On Extending RuleML for Modal Defeasible Logic

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\textit{NICTA}

\textit{University of Queensland}

Orlando, 31 October 2008
What is a rule?

A rule is a binary relationship between a set of 'expressions' and an 'expression'.

What's the strength of the relationship?

What's the type of the relationship?
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What’s the type of the relationship?
Guido gives a talk on Friday 31 October at 9:15am
BEL Guido gives a talk on Friday 31 October at 9:15am
INT Guido gives a talk on Friday 31 October at 9:15am
Modal Logic

OBL Guido gives a talk on Friday 31 October at 9:15am
Guido gives a talk on Friday 31 October at 9:15am

Normal Modal Logic

1. propositional logic

2. $\Box(A \rightarrow B) \rightarrow (\Box A \rightarrow \Box B)$

3. $\vdash A / \vdash \Box A$ or $A \vdash B / \Box A \vdash \Box B$

4. $\Box A \rightarrow A$ ($\Box A \vdash A$)

5. $\Box A \rightarrow \neg \neg \neg A$ ($\Box A \vdash \neg \neg \neg A$)

6. $\Box A \rightarrow \Box \Box A$ ($\Box A \vdash \Box \Box A$)

7. $\Box A \rightarrow \neg \neg \neg \neg A$ ($\Box A \vdash \neg \neg \neg \neg A$)
Modal Logic

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7. $\Box A \rightarrow \neg \Box \neg \Box A (\Box A \vdash \neg \Box \neg \Box A)$

- $1 + 2 + 3 = \text{Logical omniscience (and expected side-effects)}$
- $1 = \text{monotonic}$
Being Lazy

Factual omniscience and (non-)monotonic reasoning

PhD → Uni
Weekend → ¬ Uni
PublicHoliday → ¬ Uni
Sick → ¬ Uni
Weekend ∧ VICdeadline → Uni
VICdeadline ∧ PartnerBirthday → ¬ Uni
Phd ∧ (¬ Weekend ∨ (Weekend ∧ VICdeadline ∧ ¬ PartnerBirthday)) ∧ ¬ Sick → Uni

VIC = Very Important Conference
Factual omniscience and (non-)monotonic reasoning

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Factual omniscience and (non-)monotonic reasoning

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\[ \text{Weekend} \land \text{VICdeadline} \rightarrow \text{Uni} \]
\[ \text{VICdeadline} \land \text{PartnerBirthday} \rightarrow \neg \text{Uni} \]
Factual omniscience and (non-)monotonic reasoning

\[ PhD \rightarrow Uni \]
\[ Weekend \rightarrow \neg Uni \]
\[ PublicHoliday \rightarrow \neg Uni \]
\[ Sick \rightarrow \neg Uni \]
\[ Weekend \land VIC\text{deadline} \rightarrow Uni \]
\[ VIC\text{deadline} \land PartnerBirthday \rightarrow \neg Uni \]

\[ Phd \land (\neg Weekend \lor (Weekend \land VIC\text{deadline} \land \neg PartnerBirthday)) \land \neg Sick \ldots \rightarrow Uni \]
Why Defeasible Logic?

Rule-based non-monotonic formalism
- Flexible
- Efficient (linear complexity)
- Directly skeptic semantics
- Argumentation semantics
- Constrictive proof theory
- Optimised/efficient implementations (1000000 rules)
- Extensible

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Defeasible Logic: Strength of Conclusions

- Derive (plausible) conclusions with the minimum amount of information.
  - Definite conclusions
  - Defeasible conclusions

- Defeasible Theory
  - Facts
  - Strict rules ($A \rightarrow B$)
  - Defeasible rules ($A \Rightarrow B$)
  - Defeaters ($A \sim B$)
  - Superiority relation over rules
A proof is a finite sequence $P = (P(1), \ldots, P(n))$ of tagged literals satisfying four conditions.
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Give an argument for the conclusion you want to prove
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Proving Conclusions in Defeasible Logic

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   - Defeat the argument by a stronger one
   - Undercut the argument by showing that some of the premises do not hold
Example

Facts: $A_1, A_2, B_1, B_2$

Rules:  
$r_1: A_1 \Rightarrow C$
$r_2: A_2 \Rightarrow C$
$r_3: B_1 \Rightarrow \neg C$
$r_4: B_2 \Rightarrow \neg C$
$r_5: B_3 \Rightarrow \neg C$

Superiority relation:
$r_1 > r_3$
$r_2 > r_4$
$r_5 > r_1$
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Example

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Phase 2: Possible counterarguments

Phase 3: Rebut the counterarguments
$r_3$ weaker than $r_1$
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1. The strength describes how strong is the relationships between the antecedent and the consequent of a rule.

2. The mode qualifies the conclusion of a rule.
Modal Defeasible Logic: Mode and Strength

1. The strength describes how strong is the relationships between the antecedent and the consequent of a rule.
   - \( A_1, \ldots, A_n \rightarrow B \) (\( B \) is an indisputable consequence of \( A_1, \ldots, A_n \))
   - \( A_1, \ldots, A_n \Rightarrow B \) (normally \( B \) if \( A_1, \ldots, A_n \))

2. The mode qualifies the conclusion of a rule.
1. The strength describes how strong is the relationships between the antecedent and the consequent of a rule.
   - $A_1, \ldots, A_n \rightarrow B$ (B is an indisputable consequence of $A_1, \ldots, A_n$)
   - $A_1, \ldots, A_n \Rightarrow B$ (normally B if $A_1, \ldots, A_n$)

2. The mode qualifies the conclusion of a rule.
   - $A_1, \ldots, A_n \Rightarrow_{BEL} B$ (an agent forms the belief B when $A_1, \ldots, A_n$ are the case)
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1. \( A_1, \ldots, A_n \rightarrow B \) (\( B \) is an indisputable consequence of \( A_1, \ldots, A_n \))
2. \( A_1, \ldots, A_n \Rightarrow B \) (normally \( B \) if \( A_1, \ldots, A_n \))

The mode qualifies the conclusion of a rule.

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- \( A_1, \ldots, A_n \Rightarrow_{INT} B \) (an agent has the intention \( B \) when \( A_1, \ldots, A_n \) are the case)
- \( A_1, \ldots, A_n \Rightarrow_{OBL} B \) (an agent has the obligation \( B \) when \( A_1, \ldots, A_n \) are the case)
Conclusions in Basic Modal Defeasible Logic

- $\Delta^{\square_i} q$, which is intended to mean that $q$ is definitely provable (i.e., using only facts and strict rules of mode $\square_i$);
- $-\Delta^{\square_i} q$, which is intended to mean that we have proved that $q$ is not definitely provable in $D$;
- $\partial^{\square_i} q$, which is intended to mean that $q$ is defeasibly provable in $D$ using rules of mode $\square_i$;
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Conclusions in Basic Modal Defeasible Logic

- $+\Delta_{\square_i}q$, which is intended to mean that $q$ is definitely provable (i.e., using only facts and strict rules of mode $\square_i$);
- $-\Delta_{\square_i}q$, which is intended to mean that we have proved that $q$ is not definitely provable in $D$;
- $+\partial_{\square_i}q$, which is intended to mean that $q$ is defeasibly provable in $D$ using rules of mode $\square_i$;
- $-\partial_{\square_i}q$ which is intended to mean that we have proved that $q$ is not defeasibly provable in $D$ using rules of mode $\square_i$.

We obtain $\square_ip$ iff $+\partial_{\square_i}p$. 
Recipe for Modal Defeasible Logics

Choose the appropriate modalities

Create a defeasible consequence relation for each modality

Identify relationships between modalities:

- Inclusion: $\phi \rightarrow_2 \psi$
- Conflicts: $\phi_2 \rightarrow \neg \phi_2 \rightarrow \bot$
- Conversions from one modality to another modality:
  
  $A_1, \ldots, A_n \Rightarrow_2 \psi_1, \ldots, \psi_2 \psi_1, \ldots, \psi_n \vdash_2 \psi_2$
Recipe for Modal Defeasible Logics

- Choose the appropriate modalities

\[ \phi \rightarrow \neg \phi \Rightarrow \bot \]
Recipe for Modal Defeasible Logics

- Choose the appropriate modalities
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Put in a mixer and shake well!
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  - inclusion

\[ \square_1 \phi \rightarrow \square_2 \phi \]
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    \[ \Box_1 \phi \rightarrow \Box_2 \phi \]
  - conflicts
    \[ \Box_1 \phi , \Box_2 \neg \phi \rightarrow \bot \]
  - conversions from one modality to another modality
    \[
    \begin{align*}
    A_1, \ldots, A_n \Rightarrow & \Box_1 B \\
    \hline
    \Box_2 A_1, \ldots, \Box_2 A_n \vdash & \Box_2 B
    \end{align*}
    \]
Recipe for Modal Defeasible Logics

- Choose the appropriate modalities
- Create a defeasible consequence relation for each modality
- Identify relationships between modalities:
  - inclusion
    \[ \Box_1 \phi \to \Box_2 \phi \]
  - conflicts
    \[ \Box_1 \phi, \Box_2 \neg \phi \to \bot \]
  - conversions from one modality to another modality
    \[
    \frac{A_1, \ldots, A_n \Rightarrow \Box_1 B}{\Box_2 A_1, \ldots, \Box_2 A_n \vdash \Box_2 B}
    \]

- Put in a mixer and shake well!
Proofs for Modal Defeasible Logic

Inclusion $\Box_1 \rightarrow \Box_2$

1. Give an argument for the conclusion you want to prove using rules for either $\Box_1$ or $\Box_2$
2. Consider all possible counterarguments to it
3. Rebut all counterarguments
   - Defeat the argument by a stronger one (same as 1)
   - Undercut the argument by showing that some of the premises do not hold
Conflict $\square_1 \rightarrow \neg \square_2 \neg$

1. Give an argument for the conclusion you want to prove
2. Consider all possible counterarguments to it using rules for both $\square_1$ and $\square_2$
3. Rebut all counterarguments
   - Defeat the argument by a stronger one
   - Undercut the argument by showing that some of the premises do not hold
Conversion $\square_1$ to $\square_2$

1. Give an argument for the conclusion you want to prove using rules for either $\square_2$ or rules of mode $\square_1$ so that all premises are provable with mode $\square_2$.

2. Consider all possible counterarguments to it.

3. Rebut all counterarguments.
   - Defeat the argument by a stronger one (same as 1).
   - Undercut the argument by showing that some of the premises do not hold (for rules of mode $\square_1$ show that the premises are not provable with mode $\square_2$).
Social Agent

<?xml version="1.0" encoding="UTF-8"?>
<ModeSet xmlns="http://www.example.org/modeset-ns"
    xmlns:ruleml="http://www.ruleml.org/0.91/xsd"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.example.org/xsd/ruleset.xsd" >
  <Mode id="BEL1" href="http://www.example.org/mode/belief" >
    <ruleml:Ind>agent1</ruleml:Ind>
  </Mode>
  <Mode id="OBL" href="http://www.example.org/mode/obligation"/>
  <Mode id="INT1" href="http://www.example.org/mode/intention" >
    <ruleml:Ind>agent1</ruleml:Ind>
  </Mode>
  <Conflict between="OBL INT1"/>
  <Conversion from="BEL1" to="INT1"/>
  <Conversion from="BEL1" to="OBL"/>
</ModeSet>

Choose the appropriate modalities
Create a defeasible consequence relation for each modality
Identify relationships between modalities:
  - inclusion
  - conflicts
  - conversions from one modality to another modality
Put in a mixer and shake well!
Implementation

- Apply transformation to remove defeaters
- Apply transformation to remove superiority relation
- Scan the set of rules for rules with empty body
- Take the consequent of rules with empty body and check whether there are no rules for its opposite. If so the consequent is provable
  - remove provable consequents from the body of rules
  - remove rules where the negation of provable consequents are in the body
- Scan the list of literals for literal not appearing as consequent of rules. The literal is non provable
- remove rules with non provable literals
- repeat
Why Modal Defeasible Logic

- Modelling and monitoring contracts (and norms)
- Modelling BIOlogical agents
- Compliance of business processes
- Modelling workflows
- Extended with time (instant, intervals, duration and periodicity)
- Modelling norm dynamics
Why Modal Defeasible Logic

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- Modelling BIO logical agents (BDI − D + O)
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</talk>