Circumstantial and Temporal Dependence in Counterfactual Modals

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Abstract: "Counterfactual" readings of *might/could have* were previously analyzed using metaphysical modal bases. This paper presents examples and scenarios where the assumptions of such a branching-time semantics are not met, because there are facts at the base world and time which exclude the complement of the modal being true or becoming true. Additional arguments show that counterfactual readings are context-dependent. These data motivate an analysis using a circumstantial (or factual) modal base, which refers to a context-dependent set of facts about the base world and time. The semantics is formulated in a version of the premise semantics for modality.

Keywords: metaphysical modality, circumstantial modality, premise semantics, interactions between tense and modality, branching time.

1. Introduction

Sentences like (1) and (2) have readings which seem to describe unrealized past possibilities: at the mentioned time, it was possible for him to win, but this possibility was not realized. At some past time, it was possible for Ljubojevic to become world champion in 1978, but that possibility was not realized. Such readings of *might have* and *could have* are called *counterfactual* readings in this paper. The same verb complexes have epistemic readings, describing epistemic uncertainty at the present time about a situation in the past. Thus (2) can describe the speaker's uncertainty at a speech time about whether Ljubojevic was world champion in 1978 or not. Such present-oriented epistemic readings are not the topic of this paper.

(1) At that time, he might still have won the game but he didn't in the end. *Condoravdi 2002*
(2) Ljubojevic might have been the world champion of chess in 1978. *Mondadori 1978*

Mondadori (1978) and Condoravdi (2002) proposed a semantic analysis of counterfactual readings using branching world-time models. These passages from Mondadori's and Condoravdi's papers describe the idea succinctly.

> Consequently, the reason that "might" is indexed to the future must be sought elsewhere. I suggest that it can be found in the circumstance that "might" is generally associated with a picture of time as "branching". Thus when I claim that Ljubojevic might be the world champion in chess in 1978, it is (now) "open" to him to go on and become the next world champion in chess. *Mondadori 1978*

> The counterfactual reading involves a future possibility in the past and the modality is metaphysical. [1] is used to communicate that we are now located in a world whose past included the (unactualized) possibility of his winning the game. The possibility is about how the world might have turned out to be: at

> some point in the past the world was such that it could evolve into a world in which he won the game. At the relevant point in the past, the issue whether he won or not had not been settled and the world could have developed in either way.
>
> *Condoravdi 2002*

In a branching model construction, the possibility of the base world w_0 at a time t evolving into a world in which he wins the game is explicated using branching: there must be a world w in which he wins after time t, and which branches from w_0 at a time no earlier than t.

In her compositional analysis, Condoravdi proposed that for "he might have won" to be true, the clause "he might win" has to be true in the past. This is achieved by an LF where "have" has scope over the modal as shown in the syntactic representation (3b) for (3a).[1] The order of the operators is as follows: first present tense, then *might*, then the atomic sentence *he win*. (3c) gives some of Condoravdi's morpheme meanings and related definitions. The morphemes combine by function application to produce the semantics (3d) for (3b). The formula requires that there is a time t such that t precedes the utterance time n, and there is a world w which is a "metaphysical" alternative to the base world w_0 at the past time t, and an event e, which is an event of John winning in w, and whose temporal projection $\tau(e,w)$ in w is included in the unbounded interval $[t,\infty)$ running from t to positive infinity.

(3) a. John might have won.

b. Pres [have [might [he win]]]

c. $[\![\text{have}]\!] = \lambda P \lambda w \lambda t \exists t'[t'<t \wedge \text{AT}(t',w,P)]$

$[\![\text{might}]\!] = \lambda P \lambda w \lambda t \exists w'[\text{M}(w,t)(w') \wedge \text{AT}([t,\infty), w', \text{P})]$

$\text{AT}(t,w,P) = \exists e [P(w)(e) \wedge \tau(e,w) \subseteq t]$		P eventive
$= \exists e [P(w)(e) \wedge \tau(e,w) \circ t]$		P stative
$= P(w)(t)$		P temporal

d. $\exists t[t<n \wedge \exists w[\text{M}(w_0,t)(w) \wedge \exists e[\tau(e,w) \subseteq [t,\infty) \wedge \textbf{win}(w,e,\textbf{john})]]]$

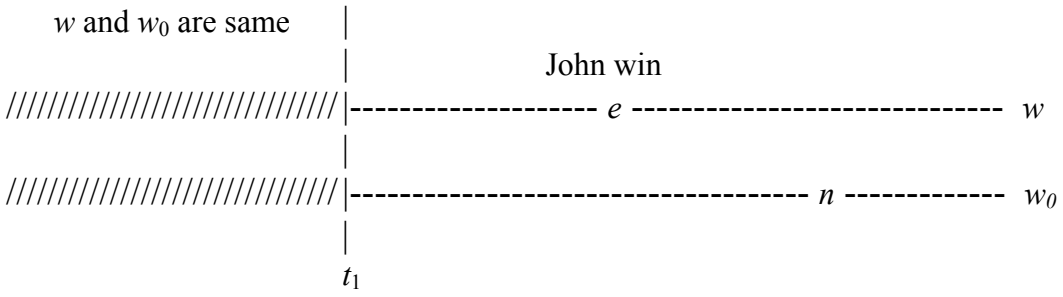
There are a couple of things to note about the meaning of *might*. First, it is an existential quantifier over worlds, and the domain of quantification is a modal base $\text{M}(w_0,t)$. Stating the semantics in this way is equivalent to using an accessibility relation. An important point is that the accessibility relation varies with times in addition to worlds. So, fixing w_0 and t, $\text{M}(w_0,t)$ is the set of accessible worlds, and in the formula (3d) w is an element of this set, that is w is accessible from w_0,t. Second, the modal builds in futurity in the requirement that the event e falls in the unbounded interval $[t,\infty)$, so that the event time for the winning event e is no earlier than t.[2] Finally, there is the idea that the modal base in such sentences consists of "metaphysical" alternatives. This was suggested by Mondadori, and Condoravdi built it into a compositional semantics. Metaphysical alternatives are a certain way of formalizing branching of worlds. A

metaphysical alternative to w_0 at t is a world w which is the same as w up to and including t. This requirement is agnostic as to whether the worlds w_0 and w literally overlap up to and including t, or whether they are merely qualitatively the same up to t. In either case, any difference between w and w_0 must come after t, and one can think of w as branching off from w_0 after t.[3]

(4b) gives a picture of Condoravdi's analysis of (4a). In a model where the sentence is true at w_0 and n, there is a time t_1 which precedes n, and a world w which is a metaphysical alternative to w_0 at t_1. In the alternative world w, there is required to be an event e of John winning, which is temporally included in the interval $[t_1,\infty)$. Informally, w is a branch from w_0 after t_1 where John later wins.

(4) a. At that time, he might/could still have won the game

b.



2. Problems with the branching-time analysis

It should be emphasized that the analysis using metaphysical alternatives must be taken literally. This means that the base world and the alternative need to be exactly the same up to the time of evaluation of the modal. I am going to give some examples and scenarios which are problematic for this aspect of the metaphysical analysis. The first one is the trees scenario given in (5). The husband's statement includes typical counterfactual uses of *might have*, which describe past possibilities which were not realized. In response, the wife made an argument to an opposite conclusion, given in (6). This is the kind of argument one makes just to win an argument, but it seems valid up to the last sentence.

(5) The trees

There were two huge beautiful old trees in my front yard. In a summer storm, one of them was blown down. Fortunately, it fell away from the house onto the driveway, rather than towards the house onto my husband's office. When we looked at the broken trunk, we saw that it was rotted inside, so this was a dangerous tree. The trees were of similar appearance and age.

Husband's argument: I might have been killed, because the tree might have fallen onto my office. Let's cut down the other tree. It might fall onto my office in another storm.

(6) Wife's Argument: We bought the house for the trees, and now you want to cut them down? Anyway the tree guy told us that because of the location of the rot in the trunk, the tree could only fall away from the house. So the tree could not have fallen onto your office. There is no reason to cut down the other tree.

Sentence (7a) is from the husband's argument, and (7b) is from the wife's argument. The relevant reading of (7b) is one where the negation scopes over the modal, so that the wife's sentence is the negation of the husband's sentence.[4] Intuitively, one feels that the sentences are superficially contradictory, but that nevertheless each of them is true in its context.

(7) a. Husband: The tree might/could have fallen on my office.

b. Wife: The tree could not have fallen on your office.

Here is the problem for the metaphysical analysis. If (7a) and (7b) are to be evaluated with respect to a single base world, then that world determines a unique set of metaphysical alternatives. So we can not get both of them to be true on a metaphysical reading. The usual strategy for resolving this kind of problem is to identify a shift in an implicit parameter between the two utterances, so that taking into account the contextual parameters, (7a) and (7b) are not contradictory. It is not clear what this parameter could be in the branching time analysis. Perhaps one could try to say that the husband and wife are referring to different worlds, which branch in different ways. But it seems that the husband and wife intend to refer to the same real situation, and do not disagree about any matter of fact. Rather the wife makes a modal argument which pays attention to the specific location of rot in the first tree, while the husband makes a modal argument which pays attention to the fact that the tree has internal rot, but considers the specific location of the rot (on the driveway side of the tree) a random factor which is to be ignored.

Consider now the next scenario, which is the ranch scenario in (8). (9a) is the sentence of interest. Notice that in place of the ordinary counterfactual existential modality expressed with *might have*, this example uses *might well have*, expressing a graded modality. The reason for this is that we would ordinarily assume that there is some small probability of there being an oil reserve under any arbitrary ranch. As a result, statements like (9b) with the purely existential models are almost trivial, and would not be relevant in discussions of the justification for investment decisions. This is also so in the Trees scenario, since the wife and husband would presumably agree that the tree could have fallen in any direction with some small probability. This is addressed by inserting a grading or equative expressions as in (9c,d).

(8) The Ranch

John is an expert petroleum geologist and investor. In 2003, he finds a ranch property in Ecuador and analyzes its geology very carefully. He applies best-practice methodology for petroleum prospecting. He decides the ranch has a good probability of containing a large oil reserve, and on December 1, 2003 buys the property together with a partner. Unfortunately, expensive drilling establishes that there is only worthless salty water under the ranch. The partner's opinion on Dec. 18, 2007:

We bought a ranch which might well have contained a significant oil reserve. But unfortunately there is no oil on this ranch. Let's sell it and move on to the next project.

(9) a. We bought a ranch which might well have contained a significant oil reserve.
b. The ranch might contain a significant oil reserve.
c. The tree might well have fallen on my office.
d. The tree could just as well have fallen on my office.

The apparent problem for the metaphysical analysis is that, at the time of the purchase, the geological situation under the ranch was the same as what was later discovered, with only salty water and no oil under the ranch. This describes the situation in the base world. Since metaphysical alternatives are the same as the base world up to and including the reference time, in the alternatives there is no oil reserve under the ranch either. This will not change, so there is no metaphysical alternative where the ranch contains an oil reserve.

A delicate point in this reasoning is the identification of the time t which determines the set of metaphysical alternatives $M(w_0,t)$. In the formula (3d), t is existentially quantified. If this existentially quantifed time is entirely unconstrained in the logical form of (9a), a witness time for that existential quantifier could be some time way back in geological history, when perhaps there still was a chance of oil developing under the ranch area. The argument in Condoravidi (2002) uses temporal frame adverbs and other temporal like *still* to constrain t. For instance in example (4a), there is a temporal adverb *at that time* which constrains the evaluation time of the modal. Let's try to do the same in the Ranch example. A month after buying the ranch, John had done some more tests, which had equivocal results. At that point, the partners brought in some more investors, supposedly to help finance the drilling. When it was discovered that there was no oil, the new investors charged the original partners with fraud. In the civil trial, John made the claim (10). The frame adverb *at that point* refers to the time when the new investors were brought in. The adverb *still* indicates that the modal claim is true over an interval running from the original purchase time to the time of the new investment.

(10) At that point, the ranch could still (by best-practice criteria) have contained a significant oil reserve.

Here is the concrete problem for the metaphysical analysis. At the time when the new investors were brought in, there was only salty water under the ranch in the base world. Since the metaphysical alternatives are the same as the base world, this is also true of the alternatives. Therefore one can not find in the metaphysical modal base a world which is a witness for the truth of the existential world quantifier expressed by the modal in (10). So the metaphysical makes sentence (10) false in this scenario (if the modal base is metaphysical), while intuitively it is true.

My hypothesis about (9a) and (10) is that there is an implicit reference to certain facts of the situation (the results of tests), and to criteria of oil geology which in combination make the presence of oil fairly likely. The test results are concrete facts about the base world, and these facts enter into the modal semantics. But not *all* facts about base world enter into the modal semantics---facts about what liquids are actually found under the ranch do not. It does not seem possible to express this hypothesis in the metaphysical

semantics, because metaphysical alternatives to w_0 at time t are identical to w in every way up to the time evaluation time of the modal.

The next group of examples involves a special kind of modality which I call sports math modality, which is used by sports announcers, writers, and fans. (11a) is an example with the verbal complex *could have*, and (11b) is a synonymous nominal example. Sports math modality is signaled by the adverb *mathematically*, and by similar ones such as *technically*. Temporal adverbs which constrain the temporal argument of the modal fit in easily, since when sports math sentences are used, there is usually an intention to talk about how possibilities evolve and are gradually foreclosed as time passes.

(11) a. In week 11 of the football season, mathematically, Buffalo could still have reached the playoffs.

b. In week 11 there was still a mathematical possibility of Buffalo reaching the playoffs.

Sports modality has a very specific semantics. In evaluating sentences like these, one pays attention only to the history of play in w_0 up to the reference time t_1, the league schedule in w_0, and league regulations in w_0. Other facts about w_0 are stipulated to be irrelevant. Suppose for instance that in week 11, all of the Buffalo players had broken legs, so that it was impossible for Buffolo to win any more games. Or suppose that the officials had been bribed to give advantage to the opponents. Facts such as these are irrelevant to assessing the truth of (11a,b) and these sentences can still be true if there are certain facts F about w_0 at t_1 which absolutely exclude the possibility of Buffolo winning any more games, and if winning some more games is essential to Buffalo qualifying.

The problem for the metaphysical analysis is that, since metaphysical alternatives are exactly the same as the base world up to the reference time, the elements of F are also facts about the alternatives---the Buffalo players also have broken legs in the alternatives. So Buffalo will not reach the playoffs in the metaphysical alternatives either, so that the sentences are false if a metaphysical modal base is used in evaluating the modal. Intuitively of course, the sentences can be true.

My conclusion from the tree, ranch, and sports-math examples is this. There are scenarios and examples which in their syntactic and semantic properties (such as the specific syntactic forms that are involved, and the time-sensitivity of the modal claim) are like the examples Mondadori and Condadori wanted to analyze, but where the modal base can not be metaphysical, because there are facts about the base world at the reference time which exclude the truth of the complement of the modal. Thus counterfactual readings of *might have* and *could have* do not always exploit a metaphysical modal base

3. Determinism

Suppose all the worlds in the model have a determinist physics: given a complete description of w_0 at t, what happens in w_0 after t is determined. Then the metaphysical alternative set for w_0 at t_1 is $\{w_0\}$, or a set of copies of w_0. By copy of w_0, I mean a world which is exactly like w_0 throughout time. In a model like this, metaphysical modals have no semantic effect. Here is why. In such a model, in the formula (12b), which is the semantics of (12a) assuming that *at that time* designates t, the existential quantifier ranges over worlds w which are copies of w_0 throughout time. Since w is a copy of w_0, the formula **win**(w,e,**john**) is true if and only if **win**(w_0,e,**john**) is true. The same goes for the formula $\exists e[\tau(e,w) \subseteq [t,\infty)]$. Therefore, in a deterministic model, (12a) is true iff (12b) is. Using the fact that w_0 is a metaphysical alternative to itself, one can show by predicate-logical reasoning that (12b) is equivalent to (12d), where the world quantifier has been eliminated, and only the temporal part of the meaning of *might* remains. So, in a deterministic model, *might* is equivalent to *will,* clearly a bad result.

(12) a. At that time, John might have won.

b. $\exists w[\mathrm{M}(w_0,t)(w) \wedge \exists e[\tau(e,w) \subseteq [t,\infty) \wedge \mathbf{win}(w,e,\mathbf{john})]]$

c. $\exists w[\mathrm{M}(w_0,t)(w) \wedge \exists e[\tau(e, w_0) \subseteq [t,\infty) \wedge \mathbf{win}(w_0,e,\mathbf{john})]]$

d. $\exists e[\tau(e, w_0) \subseteq [t,\infty) \wedge \mathbf{win}(w_0,e,\mathbf{john})]]$

There are two reactions to this problem. First, in the spirit of Bach (1986), we could simply accept that the grammar and semantics of English have metaphysical presuppositions which happen to be inconsistent with certain physical theories. This is a curious result of natural language semantics, not any kind of problem. My reaction is different. I'd like to have a theory of semantics which is compatible with a range of physical and metaphysical assumptions. This makes me suspicious about the Mondadori-Condoravdi analysis. I can't prove it, but my position is that if speakers assumed all possible worlds are deterministic, they would use counterfactual modals in exactly the way that they do.

(13) makes a different point related to determinism. I want to imagine a tournament which involves people and computer chess programs. The computer chess programs in fact play deterministically, so that once you set them up, it is determined how they are going to play. If you set up two computer chess programs to play which each other, they would play the same game again and again. Now consider a tournament involving Ljubojevic and two computer chess programs, Shredder 9 and Shredder 10. We stipulate that because of the algorithms implemented in those systems, it is in fact impossible for Shredder 9 to defeat Shredder 10. On Nov. 15, the tournament reached a stage where it was in the sports-math sense possible for Ljubojevic to reach the quarterfinals. But because of the particular pattern of results so far, that would have required Shredder 9 defeating Shredder 10. And that is impossible because of the algorithms implemented in those systems. Under these circumstances, sentence (15) can still be judged as true.

(13) On Nov. 15, Ljubojevic could still technically have reached the quarterfinals.

Here is the problem for the metaphysical semantics. We are stipulating that if we set up the situation this way it is not possible for Shredder 9 to defeat Shredder 10. Therefore, on Nov. 15, there is no metaphysical alternative where Shredder 9 defeats Shredder 10, and therefore, there is no metaphysical alternative where Ljubojevic reaches the quarterfinals. But somehow, in evaluating the modal sentence, we can reason as if a defeat of Shredder 10 by Shredder 9 is possible. This requires considering alternatives which are not metaphysical alternatives.

This kind of example does not assume that worlds in general are deterministic. It only assumes that there are some deterministic chains of events. Again, I think that natural language semantics should not rule this out.

4. Shifting assumptions

Consider this chess match story. Ljubojevic lost the title match to Karpov in 1977. When he worked on strategies throughout the 1970s, he explored strategies which Karpov was also examining. Since Karpov was in important respects more capable, Ljubojevic lost. But later analysis showed that if he had started working in 1975 on the strategy which later became known as the Mexican Defense (and which Ljubojevic became a master of), he might well have beaten Karpov. In this context, the sentences in (14) are judged true. We can justify this by pointing out that if Ljubojevic had started working on the Mexican defense, he might well have won.

(14) True In 1975, Ljubojevic might still have won.

True In 1975, Ljubojevic could still have won.

Now let's add some information: Ljubojevic in fact settled on his strategies (the ones that Karpov also examined) in the early 1970s. He was a very methodical person who never made major changes in strategy. Now the truth value seems to switch. The sentences repeated in (15) seem false because in 1975, he had already selected his strategies, and Ljubojevic never changes strategy.

(15) False (?) In 1975, Ljubojevic might still have won.

False (?) In 1975, Ljubojevic could still have won.

False, because although if he had started working on the Mexican defense, he might well have won, Ljubojevic never changes strategy.

Comparing results for the two contexts shows that a shift in contextual assumptions can change the truth value of the *might have* sentence. When the context does not bring up that Ljubojevic never changes strategy, the sentence seems true. When the context does bring up that Ljubojevic never changes strategy, the sentence seems false, though the intuition is a volatile one. How would this be captured in the branching-time analysis? A world branches in just one way, and it is not clear how the effect of context could be built into the analysis.

What is going on with (14) and (15) is intuitively pretty clear: the truth value shifts according to whether or not one "pays attention" to the fact that Ljubojevic never changes strategy. The tree scenario also involved a shift in assumptions: the wife's argument paid

attention to the particular location of the rot, while the husband's argument ignored it. The analysis developed in the next section represents this intuition in a direct way.

5. Circumstantial or factual modality

Now I am going to present my analysis, which uses a *circumstantial* or equivalently *factual* modality. (16) is an example from legal reasoning, where one talks about possibilities and impossibilities in view of facts of a specific situation. (17) is a variant with *might have*. The sentence is based on a real argument made by a defense lawyer in a court case where the defendant was charged with attempted indecent contact with a minor. The modality somehow exploits facts of the specific situation Mr. Jones was in. This seems very similar to the modality in the wife's sentence in the tree example, in that both claim impossibility in view of specific facts of the situation.

(16) Factual modality in legal reasoning
   a. It was factually impossible for Mr. Jones to indecently touch a minor, because the person in his company was a 23-year-old policewoman.
   b. Mr. Jones could not have indecently touched a minor, because the person in his company was a 23-year-old policewoman.

(17) is variation on an example from Kratzer (1991). We are looking at a region of an Earth-like planet through the lens of telescope, and observe an area with certain conditions (temperate climate, loamy soil, partial shade, morning and afternoon sun, etc.) One of us says (17). The statement can be paraphrased 'the circumstances of climate, soil, etc. there are consistent with the flourishing of Hydrangeas.' To judge the statement true, one must pay attention to these facts, but ignore some other ones, such as the fact that hydrangeas were never introduced on the planet, and that it is impossible for hydrangeas to get to the planet.

(17) Hydrangeas could grow there.

Kratzer called such readings of modals circumstantial readings. Although (17) has a certain generic flavor which is absent from the examples under discussion in this paper, the examples are in other ways similar, and this is the terminology I will apply here. Kratzer proposed that the semantic analysis of such examples refers to sets of "relevant" facts or circumstances of the situation. These sets are called *circumstantial* modal bases or ordering sources. A *fact* about the world *w* is a proposition that *w* is an element of.

The basic property I want to exploit is that we get different truth values for circumstantial modal sentences by choosing different sets of facts. Semantically, the choice is free. Pragmatically, the choice is influenced by conversational context and the aims of speakers. Earlier, I said that the wife's argument in the tree example paid attention to the specific location of the rot (on the driveway side), while the husband's argument paid attention to the fact that there was rot of a certain extent, but ignored the specific location of that rot. The difference can be formalized by assuming that the modals in the wife's and husband's statements implicitly refer to different circumstantial modal bases. (18) is a partial description of the wife's facts. We assume that the husband's facts are the same, but with F2, the fact which describes the specific location of the rot, replaced by a weaker proposition G2.

(18) Wife's facts in the Trees scenario

F1 There is a storm in our yard with such-and-such wind velocity.

F2 The tree that fell has rot in such-and-such precise position within the trunk.

F3 Facts about the top of the tree (how large it is, etc.)

F4 Location of my husband's office relative to tree.

F5 Physical or rule-of-thumb theory of tree motions under the influence of wind.

(19) Husband's facts

The same, with F2 replaced by

G2 The tree has such-and-such amount of rot within the trunk (without specifying location within the trunk).

Let $\mathfrak{F}$ be the set of facts (18), and let $\mathfrak{G}$ be the set of facts (19). The hypothesis is that the wife's modal implicity refers to $\mathfrak{F}$, with the domain of quantification for the existential modal being $\cap\mathfrak{F}$, the set of all worlds in which each element of $\mathfrak{F}$ is true. The husband's modality implicitly refers to $\mathfrak{G}$, and his existential modal ranges over $\cap\mathfrak{G}$. Because of the difference between F2 and G2, $\cap\mathfrak{F}$ is a proper subset of $\cap\mathfrak{G}$ in any realistic model. This makes it possible for there to be a world *v* where the tree falls on the office, and which is an element of $\cap\mathfrak{G}$, but not of $\cap\mathfrak{F}$. So if the modal expresses an existential world quantification ranging over the intersection of the modal base, the husband's sentence (20a) can be true with *v* as a witness for the existential world quantification, while (20b) is false. Consequently the husband's sentence (20a) and the wife's sentence (20c), which in form appear contradictory, can both be true. Simply stated, the change from $\mathfrak{F}$ to $\mathfrak{G}$ allows there to be a world in the husband's domain of quantification but not the wife's domain of quantification where the tree falls on the office.

(20) a. The tree could$_{\mathfrak{G}}$ have fallen on the office.
b. The tree could$_{\mathfrak{F}}$ have fallen on the office.
c. The tree could$_{\mathfrak{F}}$ not have fallen on the office. (not > could)

Here are some good points of this analysis. The husband's statement (20a) and the wife's statement (20c) can both be true, because although they appear to be contradictory, the semantics shows that, with the context parameters set in a certain way, they are not contradictory. This captures the intuition that both sentences are true in their contexts. Second, the wife's discourse context, which mentioned the fact about the specific location of the rot, gets a direct expression in the fact that F2 is an element of the wife's modal base $\mathfrak{F}$. Third, because (20a) and (20c) do not come out as contradictory, we capture the intuition that the husband and wife do not really disagree about any concrete facts or indeed any modal facts, and that the wife made an argument which deliberately bypasses what the husband claimed.

6. Formalization

This section formalizes the analysis using a version of the premise semantics developed by Veltman and Kratzer,[5] specifically the semantics of modals found in Kratzer (1991). That framework uses two contextual parameters, which are called the modal base function and the ordering source function. (21a) is a sports-math example, and (21b) is an LF for it where the modal takes two contextual parameters as arguments. The arguments are represented using referential indices. We have one index for the modal base function, the index 1, and another index for the ordering source function, and this is the index 2. The logical type of each of them is a function from times and worlds to sets of propositions. Since sports-math examples have such a specific meaning, it should be possible to describe the contextual parameters in detail. (22) gives the appropriate circumstantial modal base function Pr_{sm}, whose value is a set of propositions describing the results of play up to the reference time. This set is described with a multiple-wh question, assuming the semantics for questions from Karttunen (1977). In that semantics, a wh-question denotes the set of propositions which are true at the local index. Pr_{sm} maps *t* and *w* to the question 'what team NFL team plays what NFL team at what time preceding *t* in regular-season play with what final score in *w*'. NFL is the National Football League. The value of the function consists of propositions describing the results of play in *w*, up to time *t*.

(21) a. In week 11, mathematically Buffalo could have reached the playoffs .
b. [[in week 11][have [might(1)(2) [Buffalo reach the playoffs]]]]

(22) Circumstantial modal base function for sports math

Pr_{sm} = $\lambda t \lambda w$[what NFL team plays what NFL team at what time preceding *t* in regular-season play with what final score in *w*]

Since a time dependent premise function maps a time and a world to a set of premises, it has type [I $\rightarrow$W$\rightarrow$ *Prem* $\rightarrow$2], where I is the set of times, W is the set of worlds, and *Prem* is the denotation space for premises, so that [*Prem* $\rightarrow$2] is the type of a set of premises. Here there is a technical question. A premise is supposed to be a proposition. Is it a time-independent proposition (a set of worlds) or a time-dependent one (a set of world-time pairs)? Although either choice is possible, I prefer the second one, because the intersection of the premise set is used as a set of alternatives to the base world and time.[6] It seems natural to take these alternatives to be world-time pairs, rather than worlds with the time kept constant. Developing this option, *Prem* is [I$\rightarrow$W$\rightarrow$2], and the type of premise function is [I$\rightarrow$W$\rightarrow$[I$\rightarrow$W$\rightarrow$2]$\rightarrow$2].[7] For circumstantial functions, we impose the constraint that the elements of the premise set are true at the base time and world, i.e. for any *w*, *t* and *p* such that Pr(*t*)(*w*)(*p*) = 1, *p*(*t*)(*w*) = 1.

Where $u = \langle t', w' \rangle$ is a time-world pair and Pr is a premise function, I write $u \in \cap \Pr(t)(w)$ as an abbreviation for $\forall q[\Pr(t)(w)(q) \rightarrow q(t')(w')]$. The formula $u \in \cap Pr_{sm}(t)(w)$ expresses that the alternative $u = \langle t', w' \rangle$ is an element of the intersection of the circumstantial sports-math premise set at *t* and *w*, i.e. the results of play in *w*' up to *t*' are the same as the results of play in *w* up to *t*. We also need to bring in information about the schedule of play, and about the league regulations which determine participation in the playoffs. Those things are normative, and I am going to apply a rule

of thumb that normative things belong in the ordering source. So we have another contextually determined function Or_{sm} with the same semantic type which maps *w* and *t* to the set of propositions describing the schedule of season play in *w* at *t*, and league regulations in *w* at *t* determining participation in the playoffs. We assume that when (21) is used, the index 1 is understood to designate Pr_{sm}, and the index 2 is understood to designate Or_{sm}. That is what sports-math talk is: it amounts to making those two particular choices for the modal base function and the ordering source function.

(23) $Or_{sm}(t)(w)$ = set of propositions describing schedule of season play in *w* at *t*, and league regulations in *w* at *t* determining participation in the playoffs.

(24) is the semantics for an existential modal found in Kratzer's paper. The intersection of the value of the modal base function is used as the domain of quantification for the quantifiers over alternatives in the formula. In the application to sports math, the alternatives in the domain of quantification are ones that have the same results so far as *w* up to *t*. The variables *u*, *v*, and *z* are variables over alternatives, i.e. time-world pairs.

(24) $[\![\text{might}]\!]$ is the function f such that $f(\text{Pr})(\text{Or})(p)(w)(t) = 1$ iff

$(\exists u \in \cap \text{Pr}(t)(w))\ (\forall v \in \cap \text{Pr}(t)(w))[v \leq_{\text{Or}(t)(w)} u \rightarrow (\exists z \in \cap \text{Pr}(t)(w))[z \leq_{\text{Or}(t)(w)} v \wedge p(z)]]$

where $v \leq_X u$ iff $\{q |\ q \in X \wedge q(u)\} \subseteq \{q |\ q \in X \wedge q(v)\}$

The set of propositions $Or_{sm}(t)(w)$ is used to determine optimal worlds, ones where the schedule and the league regulations are followed as much as possible. The semantics for (21) is roughly 'there is some alternative which has the same results so far as week 11 as the base world, and which follows the schedule and league regulations as much as possible, and in this alternative, Buffalo reaches the playoffs.' The formula in the second line has a couple of existential quantifiers over alternatives, $\exists u$ and $\exists z$. The important point is that the witnesses for these quantifiers do not have to be metaphysical alternatives to the base world at week 11. In the obvious scenarios, the schedule of play and the league regulations are consistent with each other and with the results so far. In that case, one can use as a witness for both $\exists u$ and $\exists z$ any old alternative $\langle t_2, w_2 \rangle$ which has the same results of play as the base world at week 11, which follows the regulations and schedule, and has a pattern of results for the whole season which allows Buffalo to qualify. The witnesses for the existential quantifiers are not required to be like the base world in other respects, like whether the Buffalo players have broken legs.

In this analysis, the modal base function is used to characterize alternatives which are "relevantly" similar to the base world and time. In sports math modality, time-worlds pairs are relevantly similar if they have the same results of play so far. The wife in the trees scenario considered alternatives relevantly similar only if they had the rot in the same specific location in the trunk (the driveway side). The husband also considers alternatives relevantly similar that have the rot on the opposite side (the office side). In the ranch scenario, an alternative is relevantly similar if the observed properties of the ranch, and in particular the results of preliminary geological tests, are the same as in the base world and time. The relevantly similar alternative does not have to have the same sub-surface geology as the base world, with only salty water under the ranch.

And so on. In the first version of the scenario involving Ljubojevic and Karpov, an alternatives was considered relevantly similar in which Ljubojevic started working on the Mexican defense in the mid 1970's, became a master of it before the title match in 1977, and thus managed to defeat Karpov. In the second version, one pays attention to the fact that Ljubojevic never changes strategy, and such alternatives are not relevantly similar. The difference is captured by adding the fact that Ljubojevic never changes strategy to the value of the modal base function.

Now I would like to check whether one positive result of the metaphysical analysis carries over to the new one. A nice thing about the branching time analysis is that it provides an explanation for the time sensitivity of counterfactual modal statements. This is illustrated in (25).

(25) At noon, John still might have won the race. But at 12:30, he could not have won the race.

If (25) is true in the branching-time semantics, at w_0 at 12:00, there is a branch (a metaphysical alternative) which leads to a win of John. In w_0 at 12:30, some branches have been passed, and there are no branches which lead to a win of John. The time dependency follows directly from the architecture of the metaphysical-alternative relation, because as time passes, the metaphysical alternative set $\lambda v[\mathrm{M}(t,w)(v)]$ used as a domain of quantification shrinks monotonically, eliminating possibilities.

Here is how time dependency works in the new analysis. In the denotation (24) for *might* the temporal argument of the modal is identified with the temporal argument of the premise functions. So as long as the premise functions are time dependent, the denotation of the phrase headed by the modal can be time dependent too. For instance, the sports-math premise function $\mathrm{Pr}_{\mathrm{sm}}$ is time dependent, because $\mathrm{Pr}_{\mathrm{sm}}(t)(w)$ has information about a monotonically increasing set of game results as t increases. In fact, if $t < t'$ then $\mathrm{Pr}_{\mathrm{sm}}(t)(w) \subseteq \mathrm{Pr}_{\mathrm{sm}}(t')(w)$, and therefore $\cap\mathrm{Pr}_{\mathrm{sm}}(t')(w)$ is a subset of $\cap\mathrm{Pr}_{\mathrm{sm}}(t)(w)$. So as time passes, the domain of quantification shrinks. This is similar to what happens in the branching-time analysis. In fact, we can show that the new analysis is a generalization of the old one. We choose a circumstantial premise function Pr_{m} which maps a time and world to a set of propositions whose intersection is the set of metaphysical alternatives to the world at the time. (26) does it with a modal base function whose value is a unit set. If we combine this with a trivial ordering source, then we reconstruct Condoravdi's analysis inside my analysis.[8]

(26) $\mathrm{Pr}_{\mathrm{m}} = \lambda t\lambda w\lambda p[p=\mathrm{M}(t,w)]$

Something that is missing so far is the inclusion of temporal operators which allow the event time for the complement of the modal (e.g. Buffalo reaching the playoffs) to follow the time of the alternative. Condoravdi's definition (3) of the semantics of *might* does this by using the predication $\mathrm{AT}([t,\infty),w',P)$ in place of $P(w)(t)$, which stretches out the temporal frame in which the event is ordered. It is easy to incorporate this: we substitute $\mathrm{AT}([1(z),\infty), 2(z),p)$ for $p(t)(z)$ in (24), where $1(z)$ is the time component of the alternative z and $2(z)$ is the world component. This gives the definition (27) for *might*. The definition is written with lambda arguments Π for the modal base function, Ω for the

ordering source function, p for the complement of the modal, and w and t for world and time arguments of the resulting proposition.

(27) $[\![\text{might}]\!] = \lambda\Pi\lambda\Omega\lambda p\lambda t\lambda w\exists u\in\cap\,\Pi\,(t)(w))\,(\forall v\in\cap\,\Pi\,(t)(w))[v\leq_{\Omega(t)(w)}u \rightarrow (\exists z\in\cap\,\Pi\,(t)(w))[z\leq_{\Omega(t)(w)}v \wedge \text{AT}([1(z),\infty), 2(z),p)]]$

In this definition, the term [$\lambda t\lambda w$ …] corresponds to the denotation of a clause headed by *might*. Any operator scoping directly over this clause will interact with the time and world lambda arguments t and w. These parameters are arguments of the premise functions Π and Ω, and as a result time-dependent premise functions result in a time-dependent denotation for the clause headed by *might*.

This ties in with an embedding tests. When developing analyses of modals, it is a good idea to check that predictions are plausible for cases where the modal is embedded in intensional contexts, such as a belief context. (28) is a sports math example with *believe* scoping over a temporal operator expressed by *have*, which scopes over the modality. In the semantics, the world and time parameters of the modality interact compositionally with the temporal and belief operators. The truth of (28) depends on the value of the function Pr_{sm} when applied to an epistemic alternative w and to the time corresponding to Week 11. (And similarly for Or_{sm}.) The result is that (28) gives interdependent information about what Mary believes the history of play, schedule of play, and league regulations to have been in Week 11. This seems exactly right.

(28) a. Mary believes that in Week 11, Buffalo had a mathematical possibility of reaching the playoffs.
b. Mary believes that in Week 11, mathematically, Buffalo could have reached the playoffs.

Here is another check, this time connected with a common ground attitude. Suppose the two of us agree completely about league regulations and schedule, so that in all the worlds of our common ground, these are the same. I have more information about the results of play than you do, and I tell you sentence (29). The premise and ordering functions are fixed as Pr_{sm} and Or_{sm} and they can be evaluated at any world in the common ground. This allows the truth value of (29) to be checked at any world in the common ground, with worlds where it is false eliminated in the update. The effect is that the modal sentence gives partial information about the results of play---in other words, the modal sentence gives partial information about concrete circumstances. Intuitively, it is clear that the sentence can give information about the results of play up to Week 11, in a situation where the schedule and regulations are known. Getting concrete factual information out of the modal statement is possible because of the circumstantial modality.

(29) In Week 11, mathematically, Buffalo could still have reached the playoffs.

Sentences (28) and (29) can convey so much information because the identity of the premise functions is so clear. If you didn't know exactly what premise function I had in mind, the sentences would convey less information. In the other scenarios in this paper, the specific nature of the circumstantial premises is less clear, and it is less clear exactly how the circumstantial premises vary from world to world. But this can be improved. Kratzer (1977) suggested that adverbial phrases can be used to give hints about the

premise function. With this kind of help, (30) and (31) are pretty similar to (29). If we agree entirely about the physics of tree motion, then I can use (30) to eliminate worlds with certain combinations of wind direction and rot location. In the ranch scenario, if we agree about petroleum geology, I can use (31) to eliminate worlds with certain values for the test results. To contextualize this kind of understanding, one just has to imagine that I have much more specific information about the concrete situation than you.

(30) Considering wind direction and the specific location of the rot, the tree could not have fallen on the orchids.

(31) Considering the test results, the ranch might well have contained a significant oil reserve.

Earlier, I used wh-questions as a way of naming circumstantial premise functions. Interestingly, this device can be used directly in English, as in (32). The sense of "considering" seems precisely to be to consider certain premises about concrete facts, in conjunction with something like a theory of petroleum geology. In a context where I am well-informed about these facts and you are not, we take proposition-sets describing the test results to be world-dependent in order to explain how you can gain information about the test results from my statements (32a,b). The interaction falls nicely out of the world-dependence of the question-denotation in the Karttunen semantics, plus the semantics of the circumstantial modality.

(32) a. Considering what the result of test A was, what the result of test B was, and what the result of test C was, the ranch might well have contained a significant oil reserve.

b. In view of what the result of test A was, what the result of test B was, and what the result of test C was, the ranch might well have contained a significant oil reserve.

(33) and (34) are two more examples of modality in belief contexts. Intuitively and in the theory, (33) gives interdependent information about Mary's notions about the height of the tree, distance from the tree to the house, physical regularities of tree motions under the influence of wind, whether there was a concrete barrier between the tree and the house, etc. Intuitively and in the theory, (34) gives information about what Mary takes the geological test results to have been, in interaction with information about her views about petroleum geology. What happens in the semantics of those examples is that an intensional operator binds the world and time variables which are the arguments of the circumstantial premise function and the ordering source. That those variables can be bound in this way, and that the resulting semantic for these sentences is plausible, supports the analysis using time- and world-dependent premise functions. It also supports the more general hypothesis that there are circumstantial modalities, and that circumstantial modality is involved in the examples I am talking about.

(33) Mary believes the tree could have fallen on the office.

(34) Mary thinks the ranch could not have contained an oil reserve.

Now I would like to consider the question whether the modality in the examples discussed in this paper is properly viewed as circumstantial, or whether they may instead be epistemic or doxastic. In this paper, circumstantial or factual modality has been described as referring to the world and time dependent questions such as "what were the results of league play up to such and such time?". Epistemic modality in the strict sense refers to possibility in view of the epistemic state of an agent or collection of agents. These modalities are related and can be hard to distinguish, because agents have information about circumstantial matters.

Consider this variant of the tree scenario. The two trees are in a part of our forest reserve which we never visited before. The tree fell away from a plantation of endangered orchids. We find it several months after it fell. The facts about the rot are as before. The point about our never having visited that part of the reserve before is that at the time of the storm, there is no agent around who has information about the trees. Nobody had ever seen those trees. So it is difficult to argue that the modality in sentence (35) is epistemic in the sense of referring to the information of an agent. (In this argument, I am not discussing the present-epistemic reading of the first sentence in (35). There is such a reading for the sentence, but it is not the one which fits into the context. In the argument, I'm checking whether the reading which does fit into the context could be an epistemic reading describing some agent's information at the past time.)

(35) The tree could have fallen on the orchids. Let's cut down the other tree. It might fall on the orchids in another storm.

Pragmatically, there is arguably an epistemic or doxastic modality layered *above* the circumstantial modality in (35), because one can draw conclusions about the speaker's beliefs at the utterance time. But this is something entirely systematic, which is true also about non-modal sentences. We can make a related point about (28), (33), and (34). They clearly have a doxastic modality expressed by *believes* that is layered above the circumstantial modality. With the operator ordering *believe* > *might* > *have*, analyzing also the embedded modal as doxastic results in a different reading, where the doxastic modality is existential rather than universal. With the operator ordering *believe* > *have* > *might*, I doubt that there is any doxastic reading for the modal. Note that the "time parameters" of these modalities are different. In (28) the time parameter of the doxastic modality is the utterance time, while the time parameter of the circumstantial modality is Week 11. So, I think these data and analysis support the position that the modalities in the examples under discussion here are circumstantial, rather than epistemic or doxastic in the strict sense.

Here is an argument that goes the other way. A defining property of circumstantial modality is that the circumstances hold in the base world. Since agents can have false information, the same is not true of doxastic modality. Consider this variant of the ranch scenario (call it Ranch Scenario 2). The geological tests John uses give wildly incorrect results on rare occasions (say one time in ten thousand). The tests are not repeated because they are expensive, and because the errors are so rare. In this case, purely by chance, several measurements were wildly incorrect. As a result, some of the propositions in John's geological report are false in the base world. The partners discover the measurement errors in the drilling phase of the work. In these circumstances, I think John's partner can say (36). On the surface, this looks like a

problem for the circumstantial analysis, since it appears that the propositions on which the judgment is based were not true. Instead, the scenario and example suggest a past doxastic modality, describing what John and the partner believed at the time when they bought the ranch.

(36) We bought a ranch which might well have contained a significant oil reserve. But unfortunately there is no oil on this ranch. Let's sell it and move on to the next project.

Here is another version. John falsified all of the test results, and never doing any real geological tests. He stole the money for the tests, and wanted the project to go ahead because he could steal more money in the drilling phase. Later on the partner finds out about the fraud. In this case, it seems the partner can not say (36). There could be different explanations for this. One has to do with the modal base. It could be that any reasonable modal base should contain the fact that the tests where falsified. A second possibility is that the modality is an epistemic one restricted to justified beliefs, so that faked tests are disqualified. Or finally, maybe the modal base is circumstantial after all, so that it can not contain false propositions, such as the false things about the tests. I would like to take the last approach, because of the earlier evidence that the modalities involved in my examples are circumstantial. This means there has to be a different analysis of Ranch Scenario 2. We can say that the circumstantial modal base consists of very concrete things about the tests, such as what the numbers on the instrument were. Those concrete things about the test can be assumed to be facts.

My tentative conclusion is that the modality involved in the examples under discussion in the paper is indeed a circumstantial one, and is not always epistemic or doxastic. At least, there are some examples which fall under the circumstantial analysis which can not be epistemic or doxastic readings in the strict sense. This leaves the possibility that circumstantial and epistemic readings are related somehow. In an interesting passage, von Fintel and Gillies (2008) suggest that there is a range or "cloud" of interpretations including one making a solipsistic claim about the epistemic state of the speaker, an interpretation making a claim about the common-ground attitude of a group of agents, or "even a claim about all the evidence available to (but not necessarily already processed by) that group" (von Fintel and Gillies 2008, p. 96). Maybe the cloud extends further to include strictly circumstantial readings that are entirely independent of agents. Another hypothesis one might investigate is that epistemic interpretations (in the strict sense of interpretations reflecting the knowledge of one or more agents) are a special case of circumstantial interpretations, because whatever is known (and not just believed) is factual. A function which maps a world and a time to what an agent *knows* in that world at that time is a circumstantial modal-base function.[9]

7. A time dependence puzzle

According to the analysis from the previous section, if sentence (37a) is true, it is because the relevant premise function maps the base world w_0 and the time 12:00 to a set of propositions which is consistent with John finishing the race. If we are talking about possibility in view of the physical state of John's body, then the premises might be that the energy level in John's muscles is high, his blood sugar is high, etc. So the premise set is along the lines of what is described at the top in (38). Let's assume each premise is true at $\langle w_0,t_{12:00}\rangle$ and the set of premises is consistent with John finishing the race. Then there is an alternative $u_1 \in \cap \Pr(w_0,t_{12:00})$ where John finishes. The second part in (38) describes the value of the premise function at the later time 12:30. We assume that each proposition in $\Pr(w_0,t_{12:30})$ is true at $\langle w_0,t_{12:30}\rangle$, but that there is no world w in $\cap\Pr(w_0,t_{12:30})$ where John finishes the race. This is the analysis according to the current theory of the sequence (38a,b) being true.

(37) a. At noon, John still might have finished the race.
b. But at 12:30, he could not have finished the race.

(38) $\Pr(w_0,t_{12:00})$ = {…, the ATP level in John's leg muscles is 70%,
John's blood sugar level is 81%, … }
$\Pr(w_0,t_{12:30})$ = {…, the ATP level in John's leg muscles is 20%,
John's blood sugar level is 19%, … }

(39) presents a puzzle by further describing the function Pr', which maps $\langle w_0,t_{12:30}\rangle$ to time-shifted versions of the premises at $\langle w_0,t_{12:00}\rangle$. According to $\Pr'(w_0,t_{12:30})$ the energy level in John's legs was high half an hour earlier, John had high blood sugar levels half an hour earlier, and so forth. Since each of the original premises was true in w_0 at 12:00, the new premises are true in w_0 at 12:30. So those are facts about $\langle w_0,t_{12:30}\rangle$. Assume that all of the premises are time-shifted in this way. Then each element of $\Pr'(w_0,t_{12:30})$ is a fact at $\langle w_0,t_{12:30}\rangle$. So by the formal criteria, Pr' is a circumstantial premise function.[10]

(39) $\Pr'(w_0,t_{12:30})$ = {…, the ATP level in John's leg muscles was 70% half an hour earlier, John was confident half an hour earlier, … }

Remember that $u_1=\langle t_1,w_1\rangle$, is an alternative where John finishes the race. Because of the correspondence between $\Pr(w_0,t_{12:00})$ and $\Pr'(w_0,t_{12:30})$, the pair $\langle t_1+30\text{min},w_1\rangle$ is an element of $\cap\Pr'(w_0,t_{12:30})$. Let's make the additional assumption that, because of the length of the race, the time in w_1 where John finishes would have to be more than 30 minutes after t_1. In that case, the pair $\langle t_1+30\text{min},w_1\rangle$ is a witness for the truth of (40) relative to Pr'. This gives the unwanted result that sentence (40) is true in the described scenario, so that its negation (37b) is false. Intuitively (37b) seems false in the scenario where John has no energy in his muscles and is panicking at 12:30.

(40) At 12:30, he could have finished the race.

The problem must be that Pr' is an 'unnatural' circumstantial premise function. If we are talking about the possibilities at 12:30 of John finishing, his physical state at 12:00 is of some relevance, but his physical state at 12:30 is much more relevant. Any degree of strength in his legs at 12:00 is trumped by his legs being weak at 12:30. So, apparently, circumstantial premise functions should be constrained to involve facts about the reference time, not some earlier time. As natural as this sounds, it does not follow from just requiring that the premises be true propositions. Notice by the way how odd (41) sounds.

(41) At 12:30, in view of his physical condition half an hour before, he could have finished the race.

The need for additional constraint on premise functions is not very surprising, because in general, only certain kinds of premise functions are used in evaluating natural language modals. (42) describes an unnatural premise function for a deontic modal, which picks out the zoning regulations for the town of Ithaca at 12:00, and college regulations at 12:30. Suppose that the college regulations do not allow open book exams, but that open book exams are consistent with the zoning regulations. With this crazy premise function, (43) is true, not because any regulations have changed, but because the premise function Qr has an odd time-dependent conditional description similar to the predicate 'grue' of Goodman (1954). It seems very difficult to understand (43) as true in the described circumstances. This means that the premise function Qr must be excluded somehow, either in the semantic or the pragmatic component.

(42) $Qr(w_0,t_{12:00})$ = the set of zoning regulations of the Town of Ithaca in w_0 at $t_{12:00}$

$Qr(w_0,t_{12:30})$ = the set of regulations for giving final exams of the Cornell College of Arts and Sciences in w_0 at $t_{12:30}$

(43) At noon, I could still have given an open book exam. But by 12:30, I could not have given an open book exam.

The problems with Pr' and Qr are symptoms of the fact that the modal semantics I am working with has too much freedom in the choice of premise functions. How to constrain premise functions in this theory is an active research topic (see Kratzer 2005). Rather than solving the problem, the discussion here has brought up some specific cases which have to be covered.

As a summary of the analysis proposed in this paper, we can say that the premise sets are being used to select a domain of relevantly similar alternatives. A sentence with a circumstantial counterfactual modal is true if the complement sentence is true at some/all relevantly similar world-time pairs. While being similar to the base world and time in that certain propositions hold in both of them, the alternatives don't have to be metaphysical alternatives to the base world at the evaluation time. Time dependence is brought in by means of time-dependent premise functions, whose temporal parameter is identified with the evaluation time of the modal.

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Endnotes

1. Whatever the implementation, the evidence for this scope relation seems fairly good. Condoravdi points out that in the German example (i), the *have* form *hätte* is in the V2 position, so that it is syntactically above the modal *kőnnen*. As pointed out in Jun (2006), Korean also has the temporal and modal operators in the logical order. Examples (ii) and (iii) are quoted from Jun.

   (i) Er hätte noch gewinnen kőnnen.
   (ii) ku-ka iki-l swu-to iss-ess-ta. kulenaku-nun kyelkwuk ci-ess-ta

   he win might PAST but he eventually lost PAST

   'he might have won, but he eventually lost' Syntactic and semantic order of operators: … win) might) PAST).

   (iii) ku-ka imi iki-ess-ul swu iss-ta
   he already win PAST might
   'he might already have won' (epistemic).
   Syntactic and semantic order of operators: … win) PAST) might).

   An obvious possibility about English is that since modals do not have participial forms, a syntax-semantics mismatch is forced, with a semantically subordinate modal surfacing in the syntactically superior position. In Swedish however, the counterpart of *can* does have a participial variant, as shown in (iv). Nevertheless counterfactual have-modal combinations surface in the English configuration with the modal in the V2 position, as shown in (v). Notice however that the modal *kunde* in (v) is a past tense one, so that the temporal operator scoping over the modal could be the past tense. Stowell (2004) makes a similar proposal for English.

(iv) Jag har inte kunnat tänka på det.
I have-pres not can-supine think-inf on it
'I haven't been able to think about it.'

(v) Jag kunde ha dödats
I can-past have-inf kill-supine-passive
'I could have been killed.'

In contexts including counterfactuals, the German order is apparently possible in Swedish, cf. (vi) and (vii).

(vi) Om bomben hade sprängts, hade människor kunnat dödats, säger polisen.
'If the bomb had been detonated, people could have been killed, say the police.'
(vii) Människor hade kunnat dödats i den här katastrofen.
people have-pst can-supine kill-supine-passive in the here catastrophe.
'People could have been killed in this catastrophe.'

2. Related proposals are made in Abusch (1998) and von Stechow (2003). In the former, future-oriented modal have in their scope an operator which substitutes an interval (n,∞) for evaluation time parameter n, with the effect of stretching the evaluation time forward. This is used to analyze interaction with temporal elements such as past tense in the scope of the future-oriented modal

3. See Thomason (1984) for a formal development.

4. In (7b) the wife's sentence uses *could* rather than *might* because in a version with *might*, the negation can not scope over the modal. But as I understand it, the two modal are equivalent in this context.

5. See Veltman (1976), Kratzer (1981,1991), Lewis (1981). The main applications of premise semantics are to counterfactuals with *if*. These are not being analyzed here. However, it is interesting that in many cases, when a sentence like (i) with a counterfactual modal is true, there is a corresponding true counterfactual with *if* like (ii). Sentence (iii) is an *if*-counterfactual for the trees scenario.

(i) In week 11 of the football season, mathematically, Buffalo could still have reached the playoffs.
(ii) If Detroit had defeated Miami in week 12, Washington had defeated Cincinnati in Week 12 by at least 21 points, … , and Arizona had defeated San Diego by at least 14 points in Week 17, then Buffalo would have reached the playoffs.
(iii) If the internal rot had been on the opposite side, the tree would/might have fallen on the office.

6. Condoravdi makes the other choice, since for her the metaphysical modal base is a set of worlds (type $[W\rightarrow 2]$) rather than a set of world-time pairs (type $[I\rightarrow W\rightarrow 2]$). For Condoravdi, $M(w,t)$ is the set of worlds w' such that w up to time t is the same as w' up to time t. This uses identification of times across worlds. In the alternative corresponding to the one chosen for premise functions, $M(w,t)$ is the set of pairs of worlds w' and times t' such that w up to time t is the same as w' up to time t'.

7. The double time dependence looks funny, but actually it is a standard option. In the type system from Montague (1973), the type s is the type of world-time pairs, rather than worlds. So we can rewrite $[I\rightarrow W\rightarrow[I\rightarrow W\rightarrow 2]\rightarrow 2]$ as $[S\rightarrow[S\rightarrow 2]\rightarrow 2]$, or $\langle s,\langle\langle s,t\rangle,t\rangle\rangle$. In the standard system this is the type of the intension of a set of propositions.

8. For Pr_m to have the right type, we have to assume that $M(t,w)$ has type $[I\rightarrow W\rightarrow 2]$, instead of Condoravdi's type $[W\rightarrow 2]$. See footnote 6. Or using cross-identification of times, we can define $Pr_m = \lambda t\lambda w\lambda p[p=\lambda t'\lambda w'[M(t,w)(w')\wedge t=t']]$.

9. The importance of looking at these issues further is brought home by the fact that some data von Fintel and Gillies discuss as epistemic readings are similar to some of the readings I characterized as circumstantial. The example quoted below is basically like my ranch example, with ice cream instead of oil, and a refrigerator in place of the ranch (von Fintel an Gilles (2008), p. 87).

   Sophie is looking for some ice cream and checks the freezer. There is none there. Asked why she opened the freezer, she replies:

   (i) There might have been ice cream in the freezer.

10. To complete the example one needs a complete definition of Pr'. Pr' is a systematically time-shifted version of Pr, with Pr'(w,t) = Pr(w,t-30min).

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