A Modal Logic for Abstract Delta Modeling

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FMSPLE, 02-09-2012

Three Delta Modeling Presentations

FMSPLE 2012 — today, 15:00–15:30

A Modal Logic for Abstract Delta Modeling

DSPL 2012 — tomorrow, 11:00–11:40

Dynamic Delta Modeling

SPLC Doctoral Symposium 2012 — tomorrow, 14:00-15:00

Abstract Delta Modeling: My Research Plan

`http://www.mhelvens.net/professional/talks`

Preliminaries

Basic Concepts

Basic Terms

- Software Product
- Feature
- Feature Configuration
- Software Product Line
- (Software) Delta

Abstract Delta Modeling (ADM)

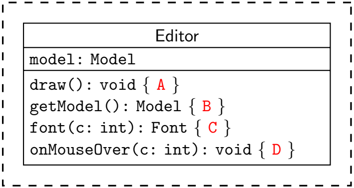
- Product
- Product Line
- Delta

Preliminaries
Abstract Delta Modeling

Editor
model: Model
draw(): void { A } getModel(): Model { B } font(c: int): Font { C } onMouseOver(c: int): void { D }

Preliminaries

Abstract Delta Modeling



Preliminaries
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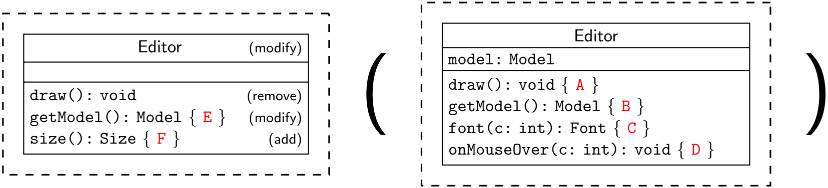

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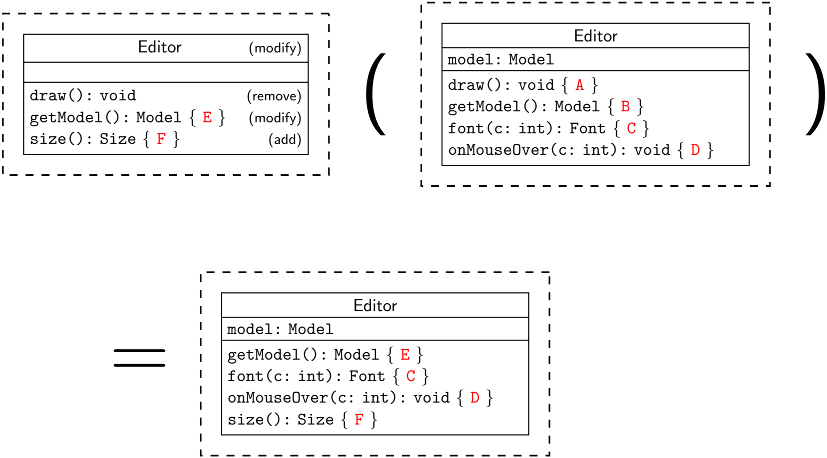

Preliminaries

Abstract Delta Modeling

$$\boxed{d}\left(\boxed{p}\right) = \boxed{p'}$$

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$$\boxed{y} \cdot \boxed{x} = \boxed{z}$$

Preliminaries

Abstract Delta Modeling

$$d\,(\,p\,) = p'$$

$$y \cdot x = z$$

$$(\,d_2 \cdot d_1\,)\,(\,p\,) = d_2\,(\,d_1\,(\,p\,)\,)$$

Preliminaries

Abstract Delta Modeling

$$\boxed{d}\,(\boxed{p}) = \boxed{p'}$$

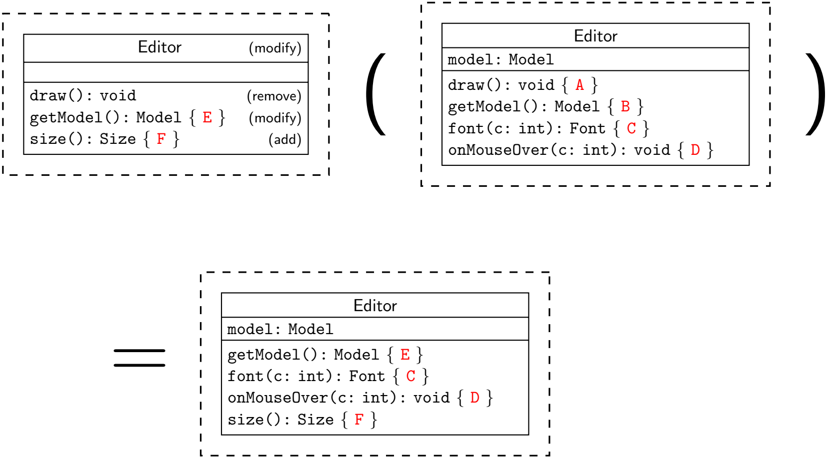
$$\boxed{y} \cdot \boxed{x} = \boxed{z}$$

$$(\boxed{d_2} \cdot \boxed{d_1})\,(\boxed{p}) = \boxed{d_2}\,(\boxed{d_1}\,(\boxed{p}))$$

$$\boxed{\epsilon}\,(\boxed{p}) = \boxed{p}$$

Preliminaries

Abstract Delta Modeling



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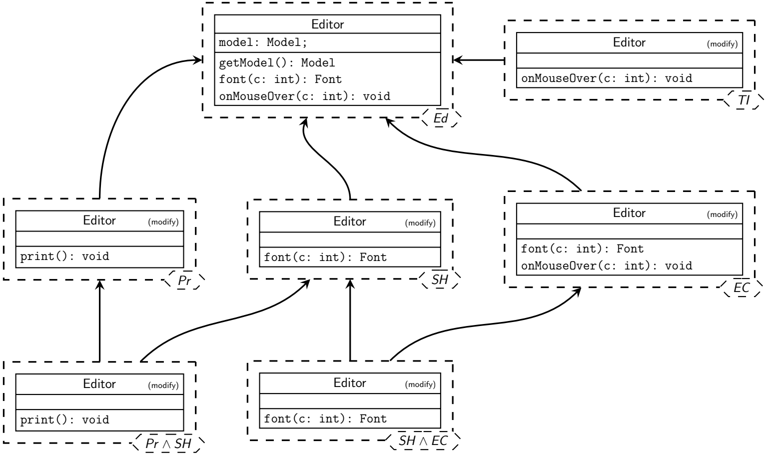

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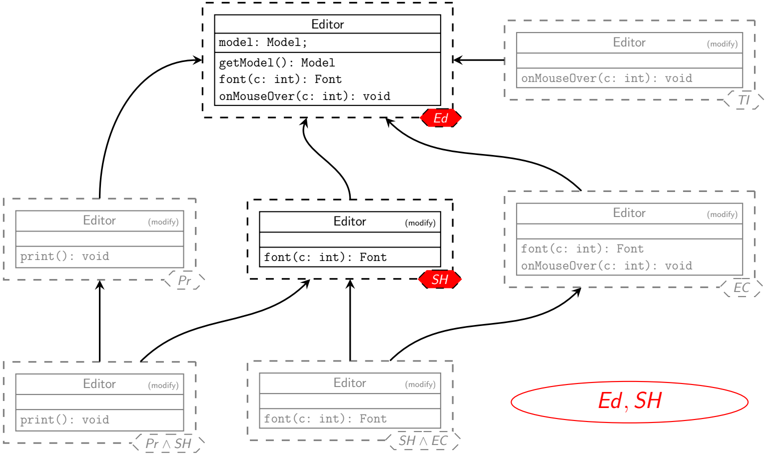

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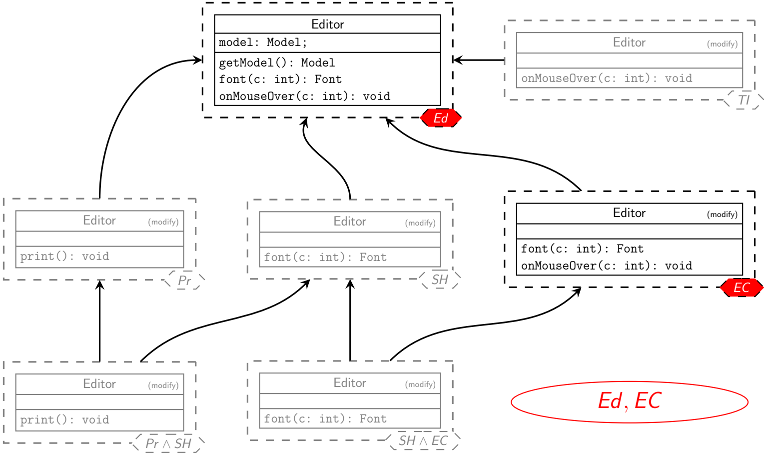

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Preliminaries

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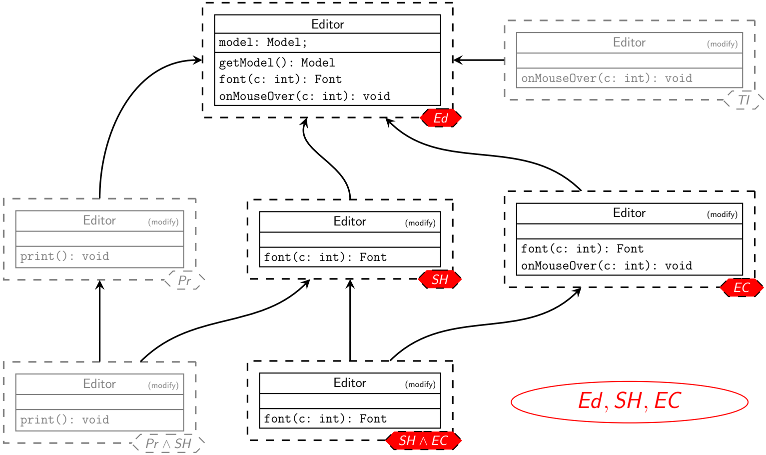

Preliminaries
Normal Modal Logic

Syntax

$$\phi \quad ::= \quad \bot \mid p \mid \phi \vee \phi \mid \neg\phi \mid \langle d \rangle\, \phi$$

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Preliminaries

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$$\mid \top \mid \phi \wedge \phi \mid \phi \to \psi \mid [d]\, \phi$$

Axioms of the logic **K**

- all propositional tautologies
- $[d]\,(p \to q) \to ([d]\, p \to [d]\, q)$ **(K)**
- $\langle d \rangle\, p \to \neg\, [d]\, \neg p$ **(Dual)**

Preliminaries
Normal Modal Logic

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$$\phi \ ::= \ \bot \ | \ p \ | \ \phi \vee \phi \ | \ \neg\phi \ | \ \langle d \rangle\, \phi$$
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Proof Rules

- if $\phi \in \Lambda$ and $\phi \to \psi \in \Lambda$, then $\psi \in \Lambda$ (Modus Ponens)
- if $\phi \in \Lambda$, then $\phi[\psi/p] \in \Lambda$ for all p and ϕ, ψ (Unif. Subst.)
- if $\phi \in \Lambda$, then $[d]\,\phi \in \Lambda$ for all $[d]$ (Generalization)

Preliminaries

Normal Modal Logic

Kripke Frame Semantics

- $\mathfrak{F} = (W, R_1, \ldots)$ (Frames)
- $\mathfrak{M} = (\mathfrak{F}, V)$ (Models)

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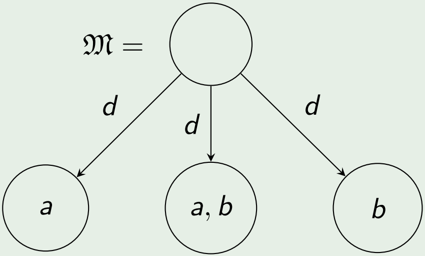

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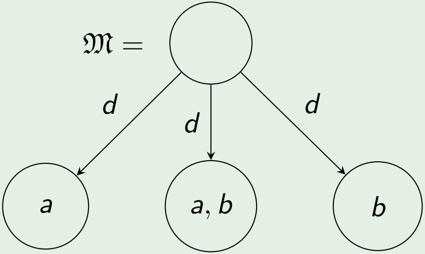
Example

$\mathfrak{M} =$



For the top world w:

$$\mathfrak{M}, w \models \langle d \rangle\, a$$
$$\mathfrak{M}, w \not\models [d]\, a$$
$$\mathfrak{M}, w \models [d]\, (a \vee b)$$

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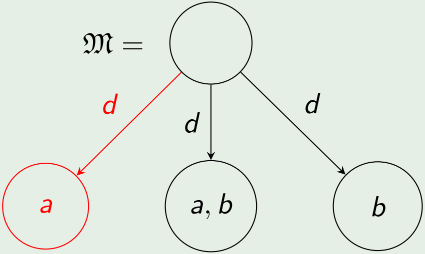

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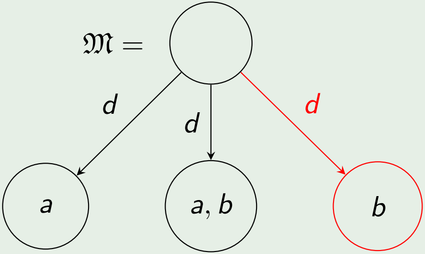

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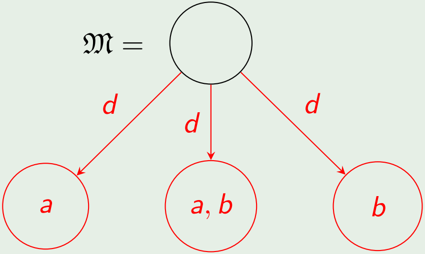

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Frame Level

Delta Terms

Delta Terms (Modalities)

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Examples

- $\models \langle d \rangle \phi \to [d] \phi$ (d is deterministic)
- $\models [d] \phi \to \langle d \rangle \phi$ (d terminates) ($\models \langle d \rangle \top$)
- $\models [DM] (f \wedge g \wedge h)$ (DM implements f, g, h)

Frame Level
Delta Terms

The Modal Logic **KΔ**: The **Δ** Axioms

- $\langle y \cdot x \rangle \phi \leftrightarrow \langle x \rangle \langle y \rangle \phi$
- $\langle x \cup y \rangle \phi \leftrightarrow (\langle x \rangle \phi \vee \langle y \rangle \phi)$
- $\langle (D, \prec) \rangle \phi \leftrightarrow \bigvee_{d \text{ min. in } \prec} \langle d \rangle \langle (D, \prec) \setminus \{d\} \rangle \phi \quad (D \text{ nonempty})$
- $\langle (\varnothing, \varnothing) \rangle \phi \leftrightarrow \phi$

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The Modal Logic KΔ: The Δ Axioms

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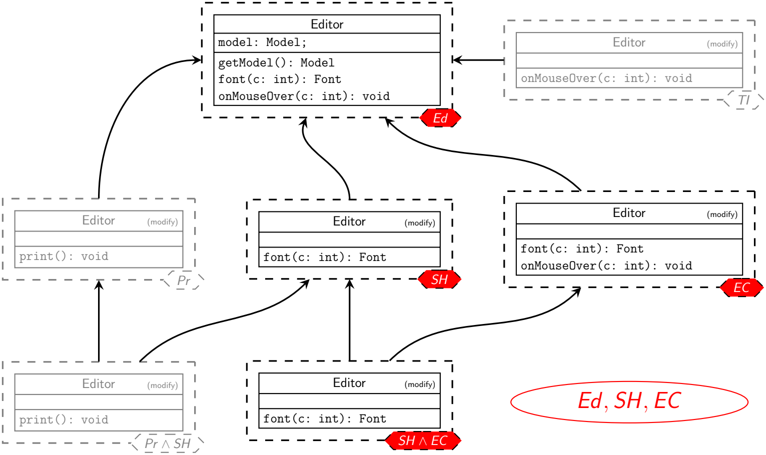
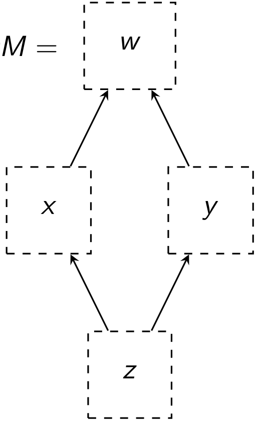
The proof rules remain the same as in **K**.

Frame Level
Delta Terms



Frame Level
Delta Frames

$DM =$



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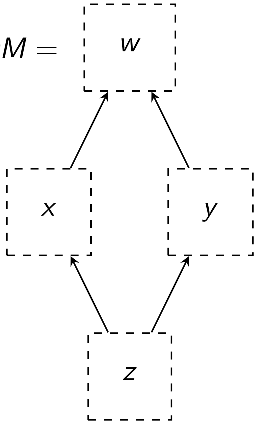

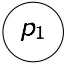

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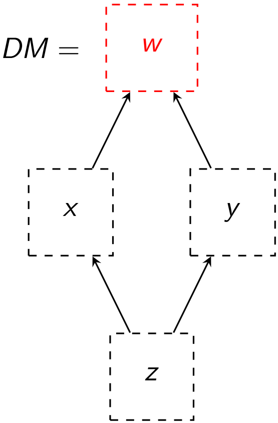

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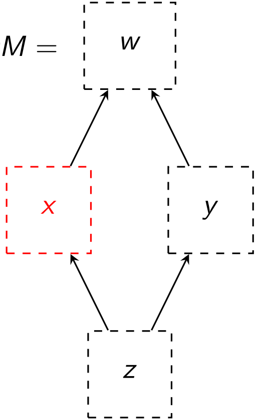

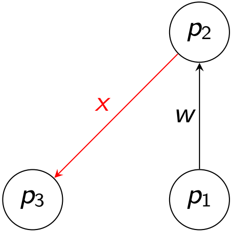

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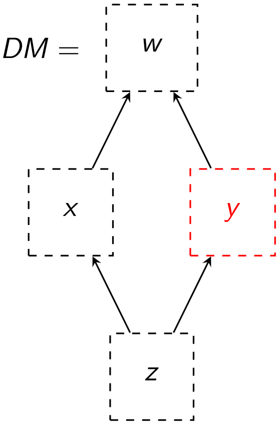

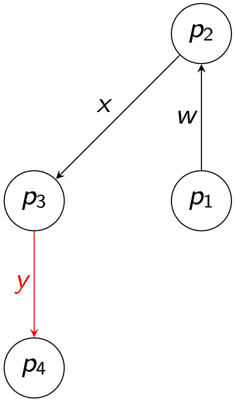

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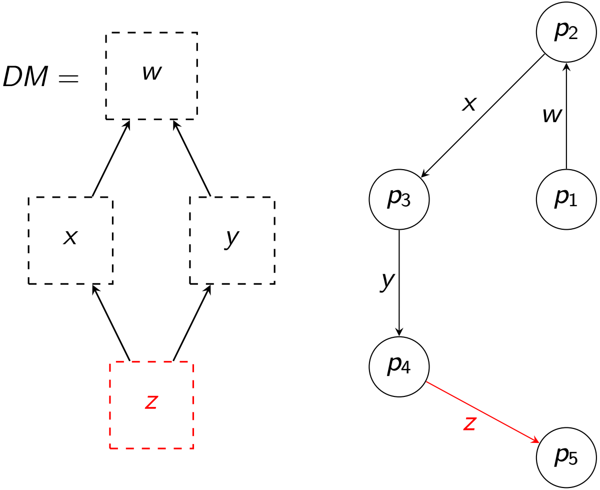

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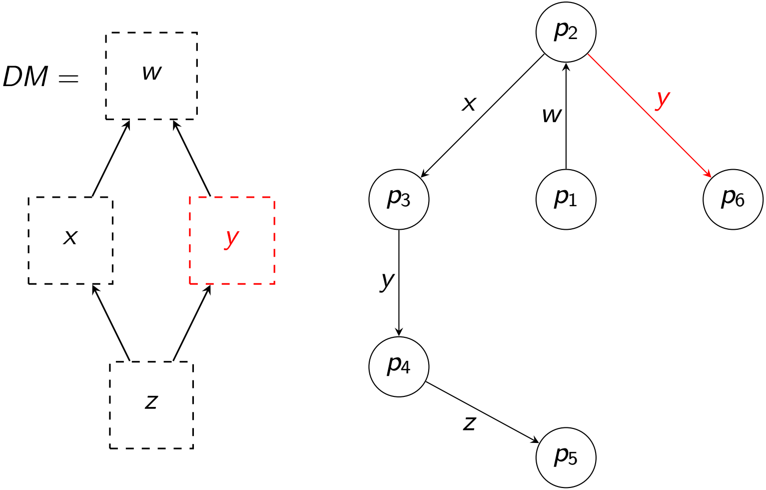

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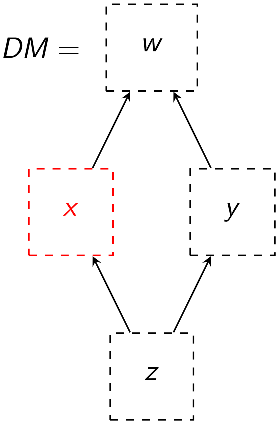

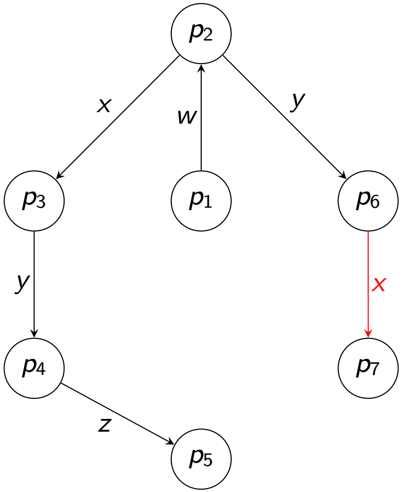

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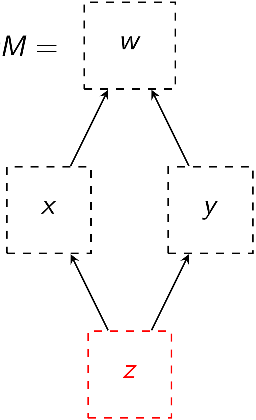

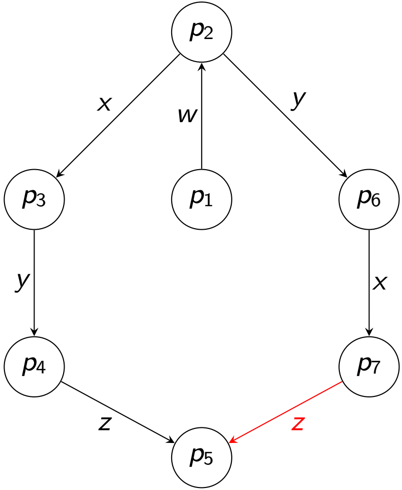

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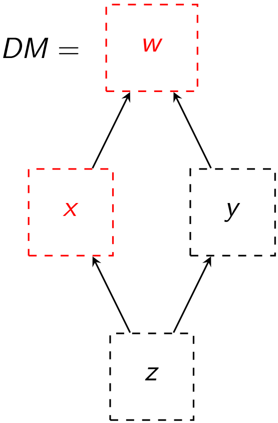

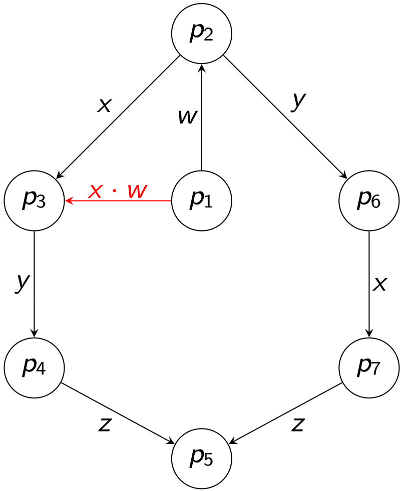

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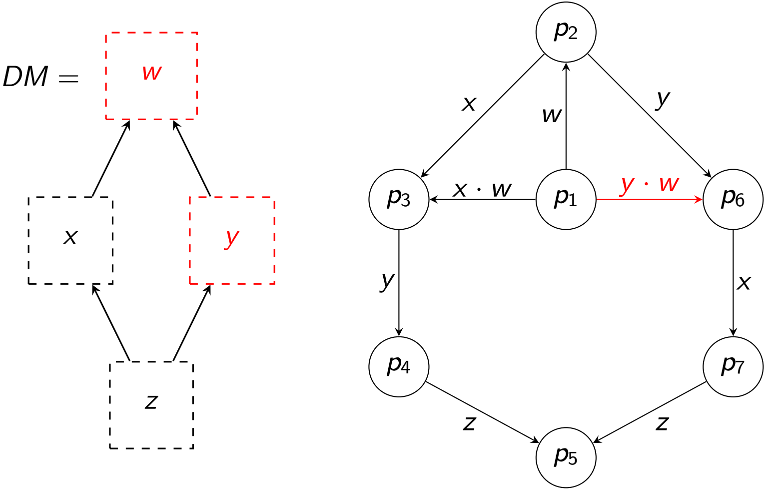

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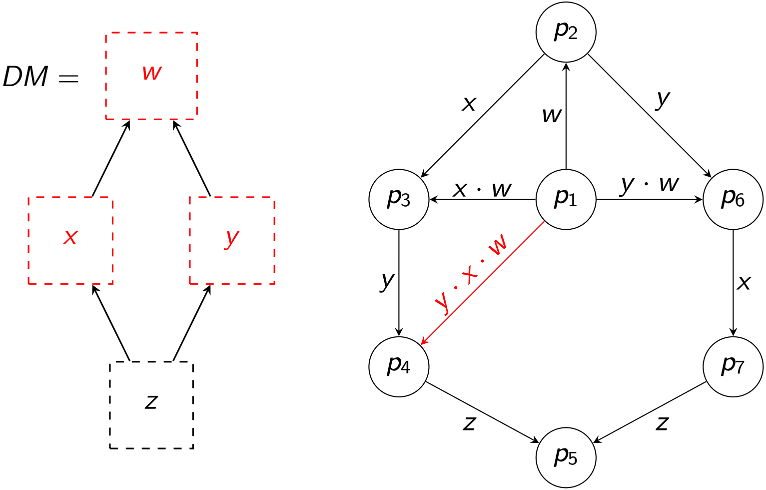

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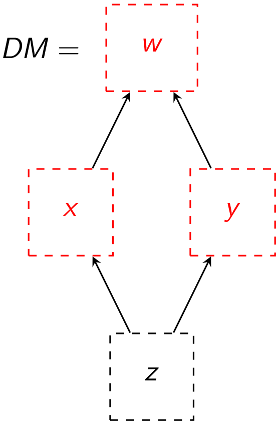

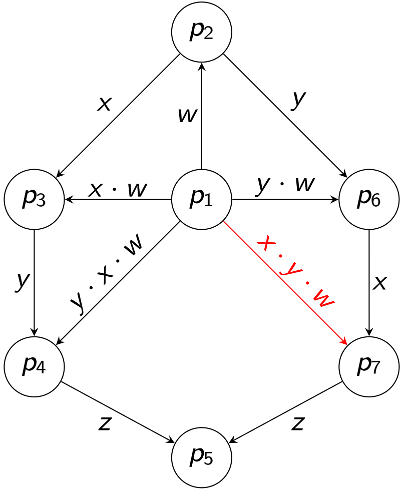

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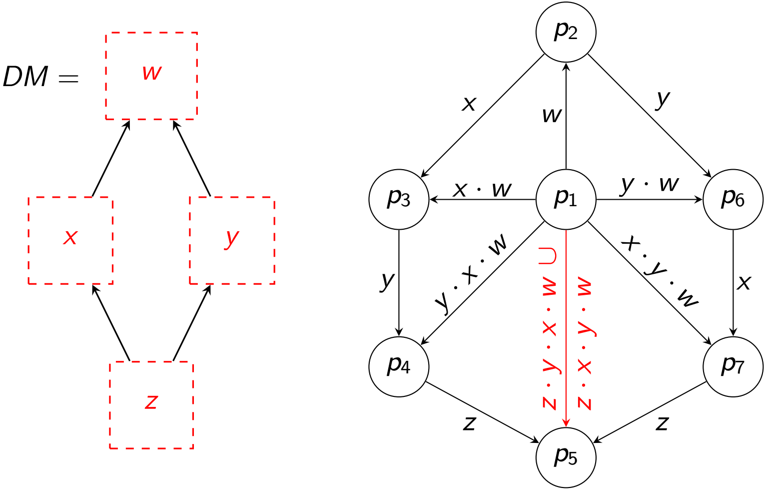

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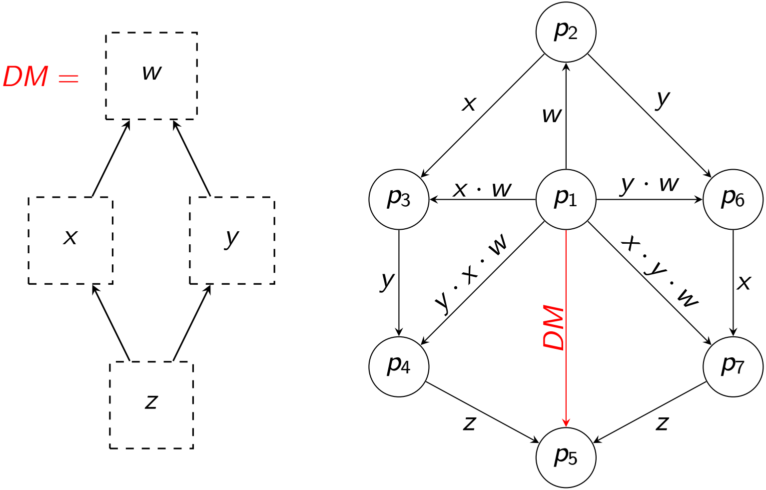

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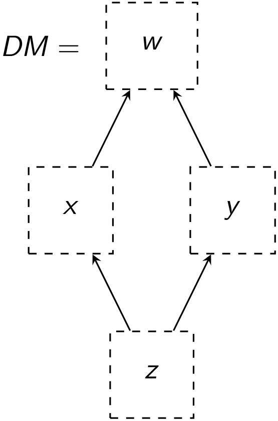

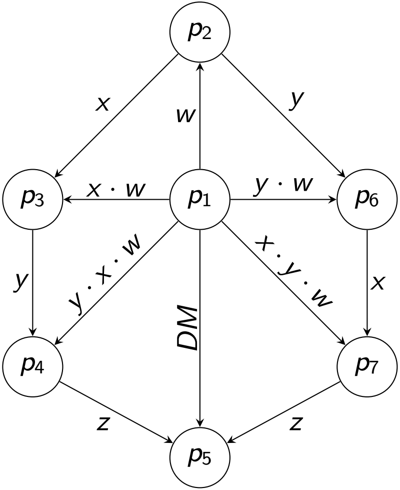

$$\mathfrak{F}, p_5 \vDash \phi \quad \Rightarrow \quad \mathfrak{F}, p_1 \vDash [DM]\,\phi$$

Frame Level
Strong Completeness

The modal logic $\mathbf{K\Delta}$ is strongly complete with regard to the class of delta frames.

Frame Level
Strong Completeness

The modal logic **KΔ** is strongly complete with regard to the class of delta frames.

How so?

We can decompose all modalities to basic delta terms:

$$
\begin{array}{lcl}
t(f) & \stackrel{\text{def}}{=} & f \quad \text{for proposition letters } f \\
t(\neg\phi) & \stackrel{\text{def}}{=} & \neg t(\phi) \\
t(\phi \vee \psi) & \stackrel{\text{def}}{=} & t(\phi) \vee t(\psi) \\
t(\langle d \rangle\, \phi) & \stackrel{\text{def}}{=} & \langle d \rangle\, t(\phi) \quad \text{for basic delta terms } d \\
t(\langle d_2 \cdot d_1 \rangle\, \phi) & \stackrel{\text{def}}{=} & t(\langle d_1 \rangle\, \langle d_2 \rangle\, \phi) \\
t(\langle d_1 \cup d_2 \rangle\, \phi) & \stackrel{\text{def}}{=} & t(\langle d_1 \rangle\, \phi \vee \langle d_2 \rangle\, \phi) \\
t(\langle DM \rangle\, \phi) & \stackrel{\text{def}}{=} & \bigvee_{d \in derv(DM)} t(\langle d \rangle\, \phi)
\end{array}
$$

Frame Level

Strong Completeness

Interesting Additional Logics / Frames

- $\langle d\rangle\,\phi \rightarrow [d]\,\phi$ **(KΔd)**
- $\langle d\rangle\,\top$ **(KΔt)**

Model Level

Proposition Letters

Kripke Frame Semantics (reminder)

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- $V : \Xi \to \mathscr{P}(W)$ (Proposition Letters)

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Possible Proposition Letter Meanings

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Possible Proposition Letter Meanings

- $\mathcal{F} \subset \Xi$ (features)

Model Level

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- $V : \Xi \to \mathscr{P}(W)$ (Proposition Letters)

Possible Proposition Letter Meanings

- $\mathcal{F} \subset \Xi$ (features)
- $\mathscr{P}(\mathcal{F}) \subset \Xi$ (feature combinations)

Model Level
Proposition Letters

Kripke Frame Semantics (reminder)

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$\vdots$

- (the presence of methods or fields in OOP?)

Model Level

Proof System

Model Level 'Proof'

(1)	$f \rightarrow [d]\, g$	axiom
(2)	$f \rightarrow [d]\, \neg g$	uniform substitution on g

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Unsound!

Uniform substitution on 'feature proposition'!

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Unsound!

Uniform substitution on ‘feature proposition’!

Nullary Modalities

Translation ‘u’ replaces proposition letters with nullary modalities:

(1)	$\textcircled{f} \rightarrow [d]\, \textcircled{g}$	axiom
(2)	$\ldots$	

Model Level
Proof System

Example Proof (straight from the paper and out of context, don't try to follow it)

(11)	$\textcircled{t} \rightarrow [w]\,[x]\,\textcircled{g}$	l4 : 6, 7
(12)	$\textcircled{t} \rightarrow [w]\,[x]\,(\textcircled{f} \wedge \textcircled{g})$	l4 : 11, 2
(13)	$\textcircled{t} \rightarrow [w]\,[x]\,(\textcircled{f} \wedge \textcircled{g} \wedge [y]\,\textcircled{h})$	l4 : 12, 8
(14)	$\textcircled{t} \rightarrow [w]\,[x]\,(\textcircled{g} \wedge [y]\,\textcircled{h})$	l4 : 13, 2
(15)	$\textcircled{t} \rightarrow [w]\,[x]\,([y]\,\textcircled{g} \wedge [y]\,\textcircled{h})$	l4 : 14, 4
(16)	$\textcircled{t} \rightarrow [w]\,[x]\,[y]\,(\textcircled{g} \wedge \textcircled{h})$	l5 : 15
(17)	$\textcircled{t} \rightarrow [w]\,[x]\,[y]\,([z]\,\textcircled{g} \wedge \textcircled{h})$	l4 : 16, 9
(18)	$\textcircled{t} \rightarrow [w]\,[x]\,[y]\,([z]\,\textcircled{g} \wedge [z]\,\textcircled{h})$	l4 : 17, 10
(19)	$\textcircled{t} \rightarrow [w]\,[x]\,[y]\,[z]\,(\textcircled{g} \wedge \textcircled{h})$	l5 : 18
(20)	$\textcircled{t} \rightarrow [w]\,[x]\,[y]\,[z]\,(\textcircled{f} \wedge \textcircled{g} \wedge \textcircled{h})$	l4 : 19, 2
(21)	$\textcircled{t} \rightarrow [w]\,[x]\,[y]\,[z]\,(\textcircled{t} \wedge \textcircled{f} \wedge \textcircled{g} \wedge \textcircled{h})$	l4 : 20, 1
(22)	$\textcircled{t} \rightarrow [w]\,[x]\,[y]\,[DM_1]\,(\textcircled{t} \wedge \textcircled{f} \wedge \textcircled{g} \wedge \textcircled{h})$	l4 : 21, $\boldsymbol{\Delta}$
(23)	$\textcircled{t} \rightarrow [w]\,[x]\,[DM_2]\,(\textcircled{t} \wedge \textcircled{f} \wedge \textcircled{g} \wedge \textcircled{h})$	l4 : 22, $\boldsymbol{\Delta}$

Formula (24) is derived in a symmetric manner to (23).

(24)	$\textcircled{t} \rightarrow [w]\,[y]\,[DM_3]\,(\textcircled{t} \wedge \textcircled{f} \wedge \textcircled{g} \wedge \textcircled{h})$	symmetric
(25)	$\textcircled{t} \rightarrow [w]\,[x]\,[DM_2]\,(\textcircled{t} \wedge \textcircled{f} \wedge \textcircled{g} \wedge \textcircled{h})$ $\wedge\, [w]\,[y]\,[DM_3]\,(\textcircled{t} \wedge \textcircled{f} \wedge \textcircled{g} \wedge \textcircled{h})$	$\mathrm{I}_\wedge$: 23, 24
(26)	$\textcircled{t} \rightarrow [w]\,([x]\,[DM_2]\,(\textcircled{t} \wedge \textcircled{f} \wedge \textcircled{g} \wedge \textcircled{h})$ $\wedge\, [y]\,[DM_3]\,(\textcircled{t} \wedge \textcircled{f} \wedge \textcircled{g} \wedge \textcircled{h}))$	l5 : 25
(27)	$\textcircled{t} \rightarrow [w]\,[DM_4]\,(\textcircled{t} \wedge \textcircled{f} \wedge \textcircled{g} \wedge \textcircled{h})$	l4 : 26, $\boldsymbol{\Delta}$
(28)	$\textcircled{t} \rightarrow [DM]\,(\textcircled{t} \wedge \textcircled{f} \wedge \textcircled{g} \wedge \textcircled{h})$	l4 : 27, $\boldsymbol{\Delta}$

Model Level
Results

Soundness

For all sets of formulas Γ and all formulas ϕ:

$$\text{if} \quad u(\Gamma) \vdash_{\mathbf{K\Delta}} u(\phi) \quad \text{then} \quad \Gamma \models^{g}_{\Delta\mathsf{F}} \phi$$

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Relative Completeness

If $\mathfrak{M}$ allows expression of weakest preconditions, then for all ϕ:

$$\text{if} \quad \mathfrak{M} \vDash \phi \quad \text{then} \quad u(\Gamma_{\mathfrak{M}}) \vdash_{\mathbf{K\Delta}} u(\phi).$$

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For all sets of formulas Γ and all formulas ϕ:

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Weakest Precondition Expressability

$\mathfrak{M}$ allows expression of weakest preconditions iff for all w, d, ϕ:

$$\mathfrak{M}, w \vDash [d]\,\phi \quad \text{iff} \quad \mathfrak{M}, w \vDash \phi' \qquad \text{(for propositional } \phi'\text{)}$$

Relative Completeness

If $\mathfrak{M}$ allows expression of weakest preconditions, then for all ϕ:

$$\text{if} \quad \mathfrak{M} \vDash \phi \quad \text{then} \quad u(\Gamma_{\mathfrak{M}}) \vdash_{\mathbf{K\Delta}} u(\phi).$$

Conclusion

Related Work

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- more interesting completeness results on model level

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Future Work

- more interesting completeness results on model level
- formal analysis of DMW using $\mathbf{K\Delta}$

Conclusion

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