Ramification analysis with structured news reports using temporal argumentation (draft paper)

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Abstract. To operate in the real-world, intelligent agents constantly need to absorb new information, and to consider the ramifications of it. This raises interesting questions for knowledge representation and reasoning. Here we consider ramification analysis in which we wish to determine both the likely outcomes from events occuring and the less likely, but very significant outcomes, from events occuring. In particular, we want to develop ramification analysis techniques for news reports in a structured text format. Structured text is a general concept that is implicit in a variety of approaches to handling information. Syntactically, an item of structured text is a number of grammatically simple phrases together with a semantic label for each phrase. Items of structured text may be nested within larger items of structured text. Much information is potentially available as structured text including tagged text in XML, text in relational and object-oriented databases, and the output from information extraction systems in the form of instantiated templates. A useful feature of structured news reports is that they can be represented by sets of ground literals and so are amenable to logical reasoning. In a previous paper, we used default logic for ramification analysis [Hun00b]. Here we want to harness a temporal logic approach to argumentation. For this, we will integrate a temporal logic with a consistency-based argumentation system leading to a richer form of argumentation for ramification analysis.

1 Introduction

In order to operate in an environment, an intelligent agent needs to consider the effects of events in that environment. These events may result from the agent's actions or result from exogenous causes. We call this assessment of events in an environment **ramification analysis**. Consider for example the news that there is a train drivers' strike tomorrow. Ramifications include many people will have difficulty getting into work on time which in turn means meetings may be running late and be poorly attended, and this is likely to have a knock-on effect on schedules for meetings in the subsequent weeks.

Formalizing ramification analysis for an intelligent agent is a difficult problem in general. It calls for comprehensive common-sense reasoning and general knowledge. However, there is the possibility to develop ramification analysis for constrained problems, where the set of events under consideration is limited.

In ramification analysis, we wish to determine both the likely outcomes from news and also the less likely, but very significant, outcomes from news. The aim is not to take news and determine just the most likely outcomes. Rather it is to explore possibilities. We are therefore not proposing some qualitative form of probabilistic reasoning. Nor are we adopting some form of possibility theory. Rather we are treating possibilities equally and focussing our attention on their interactions.

Here, we assume news is in the form of structured text. Syntactically, an item of structured text is a data structure containing a number of grammatically simple phrases together with a semantic label for each phrase. The set of semantic labels in a structured text is meant to parameterize a stereotypical situation, and so a particular item of structured text is an instance of that stereotypical situation. Using appropriate semantic labels, we can regard a structured text as an abstraction of an item of text.

```
⟨bid-report⟩
      ⟨bid-date⟩ 30 May 2000⟨/bid-date⟩
      ⟨buyer⟩
            ⟨company⟩France Telecom⟨/company⟩
            ⟨capitalization⟩150 Billion Euros⟨/capitalization⟩
      ⟨/buyer⟩
      ⟨target⟩
            ⟨company⟩Orange⟨/company⟩
            ⟨capitalization⟩35 Billion Euros⟨/capitalization⟩
      ⟨/target⟩
      ⟨bid-type⟩agreed⟨/bid-type⟩
      ⟨bid-value⟩40 Billion Euros⟨/bid-value⟩
⟨/bid-report⟩
```

Fig. 1. An example of a news report in the form of structured text.

For example, news reports on corporate acquisitions can be represented as items of structured text using semantic labels including `buyer`, `seller`, `target`, `bid-value`, and `bid-date`. Each semantic label provides semantic information, and so an item of structured text is intended to have some semantic coherence. Each phrase in structured text is very simple — such as a proper noun, a date, or a number with unit of measure, or a word or phrase from a prescribed lexicon. For an application, the prescribed lexicon delineates the types of states, actions, and attributes, that could be conveyed by the items of structured text. An example of structured text is given in Figure 1.

Because of the restricted nature of the text entries in structured news reports, we can easily represent each structred news report by a set of literals in logic. Some proposals for this have been made in [Hun00c,Hun00a,Hun01b].

Much material is potentially available as structured text. This includes items of text structured using XML tags, and the output from information extraction systems given in templates (see for example [CL96,Gri97,ARP98]). The notion of structured text also overlaps with semi-structured data (for reviews see [Abi97,Bun97]).

In [Hun00b], we proposed default logic as the basis for argumentation with structured news reports for ramification analysis. Also, we have compared various paraconsistent logics for reasoning with structured news reports [Hun00c], we have considered argument aggregation functions for argumentation with news from heterogeneous sources [BH01], we considered temporal reasoning with structured news reports [Hun01b], and we have considered hybrid argumentation systems for structured news reports [Hun01a]. Here we extend a consistency-based argumentation system with temporal logic to support temporal argumentation with structured news reports.

2 Temporal argumentation

Whilst there are many proposals for argumentation systems in AI (for reviews see [FKEG93,GK98,VLG98,PV00,CML00]), there is a need to consider temporal argumentation in more detail. Arguments in the real-world evolve over time, influences become weaker or stronger, warrants appear and disappear, and yet argumentation systems tend to be atemporal.

In the research areas of AI and logics, there is an extensive literature on temporal reasoning that could be harnessed for temporal argumentation systems. Our approach here is to take an existing proposal for argumentation, a form of consistency-based argumentation [EGH95], and combine it with a temporal logic that is a refined version of Prior's tense logic [Pri67].

2.1 Consistency-based argumentation

One of the most obvious strategies for handling inconsistency in a database is to reason with consistent subsets of the database.

Definition 1. *Let Δ be a database and let $\vdash$ be the classical consequence relation. Then:*

$$\begin{aligned}
&\mathsf{CON}(\Delta) = \{\Pi \subseteq \Delta | \Pi \nvdash \bot\}\\
&\mathsf{INC}(\Delta) = \{\Pi \subseteq \Delta | \Pi \vdash \bot\}\\
&\mathsf{MC}(\Delta) = \{\Pi \in \mathsf{CON}(\Delta) | \forall \Phi \in \mathsf{CON}(\Delta) \Pi \not\subset \Phi\}\\
&\mathsf{MI}(\Delta) = \{\Pi \in \mathsf{INC}(\Delta) | \forall \Phi \in \mathsf{INC}(\Delta) \Phi \not\subset \Pi\}\\
&\mathsf{FREE}(\Delta) = \bigcap \mathsf{MC}(\Delta)
\end{aligned}$$

Hence $\mathsf{MC}(\Delta)$ is the set of maximally consistent subsets of Δ; $\mathsf{MI}(\Delta)$ is the set of minimally inconsistent subsets of Δ; and $\mathsf{FREE}(\Delta)$ is the set of information that all maximally consistent subsets of Δ have in common.

A problem with using inferences from consistent subsets of an inconsistent database is that they are only weakly justified in general. To handle this problem, we can adopt the notion of an argument from a database, and a notion of acceptability of an argument. An argument is a subset of the database, together with an inference from that subset. Using the notion of acceptability, the set of all arguments can be partitioned into sets of (arguments of) different degrees of acceptability. This can then be used to define a class of consequence relations (see for example [BDP93,EGH95]).

Definition 2. *Let Δ be a database. An argument from Δ is a pair, (Π, ϕ), such that $\Pi \subseteq \Delta$ and $\Pi \vdash \phi$. An argument is consistent, if Π is consistent. We denote the set of arguments from Δ as $\mathsf{An}(\Delta)$, where $\mathsf{An}(\Delta) = \{(\Pi, \phi) | \Pi \subseteq \Delta \wedge \Pi \vdash \phi\}$. Γ is an argument set of Δ iff $\Gamma \subseteq \mathsf{An}(\Delta)$.*

Definition 3. *Let Δ be a database. Let (Π, ϕ) and (Θ, ψ) be any arguments constructed from Δ. If $\vdash \phi \leftrightarrow \neg\psi$, then (Π, ϕ) is a rebutting defeater of (Θ, ψ). If $\gamma \in \Theta$ and $\vdash \phi \leftrightarrow \neg\gamma$, then (Π, ϕ) is an undercutting defeater of (Θ, ψ).*

Rebutting defeat, as defined here, is a symmetrical relation. One way of changing this is by use of priorities, such as in systems based on explicit representation of preference (eg [Bre89,CRS93,BDP95]), or as in systems based on specificity (eg [Poo88]).

For a database Δ, an argumentative structure is any set of subsets of $\mathsf{An}(\Delta)$. The intention behind the definition for an argumentative structure is that different subsets of $\mathsf{An}(\Delta)$ have different degrees of acceptability. Below, we present one particular argumentative structure A^*, and then explain how the definition captures notions of acceptability.

Definition 4. *The following sets are members of the argumentative structure A^*, where Δ is a database.*

$$\mathsf{AT}(\Delta) = \{(\emptyset, \phi) | \emptyset \vdash \phi\}$$
$$\mathsf{AF}(\Delta) = \{(\Pi, \phi) | \Pi \subseteq \mathsf{FREE}(\Delta) \wedge \Pi \vdash \phi\}$$
$$\mathsf{AB}(\Delta) = \{(\Pi, \phi) | \Pi \in \mathsf{CON}(\Delta) \wedge \Pi \vdash \phi \wedge (\forall \Phi \in \mathsf{MC}(\Delta), \psi \in \Pi \Phi \vdash \psi)\}$$
$$\mathsf{AU}(\Delta) = \{(\Pi, \phi) | \Pi \in \mathsf{CON}(\Delta) \wedge \Pi \vdash \phi \wedge (\forall \Phi \in \mathsf{MC}(\Delta), \psi \in \Pi \Phi \nvdash \neg\psi)\}$$
$$\mathsf{A}\forall(\Delta) = \{(\Pi, \phi) | \Pi \in \mathsf{CON}(\Delta) \wedge \Pi \vdash \phi \wedge (\forall \Phi \in \mathsf{MC}(\Delta) \Phi \vdash \phi)\}$$
$$\mathsf{AR}(\Delta) = \{(\Pi, \phi) | \Pi \in \mathsf{CON}(\Delta) \wedge \Pi \vdash \phi \wedge (\forall \Phi \in \mathsf{MC}(\Delta) \Phi \nvdash \neg\phi)\}$$
$$\mathsf{A}\exists(\Delta) = \{(\Pi, \phi) | \Pi \in \mathsf{CON}(\Delta) \wedge \Pi \vdash \phi\}$$

The naming conventions for the argument sets are motivated as follows. T is for the tautological arguments - i.e. those that follow from the empty set of premises. F is for the free arguments - (due to Benferhat et al [BDP93]) - which are the arguments that follow from the data that is free of inconsistencies. B is for the backed arguments - i.e. those for which all the premises follow from all the maximally consistent subsets of the data. U is for the arguments that are not subject to undercutting. $\forall$ is for the universal arguments - (essentially due to Manor and Rescher [MR70], where it was called inevitable arguments) - which are the arguments that follow from all maximally consistent subsets of the data. R is for the arguments that are not subject to rebutting. $\exists$ is for existential arguments - (essentially due to Manor and Rescher [MR70]) - which are the arguments with consistent premises.

Example 1. We give an example of a database, and some of the items in each argument set. Take $\Delta = \{\alpha, \neg\alpha\}$. Then $(\{\alpha, \neg\alpha\}, \alpha \wedge \neg\alpha) \in \mathsf{An}(\Delta)$, $(\{\alpha\}, \alpha) \in \mathsf{A}\exists(\Delta)$, $(\{\alpha\}, \alpha \vee \beta) \in \mathsf{AR}(\Delta)$, if $\beta \not\vdash \alpha$, $(\{\}, \alpha \vee \neg\alpha) \in \mathsf{A}\forall(\Delta)$. Furthermore, $\mathsf{A}\forall(\Delta) = \mathsf{AF}(\Delta) = \mathsf{AB}(\Delta) = \mathsf{AU}(\Delta) = \mathsf{AT}(\Delta)$.

Example 2. As another example, consider $\Delta = \{\neg\alpha \wedge \beta, \alpha \wedge \beta\}$. Then for $\Pi = \{\alpha \wedge \beta\}$, $(\Pi, \beta) \in \mathsf{A}\exists(\Delta)$, $(\Pi, \beta) \in \mathsf{AR}(\Delta)$, and $(\Pi, \beta) \in \mathsf{A}\forall(\Delta)$. But there is no $\Pi \subseteq \Delta$ such that $(\Pi, \beta) \in \mathsf{AU}(\Delta)$, $(\Pi, \beta) \in \mathsf{AB}(\Delta)$, or $(\Pi, \beta) \in \mathsf{AF}(\Delta)$.

The concept of an argumentative structure, with the two notions of argument and acceptability, are a convenient framework for developing practical reasoning tools. Although, they are based on simple definitions of arguments and acceptability, the concepts carry many possibilities for further refinement.

2.2 Temporal logic with calendar timelines

We can assume that a logic L such as classical logic can describe some system S in a static state. Let D be the description of S in a static state. We will define D as a set of formulae of L that are true about S in this static state. Now we want to describe how the system S evolves over time. To do this we take snapshots of the state of S as it evolves over time. Let D_i be the description of S at time i. This gives us a sequence of descriptions:

$$D_i, D_{i+1}, D_{i+2}, D_{i+3}, D_{i+4}, \ldots..$$

In this way, we have associated each snapshot with a point in time, where the sequence of points can be represented by the natural numbers. We also assume that each time point is instantaneous and so has no duration. We can consider different formulae that are true at every point in time, and formulae that true only at some points in time. Already we have a form of possible worlds. Point-based temporal logic is just a special form of modal logic where the modal operators are temporal operators. The possible worlds are ordered according to a flow of time. In this way, we are capturing the statics and dynamics of systems. Reviews of temporal logics include [McA76,Gol87,GHR94,GRF00]. In this paper, we focus on the flow of time being at the granularity of days, and formalize this using a timeline.

Definition 5. *A* **timeline** *is a pair* $(\Omega, \leq)$ *where* Ω *is a set of time points representing days and the following conditions hold for the ordering relation* $\leq$*: (Reflexivity)* $\forall x \in \Omega\ x \leq x$*; (Antisymmetry)* $\forall x, y \in \Omega_i\ x \leq y \wedge y \leq x \rightarrow x = y$*; and (Transitivity)* $\forall x, y, z \in \Omega\ x \leq y \wedge y \leq z \rightarrow x \leq z$.

To represent temporal information in the language, we use the temporal operators F, P, G, and H, where $F\alpha$ means α is true at some point in time in the future, $P\alpha$ means α is true at some point in time in the past, $G\alpha$ means α is true at all points in time in the future, and $H\alpha$ means α is true at all points in time in the past. We also introduce additional temporal operators N_{day}, L_{day}, N_{week}, L_{week}, N_{month}, L_{month}, N_{month}, L_{month}, N_{year}, and L_{year}. So $N_{day}\alpha$ means α is true at the next point in time, $L_{day}\alpha$ means α is true at the last (previous) point in time, $N_{week}\alpha$ means α is true some of the next seven points in time, and $L_{week}\alpha$ means α is true at some of the last seven points in time. The remaining operators are defined similarly. The definition of classical logic is extended to accommodate these temporal operators.

Definition 6. *The set of tense formulae is obtained as follows: (1) If α is a classical formula, then α is a temporal formula; (2) If α is a temporal formula, and $\clubsuit$ is a temporal operator, then $\clubsuit\alpha$, is a temporal formula; (3) If α and β are temporal formulae, then $\alpha \wedge \beta$, $\alpha \vee \beta$, $\alpha \rightarrow \beta$, and $\neg\alpha$ are temporal formulae.*

Definition 7. *A temporal interpretation is a pair $(\Omega, \leq, \pi)$ where $(\Omega, \leq)$ is a timeline, and π is a function that associates a classical model with each timepoint. For the axioms, t is a timepoint known as the reference point.*

$$(\Omega, \leq, \pi) \models_t \alpha \text{ iff } \alpha \text{ is an atom and } \alpha \text{ is true in } \pi(t)$$

$$(\Omega, \leq, \pi) \models_t F\alpha \text{ iff } \exists t' \text{such that } t < t' \text{ and } (\Omega, \leq, \pi) \models_{t'} \alpha$$

$$(\Omega, \leq, \pi) \models_t G\alpha \text{ iff } \forall t' \text{such that } t < t' \text{ and } (\Omega, \leq, \pi) \models_{t'} \alpha$$

$$(\Omega, \leq, \pi) \models_t N_{day}\alpha \text{ iff } (\Omega, \leq, \pi) \models_{t+1} \alpha$$

$$(\Omega, \leq, \pi) \models_t N_{week}\alpha \text{ iff } (\Omega, \leq, \pi) \models_{t+1} \alpha \text{ or .. or } (\Omega, \leq, \pi) \models_{t+7} \alpha$$

$$(\Omega, \leq, \pi) \models_t L_{day}\alpha \text{ iff } (\Omega, \leq, \pi) \models_{t-1} \alpha$$

$$(\Omega, \leq, \pi) \models_t L_{week}\alpha \text{ iff } (\Omega, \leq, \pi) \models_{t-1} \alpha \text{ or .. or } (\Omega, \leq, \pi) \models_{t-7} \alpha$$

$$(\Omega, \leq, \pi) \models_t \alpha \wedge \beta \text{ iff } (\Omega, \leq, \pi) \models_t \alpha \text{ and } (\Omega, \leq, \pi) \models_t \beta$$

$$(\Omega, \leq, \pi) \models_t \neg\alpha \text{ iff } (\Omega, \leq, \pi) \not\models_t \alpha$$

The remaining temporal formulae can be defined similarly.

Definition 8. *A temporal interpretation $(\Omega, \leq, \pi)$ is a model for a formula α, denoted $(\Omega, \leq, \pi) \models_T \alpha$, iff for all $t \in \Omega$, $(\Omega, \leq, \pi) \models_t \alpha$*

Example 3. Consider a temporal interpretation $(\Omega, \leq, \pi)$ where for all $t \in \Omega$, α is true in $\pi(t)$, and for all $t \in \Omega$, if β is true in $\pi(t)$, then β is not true in $\pi(t+1)$. So $(\Omega, \leq, \pi) \models_T G\alpha \wedge \alpha \wedge H\alpha$, $(\Omega, \leq, \pi) \models_T \beta \rightarrow N_{day}\neg\beta$, and $(\Omega, \leq, \pi) \models_T L_{day}\beta \rightarrow \neg\beta$.

Definition 9. *The entailment relation for temporal logic, denoted* $\models_T$*, is defined as follows:* $\{\beta_1, ..., \beta_n\} \models_T \alpha$ *holds iff for all temporal interpretations* $(\Omega, \leq, \pi)$

$$(\Omega, \leq, \pi) \models_T \beta_1 \wedge ... \wedge (\Omega, \leq, \pi) \models_T \beta_n \textit{ implies } (\Omega, \leq, \pi) \models_T \alpha$$

Definition 10. *Let* $\vdash_T$ *be the consequence relation for temporal logic.*

We will not provide details on the proof theory for temporal logic. However, we can assume that $\vdash_T$ is equivalent to $\models_T$. For implementing $\vdash_T$, we can either use an equivalence with an axiomatization of first-order classical logic quantifying over the natural numbers, and then use a classical logic theorem prover, or we can use temporal logic theorem proving technology.

2.3 Consistency-based temporal argumentation

In order to simplify our exposition, we will restrict consideration to propositional arguments. For this we will treat formulae with variables as schema that can be systematically grounded with constant symbols in the language to create propositional formulae. This means we have no quantifiers and no function symbols in this exposition.

Our integration of temporal logic with consistency-based argumentation is achieved by replacing the underlying logic for argument structures with the temporal logic $\vdash_T$ defined in the previous section. This gives us the following definitions.

Definition 11. *Let* Δ *be a database. Then:*

$$\begin{array}{l}
\mathsf{TCON}(\Delta) = \{\Pi \subseteq \Delta | \Pi \not\vdash_T \bot\} \\
\mathsf{TINC}(\Delta) = \{\Pi \subseteq \Delta | \Pi \vdash_T \bot\} \\
\mathsf{TMC}(\Delta) = \{\Pi \in \mathsf{TCON}(\Delta) | \forall \Phi \in \mathsf{TCON}(\Delta) \Pi \not\subset \Phi\} \\
\mathsf{TMI}(\Delta) = \{\Pi \in \mathsf{TINC}(\Delta) | \forall \Phi \in \mathsf{TINC}(\Delta) \Phi \not\subset \Pi\} \\
\mathsf{TFREE}(\Delta) = \bigcap \mathsf{TMC}(\Delta)
\end{array}$$

Using these revised definitions for consistent and inconsistent sunsets, and for minimal inconsistent subsets, maximal consistent subsets, and for free subsets, we give some of the members of the revised argument structure.

Definition 12. *The following sets are members of the argumentative structure* T^**, where* Δ *is a database.*

$$\begin{array}{l}
\mathsf{TF}(\Delta) = \{(\Pi, \phi) | \Pi \subseteq \mathsf{TFREE}(\Delta) \wedge \Pi \vdash \phi\} \\
\mathsf{T}\forall(\Delta) = \{(\Pi, \phi) | \Pi \in \mathsf{TCON}(\Delta) \wedge \Pi \vdash_T \phi \wedge (\forall \Phi \in \mathsf{TMC}(\Delta) \Phi \vdash_T \phi)\} \\
\mathsf{TR}(\Delta) = \{(\Pi, \phi) | \Pi \in \mathsf{TCON}(\Delta) \wedge \Pi \vdash_T \phi \wedge (\forall \Phi \in \mathsf{TMC}(\Delta) \Phi \not\vdash_T \neg\phi)\} \\
\mathsf{T}\exists(\Delta) = \{(\Pi, \phi) | \Pi \in \mathsf{TCON}(\Delta) \wedge \Pi \vdash_T \phi\}
\end{array}$$

We call $\mathsf{TF}(\Delta)$ the set of free temporal arguments, $\mathsf{T}\forall(\Delta)$ the set of universal temporal arguments, $\mathsf{TR}(\Delta)$ the set of non-rebutted temporal arguments, and $\mathsf{T}\exists(\Delta)$ the set of existential temporal arguments.

To use the the T^*argumentative structure, with structured news reports, we need to refine our notion of a database as follows.

Definition 13. *A* **ramification analysis database** *is a tuple* (Φ, Ψ, Λ) *where* Φ *is background knowledge in the form of temporal formulae,* Ψ *is background knowledge in the form of schema for temporal formulae, and* Λ *is a set of literals in temporal logic that represent one or more structured news reports.*

We illustrate this definition in the following example of a ramification analysis database.

Example 4. Suppose we have the following schema in Ψ, with variable $\mathtt{X}$.

$$((L_{month}\mathtt{DecreaseInOrders(X)} \vee L_{month}\mathtt{DirectorResigned(X)}) \\ \wedge L_{day}\mathtt{SuspensionOfShares(X)}) \rightarrow (\mathtt{Bankrupt(X)} \wedge \neg\mathtt{TakeoverBid(X)})$$

$$(L_{week}\mathtt{DecreaseInSharePrice(X)} \wedge L_{day}\mathtt{SuspensionOfShares(X)}) \\ \rightarrow (\neg\mathtt{Bankrupt(X)} \wedge \mathtt{TakeoverBid(X)})$$

and the propositional formulae in Φ,

$$L_{month}\mathtt{DecreaseInOrders(BloggsCo)}$$
$$L_{month}\mathtt{DirectorResigned(BloggsCo)})$$

together with the following information from a news report in Λ,

$$L_{day}\mathtt{SuspensionOfShares(BloggsCo)})$$
$$L_{week}\mathtt{DecreaseInSharePrice(BloggsCo)}$$

Definition 14. *Let* (Φ, Ψ, Λ) *be a ramification analysis database.* $\mathsf{Grounded}(\Phi, \Psi, \Lambda)$ *is a set of propositional formulae that contains* Φ *and* Λ *together with all the grounded formulae that can be obtained from the schema in* Ψ *using the constant symbols in* Λ *and* Φ*.*

Example 5. Continuing Example 4, $\mathsf{Grounded}(\Phi, \Psi, \Lambda) = \Phi \cup \Lambda \cup \Psi'$ where Ψ' is the set containing the following two formulae:

$$((L_{month}\mathtt{DecreaseInOrders(BloggsCo)} \vee L_{month}\mathtt{DirectorResigned(BloggsCo)}) \\ \wedge L_{day}\mathtt{SuspensionOfShares(BloggsCo)}) \\ \rightarrow (\mathtt{Bankrupt(BloggsCo)} \wedge \neg\mathtt{TakeoverBid(BloggsCo)})$$

$$(L_{week}\mathtt{DecreaseInSharePrice(BloggsCo)} \wedge L_{day}\mathtt{SuspensionOfShares(BloggsCo)}) \\ \rightarrow (\neg\mathtt{Bankrupt(BloggsCo)} \wedge \mathtt{TakeoverBid(BloggsCo)})$$

Definition 15. *A temporal argument from a ramification analysis database* $\Delta = \mathsf{Grounded}(\Phi, \Psi, \Lambda)$ *is a pair,* (Π, ϕ)*, such that* $\Pi \subseteq \Delta$ *and* $\Pi \vdash_T \phi$*.*

Example 6. Continuing Example 4, we get two arguments with inferences of particular interest.

$$(\Gamma_1, \mathtt{Bankrupt(BloggsCo)} \wedge \neg\mathtt{TakeoverBid(BloggsCo)})$$
$$(\Gamma_2, \neg\mathtt{Bankrupt(BloggsCo)} \wedge \mathtt{TakeoverBid(BloggsCo)})$$

where Γ_1 and Γ_2 are subsets of $\mathsf{Grounded}(\Phi, \Psi, \Lambda)$. Clearly, both arguments are existential temporal arguments but neither is a universal or free temporal argument.

3 Conclusions

In this paper, we have sketched how we can develop temporal argumentation by extending an existing proposal for argumentation with a temporal logic. We believe that such a development is useful in ramification analysis with structured news reports. Moreover, we believe that further forms of temporal argumentation can be developed by extending various proposals for argumentation with various proposals for argumentation.

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