashes with the possible conditional enthymeme, and also does not contain a topos supporting an enthymeme with an explicit constraint enforcing independence between the two.

4 Conclusion

The acceptability of a conditional is often determined by the conditional probability of the consequent on the antecedent, and recognition of some meaningful link between the two. However, both intuitively and according to experimental evidence, positive acceptability judgements can still be made without foreknowledge of such a connection. This paper presented two proposals on the basis that the knowledge enabling these judgements is topoic, integrating these factors into the representation of the dialogue state and agent resources. First, a formalisation of enthymemes and topoi as graphs was presented, on the grounds that they should be in the same form as other knowledge about causal and correlational relationships. Second, update rules for conditionals using topoi and enthymemes were presented, drawing on topoi to recognise the presence and direction of a 'meaningful' connection between antecedent and consequent, and making an assumption of one in the absence of any evidence.

There are several avenues for further work. Most work focuses on declarative conditionals, the most common form by far. However, conditional clauses are also used to form conditionalised questions and directives. The proposals here should be related to these forms, whether because to an extent they apply in those cases too, or because this topoic association is exclusive to declarative conditionals. This paper has also said nothing about more standard propositional aspects of conditionals. The proposals here about structural knowledge associated with conditionals should be integrated with this more standard fare.

Acknowledgements

Thanks to Jonathan Ginzburg for helpful discussion of and feedback on this work. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 665850.

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