Optimal Reflection of Bidirectional View Updates using Information-Based Distance Measures

Stephen J. Hegner
Umeå University
Department of Computing Science
Sweden

The Update Problem for Database Views

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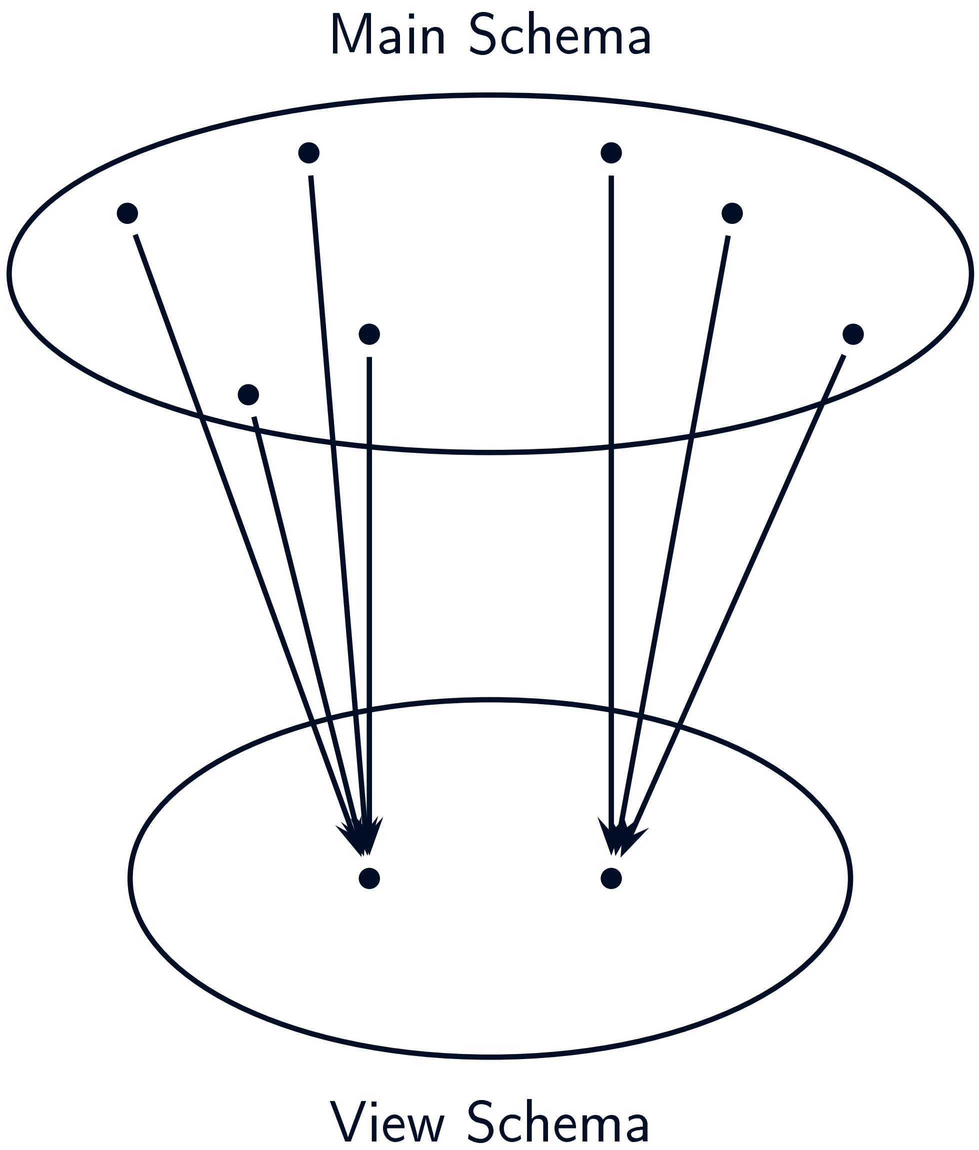

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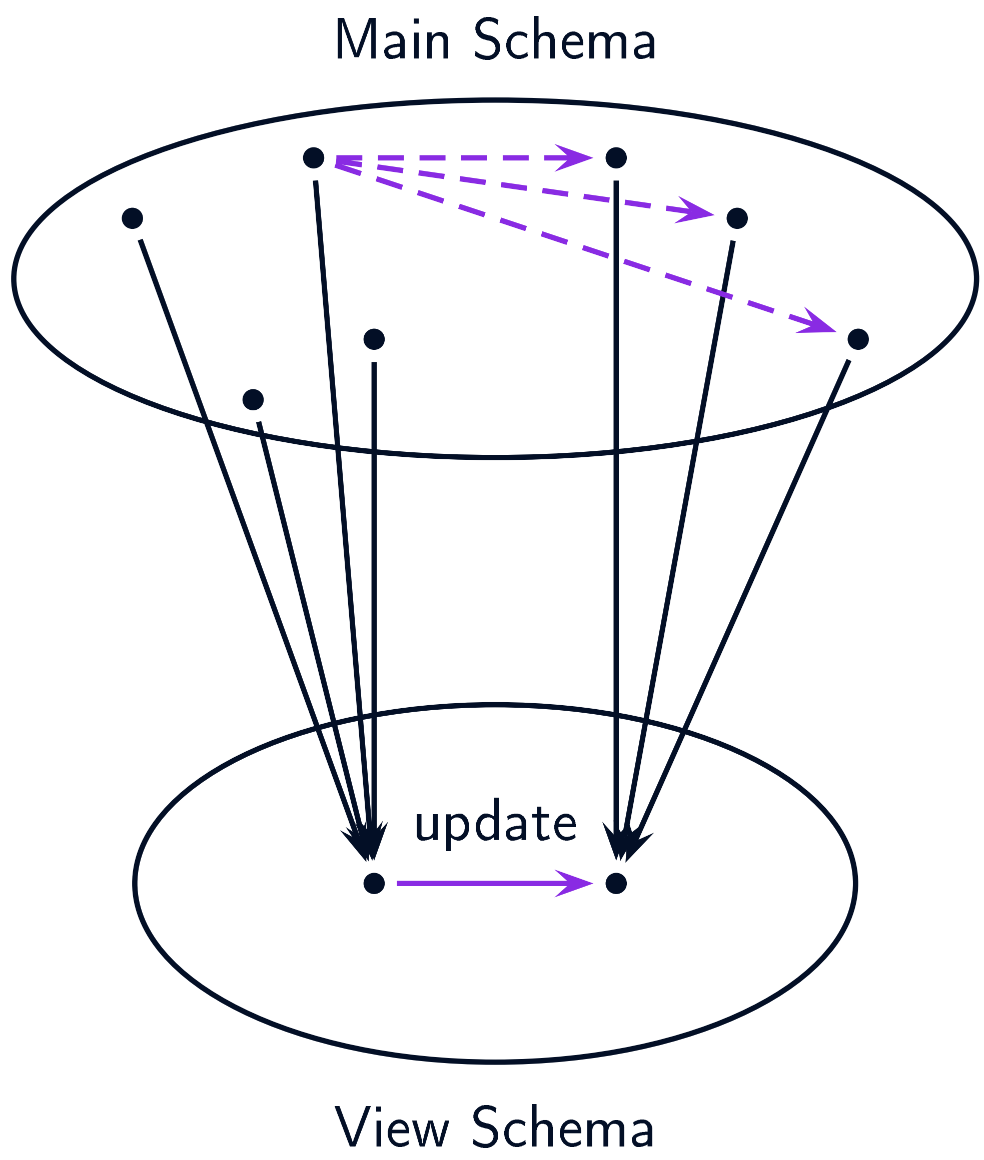

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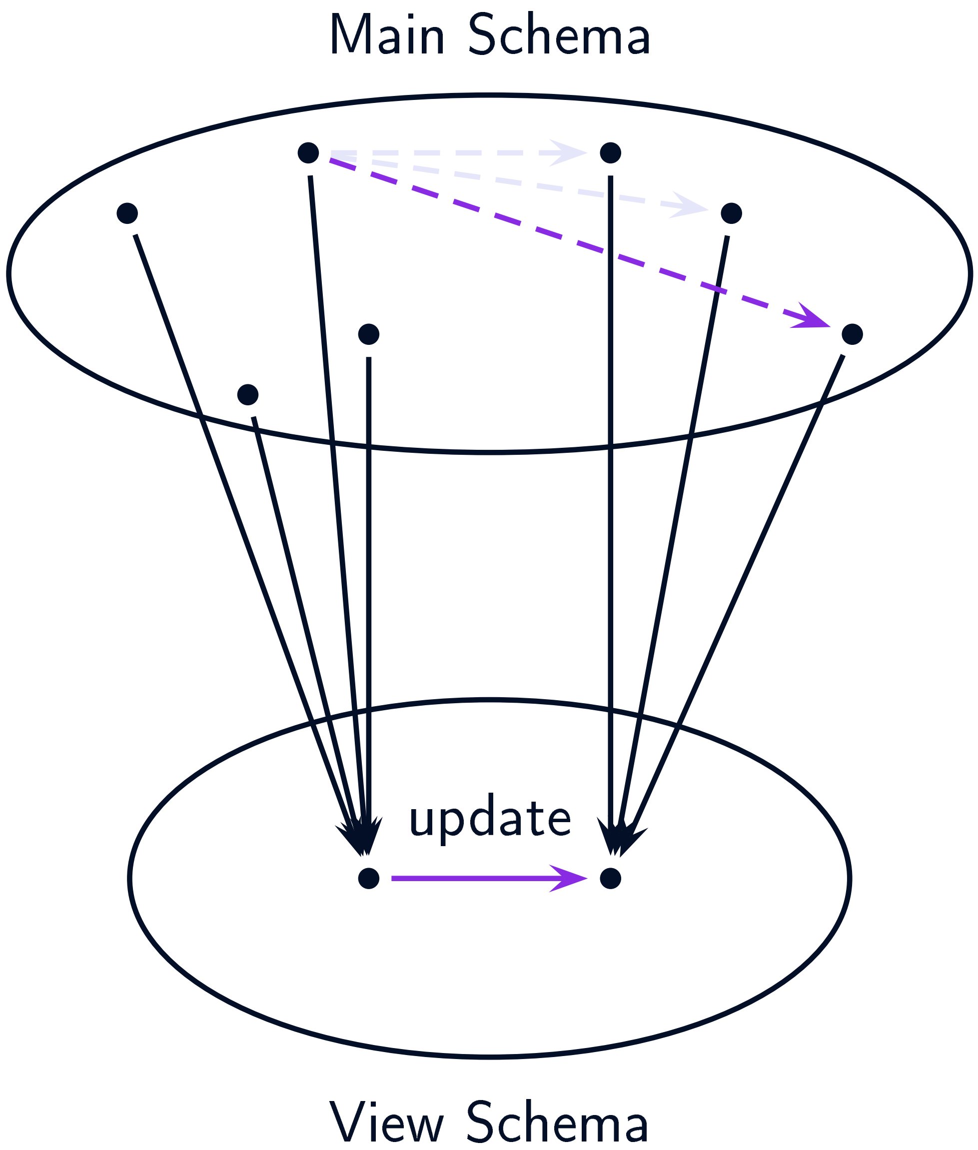

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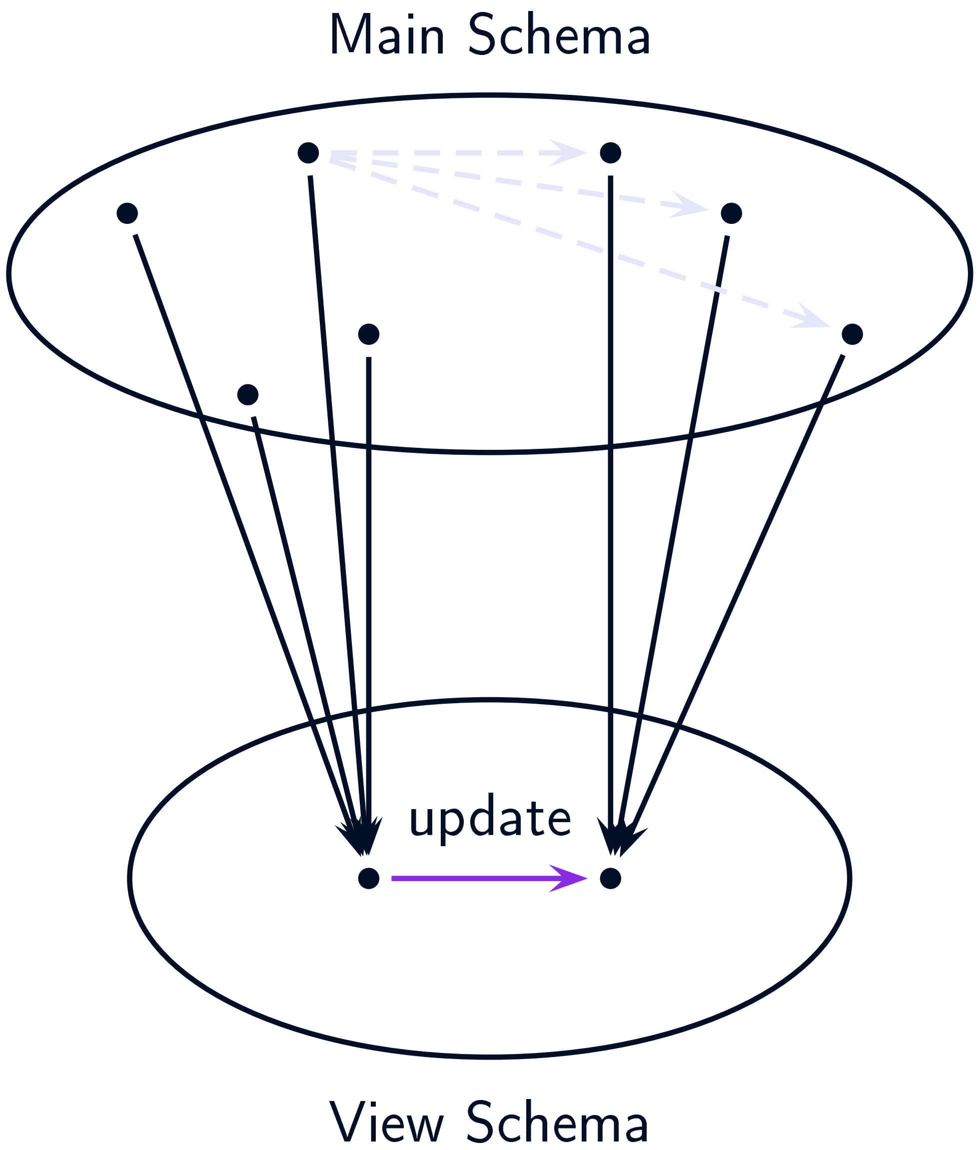
- With a reasonable definition of suitability, it may not be the case that every view update has a suitable translation.



Three Main Approaches to the View Update Problem

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  - Focus of this talk.

Typical Characterization of Distance

- Given is the two-relation main schema $\mathbf{E}_0$.

Main Schema $\mathbf{E}_0$

$R : B \to C \qquad R[C] \subseteq S[C]$

$R[ABC] \qquad S[CD]$

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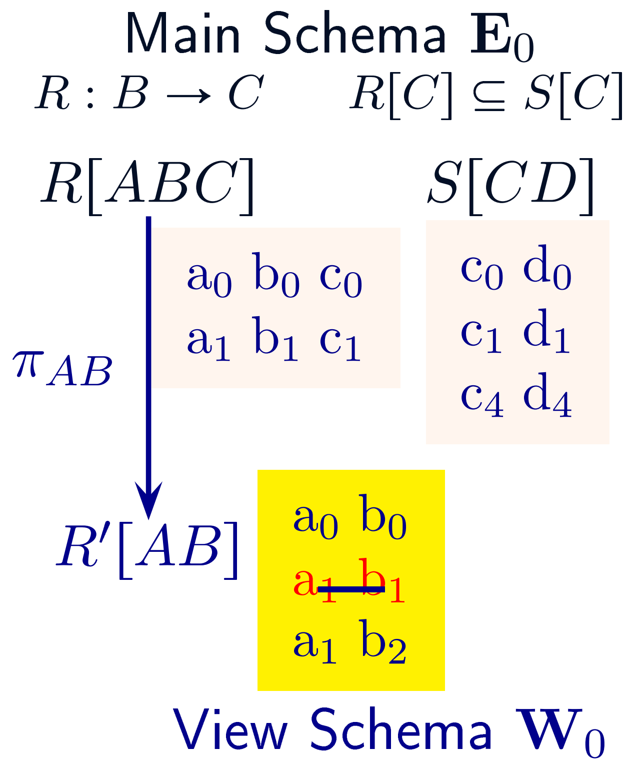

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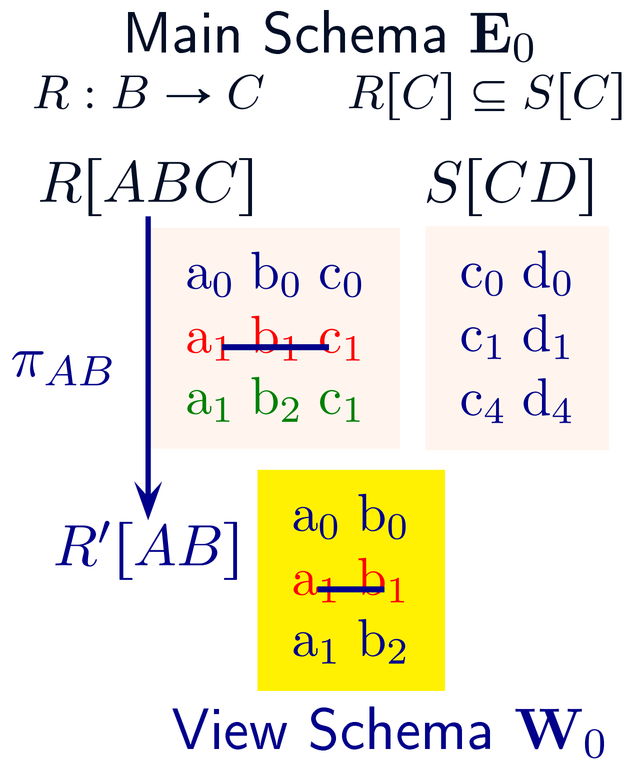

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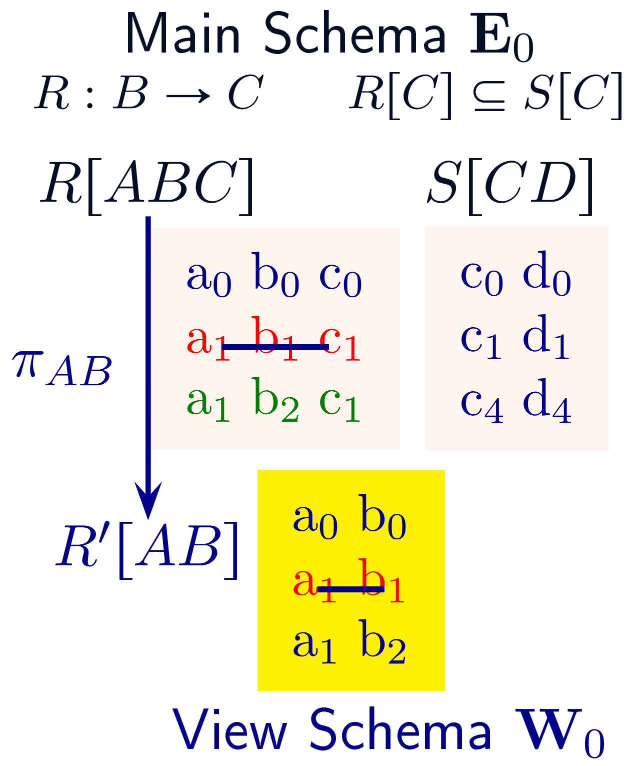

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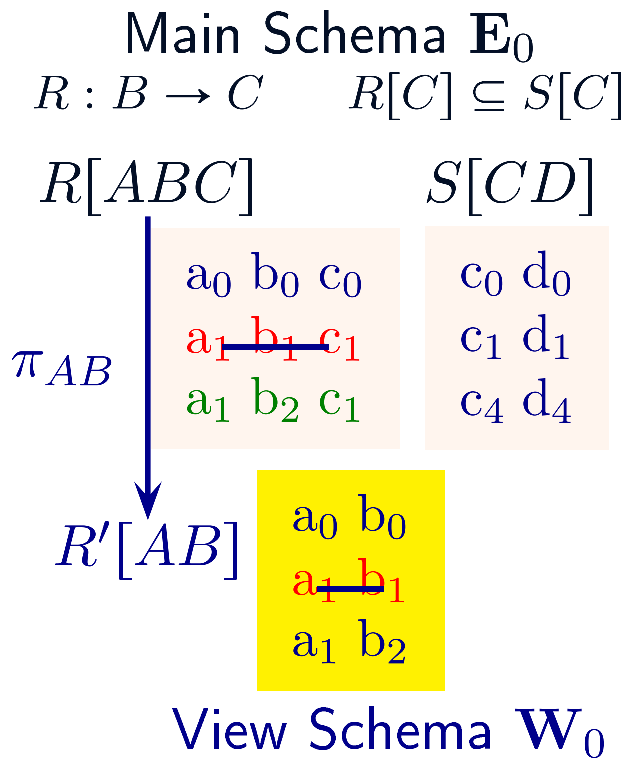

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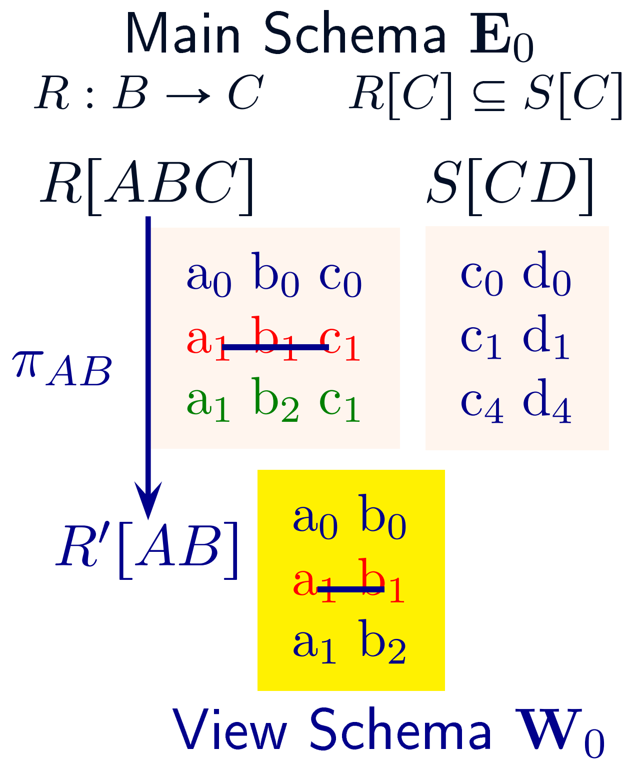

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- These may in turn be used in formulas to compute a numerical distance between sets of tuples (Eiter-Mannila 1997]).
- *Question:* Are such *syntactic* notions of distance always the best choice?

Information Content

Idea: Exploit the first-order properties of the model, rather than just counting and summing syntactic differences.

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- $\mathrm{WFS}(\mathbf{D}, \exists\wedge+)$ denotes the set of all *Boolean conjunctive queries* on the database schema $\mathbf{D}$: $\exists$ $\wedge$ $\cancel{\forall}$ $\cancel{\vee}$ $\cancel{\neg}$

  Examples: $R(\mathrm{a}_0, \mathrm{b}_0, \mathrm{c}_0)$, $(\exists y)(\exists z)(R(\mathrm{a}_0, y, z) \wedge S(y, \mathrm{d}_0))$

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Example:

$$M = \{R(\mathrm{a}_0, \mathrm{b}_0, \mathrm{c}_0), R(\mathrm{a}_1, \mathrm{b}_2, \mathrm{c}_2), S(\mathrm{c}_0, \mathrm{d}_0), S(\mathrm{c}_1, \mathrm{d}_1), S(\mathrm{c}_4, \mathrm{d}_4), S(\mathrm{c}_2, \mathrm{d}_2)\}$$

$$K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4\}$$

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Distance Measure Based upon Information Content

- The *update difference* for an update (M_1, M_2) on the main schema relative to K:

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\Delta^{+}\langle (M_1, M_2), \Upsilon_K^{\mathbf{D}} \rangle &= \mathsf{Info}\langle M_2, \Upsilon_K^{\mathbf{D}} \rangle \backslash \mathsf{Info}\langle M_1, \Upsilon_K^{\mathbf{D}} \rangle \\
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- The distance is thus not a number but rather the set of Boolean conjunctive queries whose values have changed as a result of the update.

- K consists of all constant symbols which occur in:

M_1 = Old state of the main schema

N_1 = Old state of the view schema $\quad$ N_2 = New state of the view schema

γ = View-definition formula $\quad$ $\mathsf{Constr}(\mathbf{D})$ = Constraints on the main schema

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- *Admissible/optimal reflection* of a view update: a reflection to the main schema for which the update difference is minimal/least and which is tuple minimal.

Examples of Information-Based Reflection of View Update

Example:

Main Schema $\mathbf{E}_0$

$R : B \to C \qquad R[C] \subseteq S[C]$

$R[ABC]$

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Example: The insertion of $R'(\mathrm{a}_1, \mathrm{b}_2)$ into the view.

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- Changing constant names $\rightsquigarrow$ another optimal solution.

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a_1	b_2

View Schema $\mathbf{W}_0$

Examples of Information-Based Reflection of View Update

Example: The insertion of $R'(\mathrm{a}_1, \mathrm{b}_2)$ into the view.

- Optimal for insertions to the main schema.
- $K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4, \cancel{\bar{\mathrm{c}}_2}, \cancel{\bar{\mathrm{d}}_2}\}$.
- $\Delta\langle (M_1, M_2), \Upsilon_K^{\mathbf{D}}\rangle = \Delta^+\langle (M_1, M_2), \Upsilon_K^{\mathbf{D}}\rangle =$
  $(M_1 \cup \{(\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w))\})^+$.
- Changing constant names $\rightsquigarrow$ another optimal solution.

Example:

Main Schema $\mathbf{E}_0$

$R : B \to C \qquad R[C] \subseteq S[C]$

$R[ABC]$

a_0	b_0	c_0
a_1	b_1	c_1

$S[CD]$

c_0	d_0
c_1	d_1
c_4	d_4

$R[ABC] \xrightarrow{\pi_{AB}} R'[AB]$

$R'[AB]$

a_0	b_0
a_1	b_1

View Schema $\mathbf{W}_0$

Example: The insertion of $R'(\mathrm{a}_1, \mathrm{b}_2)$ into the view.

- Optimal for insertions to the main schema.
- $K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4, \cancel{\bar{\mathrm{c}}_2}, \cancel{\bar{\mathrm{d}}_2}\}$.
- $$\Delta\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_K \rangle = \Delta^{+}\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_K \rangle = (M_1 \cup \{(\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w))\})^{+}.$$
- Changing constant names $\rightsquigarrow$ another optimal solution.

Example: The deletion of $R'(\mathrm{a}_1, \mathrm{b}_1)$ from the view.

Main Schema $\mathbf{E}_0$

$R : B \to C \qquad R[C] \subseteq S[C]$

$R[ABC]$

a_0	b_0	c_0
a_1	b_1	c_1

$S[CD]$

c_0	d_0
c_1	d_1
c_4	d_4

π_{AB} $\downarrow$

$R'[AB]$

a_0	b_0
~~a_1~~	~~b_1~~

View Schema $\mathbf{W}_0$

Examples of Information-Based Reflection of View Update

Example: The insertion of $R'(\mathrm{a}_1, \mathrm{b}_2)$ into the view.

- Optimal for insertions to the main schema.
- $K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4, \cancel{\bar{\mathrm{c}}_2}, \cancel{\bar{\mathrm{d}}_2}\}$.
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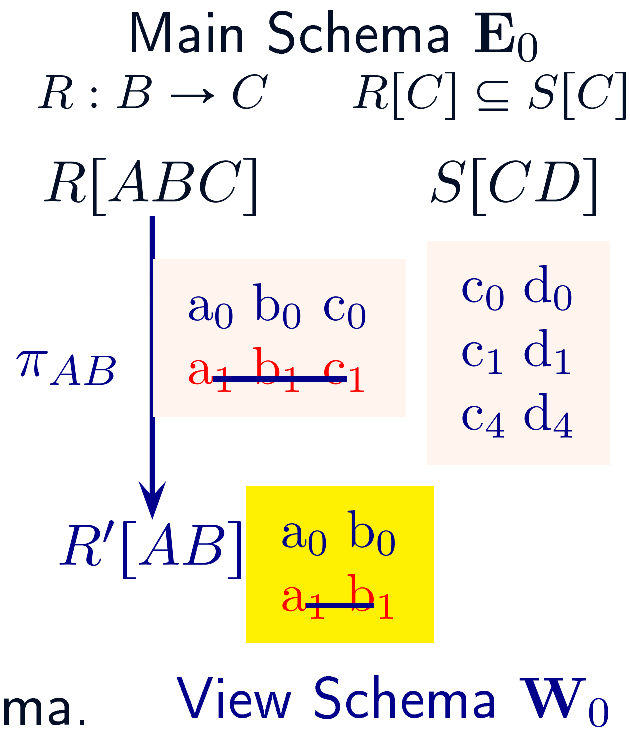
- Changing constant names $\rightsquigarrow$ another optimal solution.

Example: The deletion of $R'(\mathrm{a}_1, \mathrm{b}_1)$ from the view.

- The solution shown is optimal for deletions to the main schema.



Examples of Information-Based Reflection of View Update

Example: The insertion of $R'(\mathrm{a}_1, \mathrm{b}_2)$ into the view.

- Optimal for insertions to the main schema.
- $K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4, \cancel{\bar{\mathrm{c}}_2}, \cancel{\bar{\mathrm{d}}_2}\}$.
- $\Delta\langle(M_1, M_2), \Upsilon^{\mathbf{D}}_K\rangle = \Delta^+\langle(M_1, M_2), \Upsilon^{\mathbf{D}}_K\rangle =$
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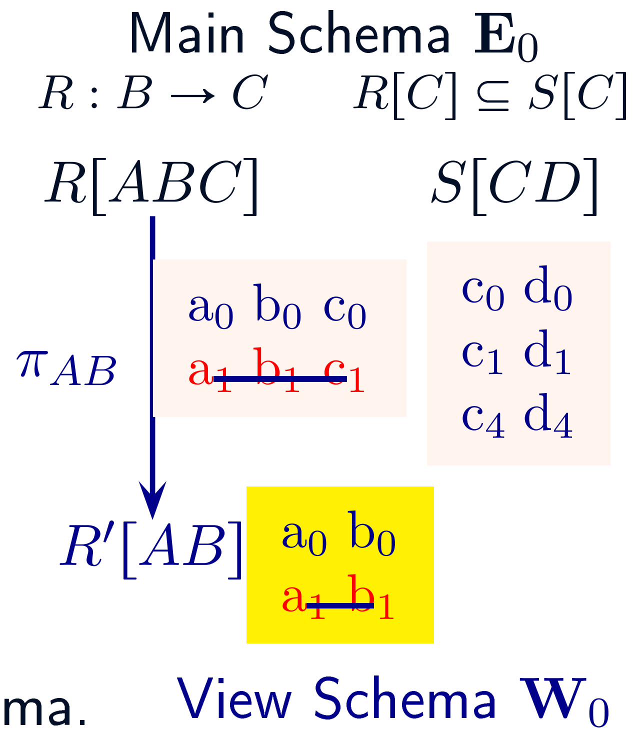
- The solution shown is optimal for deletions to the main schema.
- $K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4\}$.



Example: The insertion of $R'(\mathrm{a}_1, \mathrm{b}_2)$ into the view.

- Optimal for insertions to the main schema.
- $K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4, \cancel{\bar{\mathrm{c}}_2}, \cancel{\bar{\mathrm{d}}_2}\}$.
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- Changing constant names $\rightsquigarrow$ another optimal solution.

Example: The deletion of $R'(\mathrm{a}_1, \mathrm{b}_1)$ from the view.

- The solution shown is optimal for deletions to the main schema.
- $K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4\}$.
- An explicit representation of $\Delta\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_K \rangle = \Delta^{-}\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_K \rangle$ is complex.

Main Schema $\mathbf{E}_0$

$R : B \to C \qquad R[C] \subseteq S[C]$

$R[ABC]$

a_0	b_0	c_0
~~a_1~~	~~b_1~~	~~c_1~~

$S[CD]$

c_0	d_0
c_1	d_1
c_4	d_4

$\downarrow \pi_{AB}$

$R'[AB]$

a_0	b_0
~~a_1~~	~~b_1~~

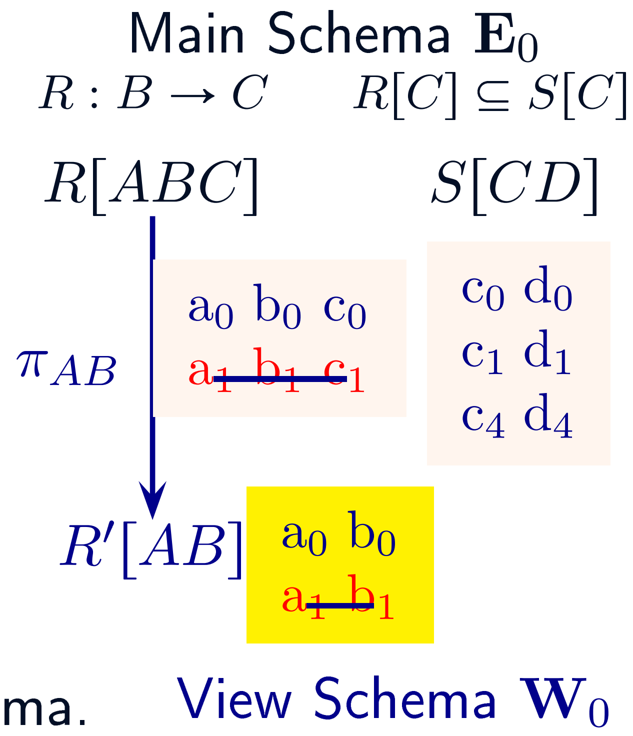
View Schema $\mathbf{W}_0$

Examples of Information-Based Reflection of View Update

Example: The insertion of $R'(\mathrm{a}_1, \mathrm{b}_2)$ into the view.

- Optimal for insertions to the main schema.
- $K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4, \cancel{\bar{\mathrm{c}}_2}, \cancel{\bar{\mathrm{d}}_2}\}$.
- $$\Delta\langle(M_1, M_2), \Upsilon_K^{\mathbf{D}}\rangle = \Delta^+\langle(M_1, M_2), \Upsilon_K^{\mathbf{D}}\rangle = (M_1 \cup \{(\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w))\})^+.$$
- Changing constant names $\leadsto$ another optimal solution.

Example: The deletion of $R'(\mathrm{a}_1, \mathrm{b}_1)$ from the view.



- The solution shown is optimal for deletions to the main schema.
- $K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4\}$.
- An explicit representation of $\Delta\langle(M_1, M_2), \Upsilon_K^{\mathbf{D}}\rangle = \Delta^-\langle(M_1, M_2), \Upsilon_K^{\mathbf{D}}\rangle$ is complex.
- However, it is easy to see that Info$\langle M_2, \Upsilon_K^{\mathbf{D}}\rangle$ is *preserved* and nothing more.

Examples of Information-Based Reflection of View Update

Example: The insertion of $R'(\mathrm{a}_1, \mathrm{b}_2)$ into the view.

- Optimal for insertions to the main schema.
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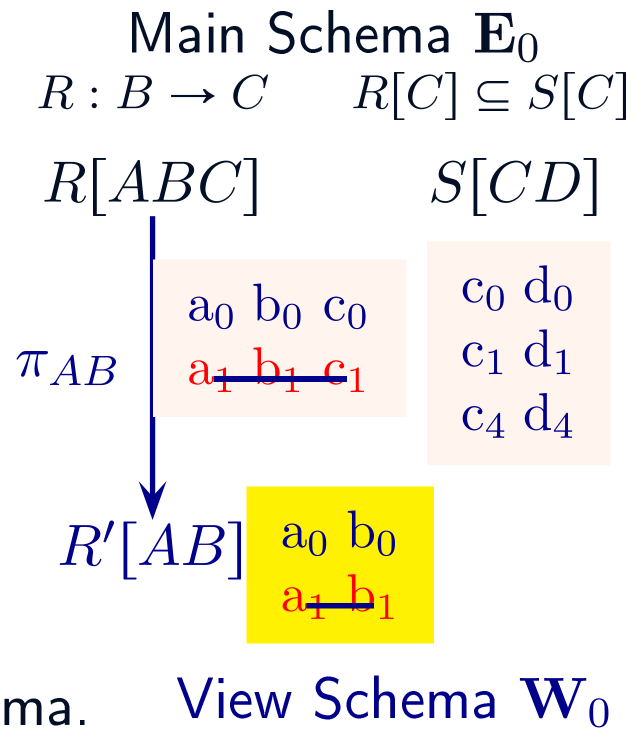

- The solution shown is optimal for deletions to the main schema.
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- An explicit representation of $\Delta\langle(M_1, M_2), \Upsilon^{\mathbf{D}}_K\rangle = \Delta^{-}\langle(M_1, M_2), \Upsilon^{\mathbf{D}}_K\rangle$ is complex.
- However, it is easy to see that Info$\langle M_2, \Upsilon^{\mathbf{D}}_K\rangle$ is *preserved* and nothing more.
- A general theory of optimality for *monotonic* reflections: [Hegner 2008-2009].

Examples of Information-Based Reflection of View Update

Example: The insertion of $R'(\mathrm{a}_1, \mathrm{b}_2)$ into the view.

- Optimal for insertions to the main schema.
- $K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4, \cancel{\bar{\mathrm{c}}_2}, \cancel{\bar{\mathrm{d}}_2}\}$.
- $\Delta\langle(M_1, M_2), \Upsilon^{\mathbf{D}}_{K}\rangle = \Delta^{+}\langle(M_1, M_2), \Upsilon^{\mathbf{D}}_{K}\rangle =$
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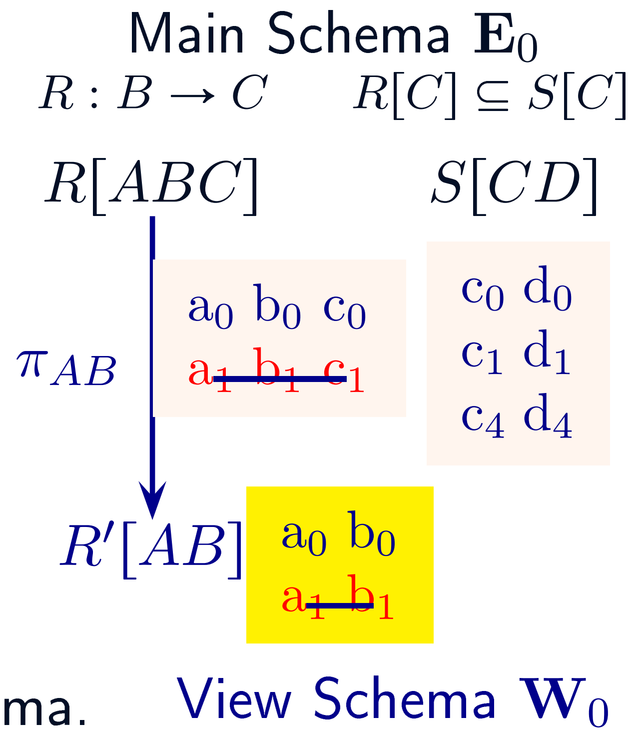


- The solution shown is optimal for deletions to the main schema.
- $K = \{\mathrm{a}_0, \mathrm{a}_1, \mathrm{b}_0, \mathrm{b}_1, \mathrm{b}_2, \mathrm{c}_0, \mathrm{c}_1, \mathrm{c}_4, \mathrm{d}_0, \mathrm{d}_1, \mathrm{d}_4\}$.
- An explicit representation of $\Delta\langle(M_1, M_2), \Upsilon^{\mathbf{D}}_{K}\rangle = \Delta^{-}\langle(M_1, M_2), \Upsilon^{\mathbf{D}}_{K}\rangle$ is complex.
- However, it is easy to see that Info$\langle M_2, \Upsilon^{\mathbf{D}}_{K}\rangle$ is *preserved* and nothing more.
- A general theory of optimality for *monotonic* reflections: [Hegner 2008-2009].

Goal of this work: Extend this theory to non-monotonic reflections (involving both insertion and deletion).

The Problem of Non-Monotonic Updates and Collateral Change

Example: Consider again the insertion of $(\mathrm{a}_1, \mathrm{b}_2)$ into the view with the insertion-optimal solution.

Main Schema $\mathbf{E}_0$

$R : B \to C \qquad R[C] \subseteq S[C]$

$R[ABC]$

a_0	b_0	c_0
a_1	b_1	c_1
a_1	b_2	$\bar{\mathrm{c}}_2$

$S[CD]$

c_0	d_0
c_1	d_1
c_4	d_4
$\bar{\mathrm{c}}_2$	$\bar{\mathrm{d}}_2$

$R[ABC] \xrightarrow{\pi_{AB}} R'[AB]$

$R'[AB]$

a_0	b_0
a_1	b_1
a_1	b_2

View Schema $\mathbf{W}_0$

The Problem of Non-Monotonic Updates and Collateral Change

Example: Consider again the insertion of $(\mathrm{a}_1, \mathrm{b}_2)$ into the view with the insertion-optimal solution.

- $\varphi = (\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w)) \wedge S(\mathrm{c}_4, \mathrm{d}_4)$
$$\in \Delta^{+}\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_{K} \rangle.$$

Main Schema $\mathbf{E}_0$

$R : B \to C \qquad R[C] \subseteq S[C]$

$R[ABC]$

a_0	b_0	c_0
a_1	b_1	c_1
a_1	b_2	$\bar{\mathrm{c}}_2$

$S[CD]$

c_0	d_0
c_1	d_1
c_4	d_4
$\bar{\mathrm{c}}_2$	$\bar{\mathrm{d}}_2$

$R[ABC] \xrightarrow{\pi_{AB}} R'[AB]$

$R'[AB]$

a_0	b_0
a_1	b_1
a_1	b_2

View Schema $\mathbf{W}_0$

The Problem of Non-Monotonic Updates and Collateral Change

Example: Consider again the insertion of $(\mathrm{a}_1, \mathrm{b}_2)$ into the view with the insertion-optimal solution.

- $\varphi = (\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w)) \wedge S(\mathrm{c}_4, \mathrm{d}_4)$
$$\in \Delta^{+}\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_{K} \rangle.$$
- If $S(\mathrm{c}_4, \mathrm{d}_4)$ is deleted, φ will not be added.

Main Schema $\mathbf{E}_0$

$R : B \rightarrow C \qquad R[C] \subseteq S[C]$

$R[ABC]$

a_0	b_0	c_0
a_1	b_1	c_1
a_1	b_2	$\bar{\mathrm{c}}_2$

$S[CD]$

c_0	d_0
c_1	d_1
$\cancel{\mathrm{c}_4}$	$\cancel{\mathrm{d}_4}$
$\bar{\mathrm{c}}_2$	$\bar{\mathrm{d}}_2$

$\big\downarrow \pi_{AB}$

$R'[AB]$

a_0	b_0
a_1	b_1
a_1	b_2

View Schema $\mathbf{W}_0$

Example: Consider again the insertion of $(\mathrm{a}_1, \mathrm{b}_2)$ into the view with the insertion-optimal solution.

- $\varphi = (\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w)) \wedge S(\mathrm{c}_4, \mathrm{d}_4)$
  $$\in \Delta^{+}\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_{K} \rangle.$$
- If $S(\mathrm{c}_4, \mathrm{d}_4)$ is deleted, φ will not be added.
- But deleting $S(\mathrm{c}_4, \mathrm{d}_4)$ does not make the solution better in any reasonable way.

Main Schema $\mathbf{E}_0$

$R : B \to C$ $R[C] \subseteq S[C]$

$R[ABC]$

a_0	b_0	c_0
a_1	b_1	c_1
a_1	b_2	$\bar{\mathrm{c}}_2$

$S[CD]$

c_0	d_0
c_1	d_1
$\cancel{\mathrm{c}_4}$	$\cancel{\mathrm{d}_4}$
$\bar{\mathrm{c}}_2$	$\bar{\mathrm{d}}_2$

π_{AB}

$R'[AB]$

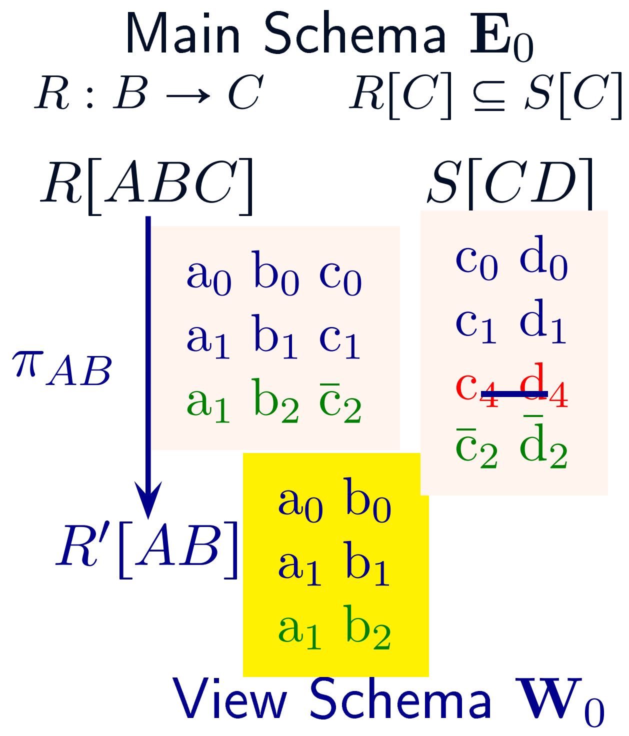
a_0	b_0
a_1	b_1
a_1	b_2

View Schema $\mathbf{W}_0$

The Problem of Non-Monotonic Updates and Collateral Change

Example: Consider again the insertion of $(\mathrm{a}_1, \mathrm{b}_2)$ into the view with the insertion-optimal solution.

- $\varphi = (\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w)) \wedge S(\mathrm{c}_4, \mathrm{d}_4)$
  $\in \Delta^+\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_{K} \rangle.$
- If $S(\mathrm{c}_4, \mathrm{d}_4)$ is deleted, φ will not be added.
- But deleting $S(\mathrm{c}_4, \mathrm{d}_4)$ does not make the solution better in any reasonable way.
- φ is called a *collateral change*.



Example: Consider again the insertion of $(\mathrm{a}_1, \mathrm{b}_2)$ into the view with the insertion-optimal solution.

- $\varphi = (\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w)) \wedge S(\mathrm{c}_4, \mathrm{d}_4)$
  $$\in \Delta^{+}\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_{K} \rangle.$$
- If $S(\mathrm{c}_4, \mathrm{d}_4)$ is deleted, φ will not be added.
- But deleting $S(\mathrm{c}_4, \mathrm{d}_4)$ does not make the solution better in any reasonable way.
- φ is called a *collateral change*.
- With monotonic view updates (insertions and deletions), collateral change can be avoided by requiring that the reflection be of the same type as the view update.

Main Schema $\mathbf{E}_0$

$R : B \to C \qquad R[C] \subseteq S[C]$

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a_0	b_0	c_0
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$\cancel{\mathrm{c}_4}$	$\cancel{\mathrm{d}_4}$
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$R'[AB]$

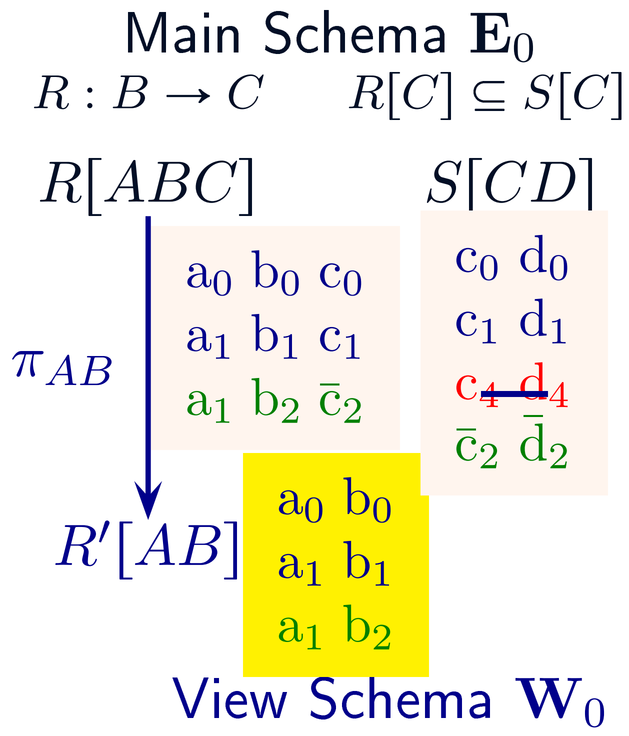
a_0	b_0
a_1	b_1
a_1	b_2

View Schema $\mathbf{W}_0$

The Problem of Non-Monotonic Updates and Collateral Change

Example: Consider again the insertion of $(\mathrm{a}_1, \mathrm{b}_2)$ into the view with the insertion-optimal solution.

- $\varphi = (\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w)) \wedge \boxed{S(\mathrm{c}_4, \mathrm{d}_4)}$
$$\in \Delta^{+}\langle (M_1, M_2), \Upsilon_K^{\mathbf{D}} \rangle.$$
- If $S(\mathrm{c}_4, \mathrm{d}_4)$ is deleted, φ will not be added.
- But deleting $S(\mathrm{c}_4, \mathrm{d}_4)$ does not make the solution better in any reasonable way.
- φ is called a *collateral change*.
- With monotonic view updates (insertions and deletions), collateral change can be avoided by requiring that the reflection be of the same type as the view update.
- For view updates which are not monotonic, a more general technique for avoiding collateral change is necessary.



The Problem of Non-Monotonic Updates and Collateral Change

Example: Consider again the insertion of $(\mathrm{a}_1, \mathrm{b}_2)$ into the view with the insertion-optimal solution.

- $\varphi = (\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w)) \wedge S(\mathrm{c}_4, \mathrm{d}_4)$
  $\in \Delta^{+}\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_{K} \rangle$.
- If $S(\mathrm{c}_4, \mathrm{d}_4)$ is deleted, φ will not be added.
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$\bar{\mathrm{c}}_2$	$\bar{\mathrm{d}}_2$

$R[ABC] \xrightarrow{\pi_{AB}} R'[AB]$

$R'[AB]$

a_0	b_0
a_1	b_1
a_1	b_2

View Schema $\mathbf{W}_0$

- With monotonic view updates (insertions and deletions), collateral change can be avoided by requiring that the reflection be of the same type as the view update.
- For view updates which are not monotonic, a more general technique for avoiding collateral change is necessary.
- The approach is to characterize $\Delta^{+}\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_{K} \rangle$ and $\Delta^{-}\langle (M_1, M_2), \Upsilon^{\mathbf{D}}_{K} \rangle$ via *generators*, and then place minimal/least constraints on these generators.

Update Generators

Idea: A *generator* for the update (M_1, M_2) on the schema $\mathbf{D}$ is a pair $\langle G_+, G_{\not+} \rangle$ with the following properties:

Update Generators

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Update Generators

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❶ $G_+ \subseteq \Delta^+\langle (M_1, M_2), \Upsilon_K^{\mathbf{D}} \rangle$ generates the added information.

❷ $G_{\not -} \subseteq \mathsf{Info}\langle M_1, \Upsilon_K^{\mathbf{D}} \rangle \backslash \Delta^-\langle (M_1, M_2), \Upsilon_K^{\mathbf{D}} \rangle$ generates the retained information.

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❸ $G_+ \cup G_{\not+} \equiv_{\mathbf{D}} M_2$ ($G_+ \cup G_{\not+}$ defines the new state).

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❸ $G_+ \cup G_{\not+} \equiv_{\mathbf{D}} M_2$ ($G_+ \cup G_{\not+}$ defines the new state).

Ordering: $\langle G_+^1, G_{\not+}^1 \rangle \sqsubseteq_{\mathbf{D}} \langle G_+^2, G_{\not+}^2 \rangle$ iff

Update Generators

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❷ $G_{\not+} \subseteq \mathsf{Info}\langle M_1, \Upsilon_K^{\mathbf{D}} \rangle \backslash \Delta^-\langle (M_1, M_2), \Upsilon_K^{\mathbf{D}} \rangle$ generates the retained information.

❸ $G_+ \cup G_{\not+} \equiv_{\mathbf{D}} M_2$ ($G_+ \cup G_{\not+}$ defines the new state).

Ordering: $\langle G_+^1, G_{\not+}^1 \rangle \sqsubseteq_{\mathbf{D}} \langle G_+^2, G_{\not+}^2 \rangle$ iff

❶ $G_+^2 \vDash_{\mathbf{D}} G_+^1$ (G_+^1 is weaker than G_+^2 — want to minimize G_+).

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- Thus $\sqsubseteq_{\mathbf{D}}$ is a preorder (and a partial order on the associated equivalence classes).

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- *Admissibility* and *optimality* are defined in terms of this ordering.
  - *Admissible* = minimal in the ordering.
  - *Optimal* = least in the ordering.

Example of Update Generator

Example: For the insertion-only reflection of the insertion of $(\mathrm{a}_1, \mathrm{b}_2)$ into the view:

$$G_+ = \{(\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w)\}$$

$$G_{\not+} = M_1 \quad \text{(original state of } \mathbf{E}_0\text{)}$$

Main Schema $\mathbf{E}_0$

$R : B \to C \qquad R[C] \subseteq S[C]$

$R[ABC]$

a_0	b_0	c_0
a_1	b_1	c_1
a_1	b_2	$\bar{\mathrm{c}}_2$

$S[CD]$

c_0	d_0
c_1	d_1
c_4	d_4
$\bar{\mathrm{c}}_2$	$\bar{\mathrm{d}}_2$

π_{AB}

$R'[AB]$

a_0	b_0
a_1	b_1
a_1	b_2

View Schema $\mathbf{W}_0$

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- For the solution in which $S(\mathrm{c}_4, \mathrm{d}_4)$ is also deleted:

$$G'_{+} = \{(\exists z)(\exists w)(R(\mathrm{a}_1, \mathrm{b}_2, z) \wedge S(z, w)\}$$
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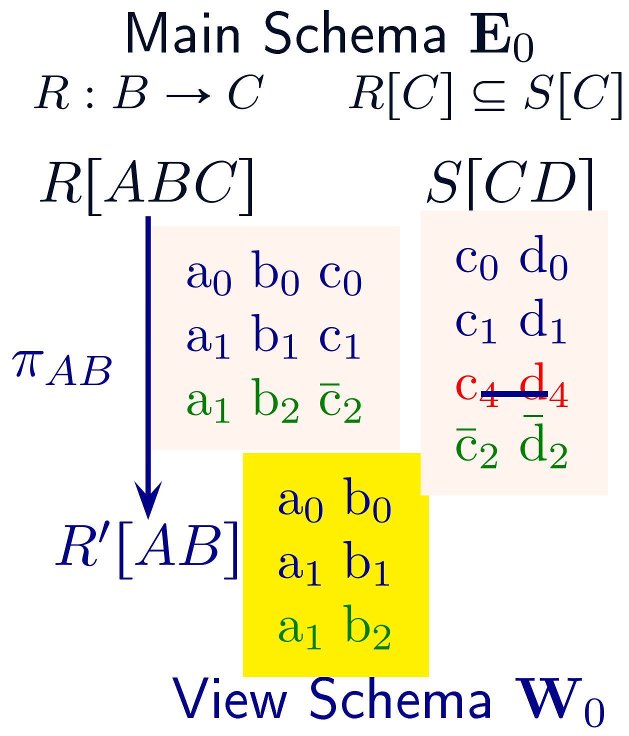

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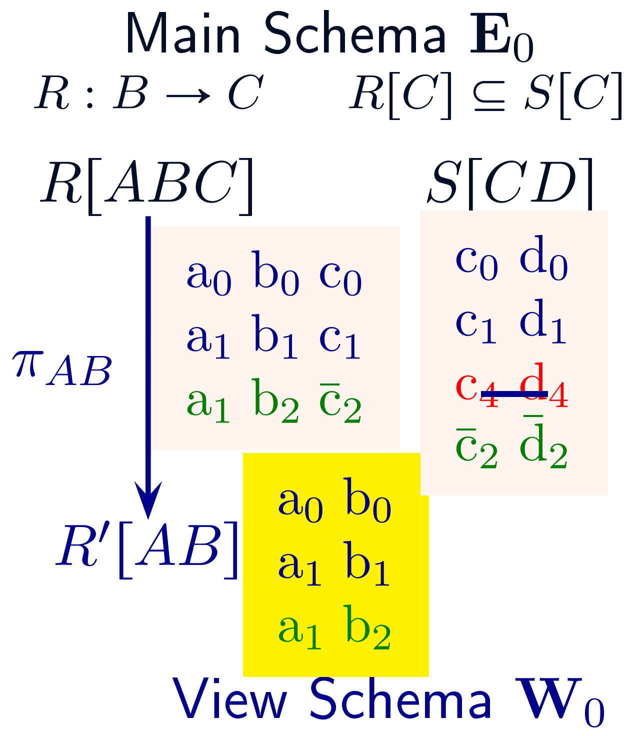

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c_0	d_0
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$\bar{\mathrm{c}}_2$	$\bar{\mathrm{d}}_2$

$R[ABC] \xrightarrow{\pi_{AB}} R'[AB]$

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a_0	b_0
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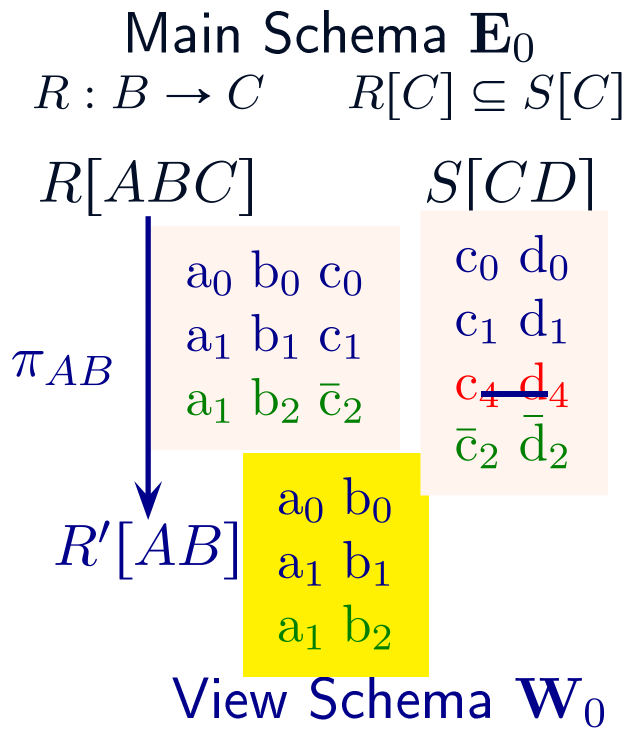

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- Since $\langle G_{+}, G_{\not+} \rangle \subsetneq_{\mathbf{D}} \langle G'_{+}, G'_{\not+} \rangle$, the insertion-only solution is preferred, as desired.
- The collateral change entails in a suboptimal reflection.
- This is a simplification; technical details have been ignored.
  - Constraints on $\mathbf{D}$: Horn with finite chase. (Implies *finite initial-model property*.)
  - G_{+} and $G_{\not+}$ are *ideals*: closed under implication in the context of $\mathrm{Constr}(\mathbf{D})$.

Least-Insertion Optimality

Theorem: Under suitable conditions, every view update has a reflection which is *insertion optimal* in the sense that G_+ is least. $\square$

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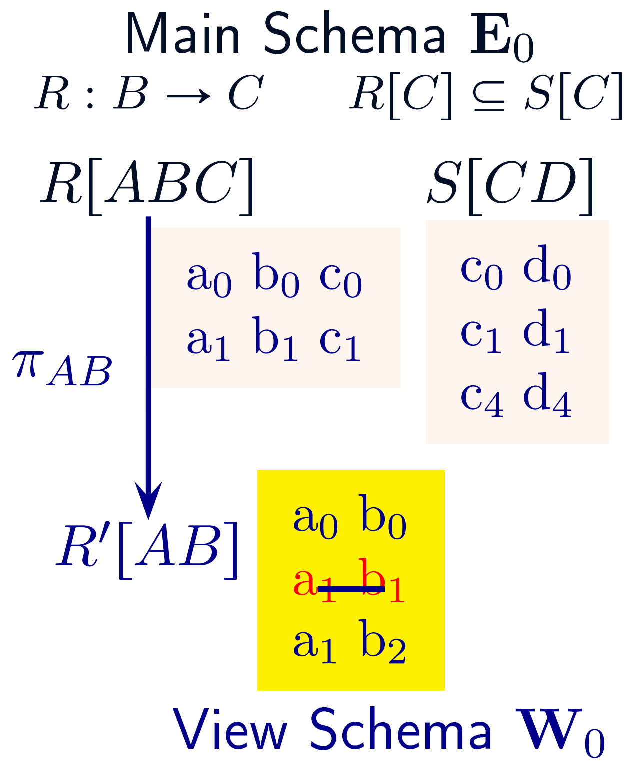

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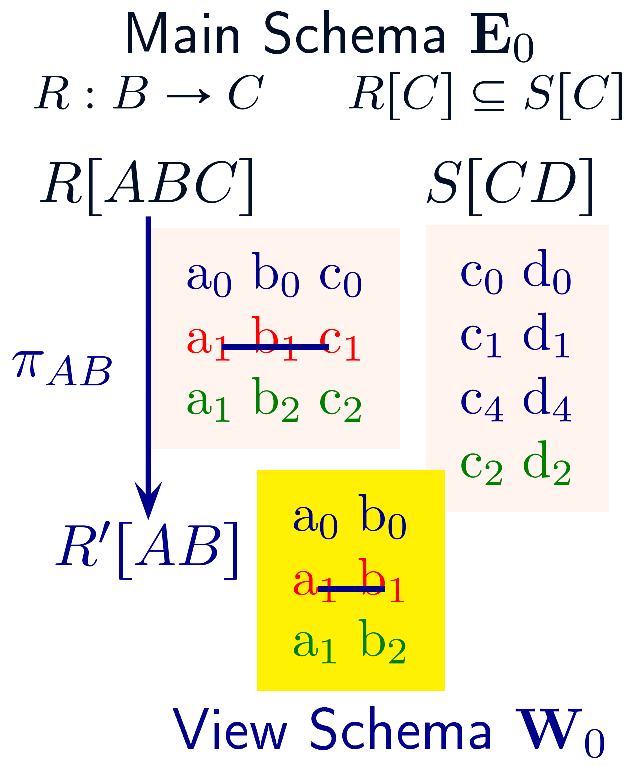

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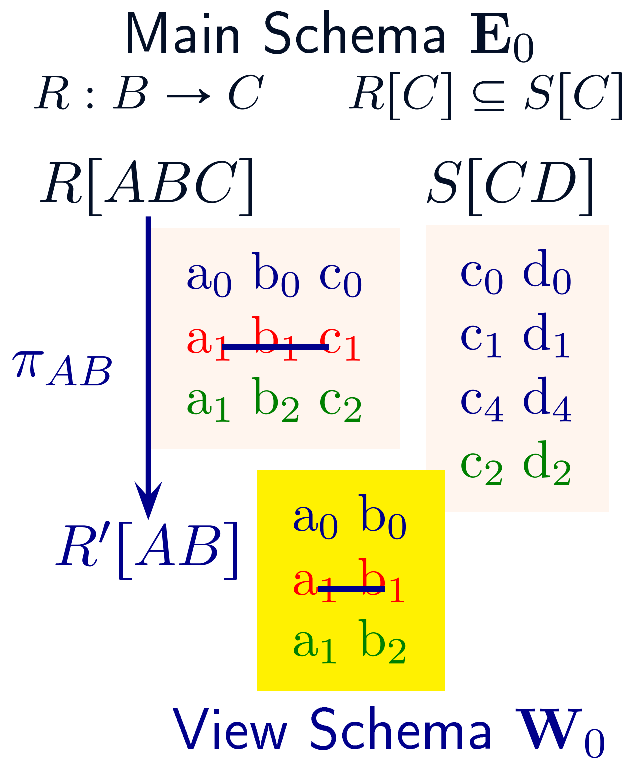

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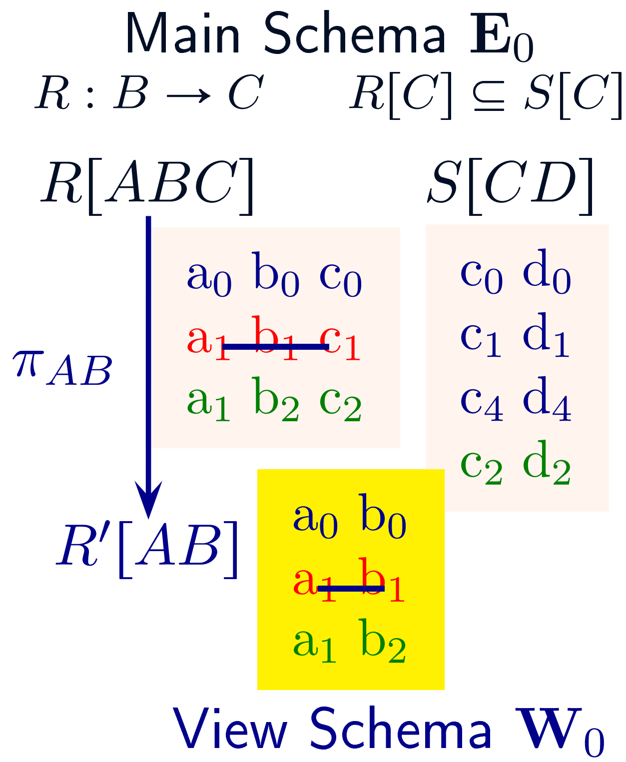

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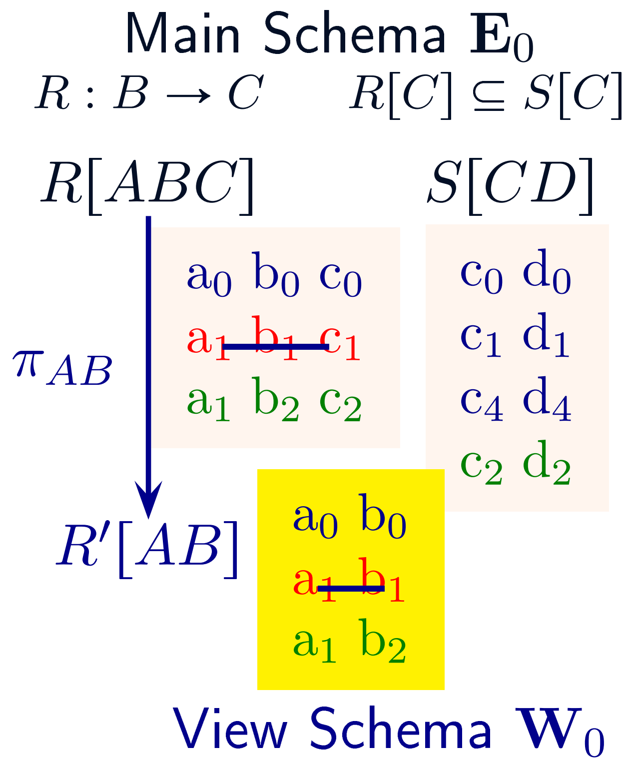

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~~a_1~~	~~b_1~~	~~c_1~~
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Optimal deletion: There may not be a least reflection of a deletion.

Solution: View must define a *unit-head pair*. (No rules with more than one antecedent) [Hegner 2009]

Deletion Optimality

- The example under consideration is not *deletion optimal for information*.

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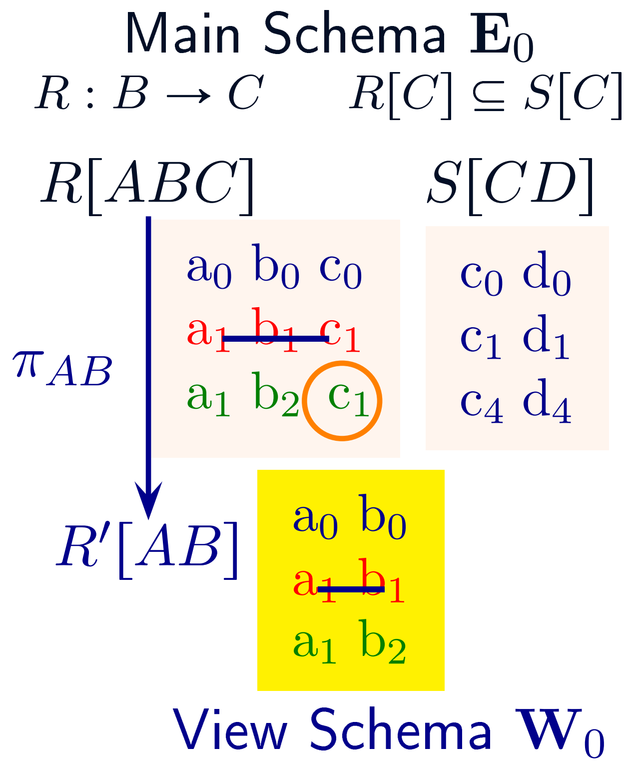
View Schema $\mathbf{W}_0$

Deletion Optimality

- The example under consideration is not *deletion optimal for information*.
- The reflection shown preserves more information (but adds more as well).

Preserves: $(\exists y)(R(\mathrm{a}_1, y, \mathrm{c}_1))$ *Adds*: $R(\mathrm{a}_1, \mathrm{b}_2, \mathrm{c}_1)$



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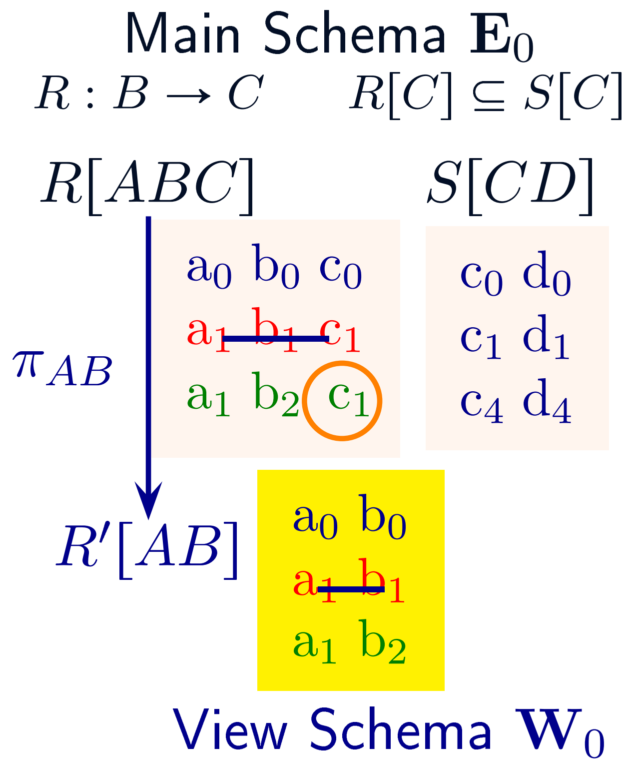

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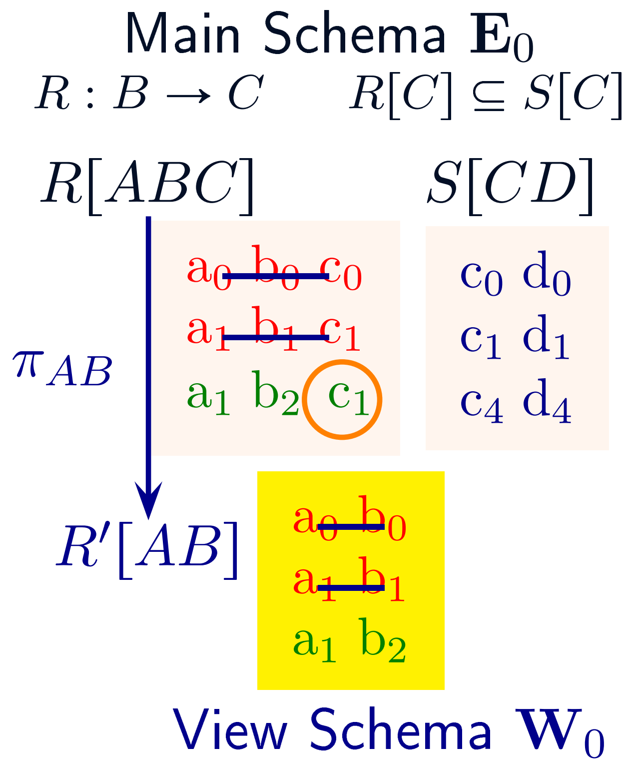

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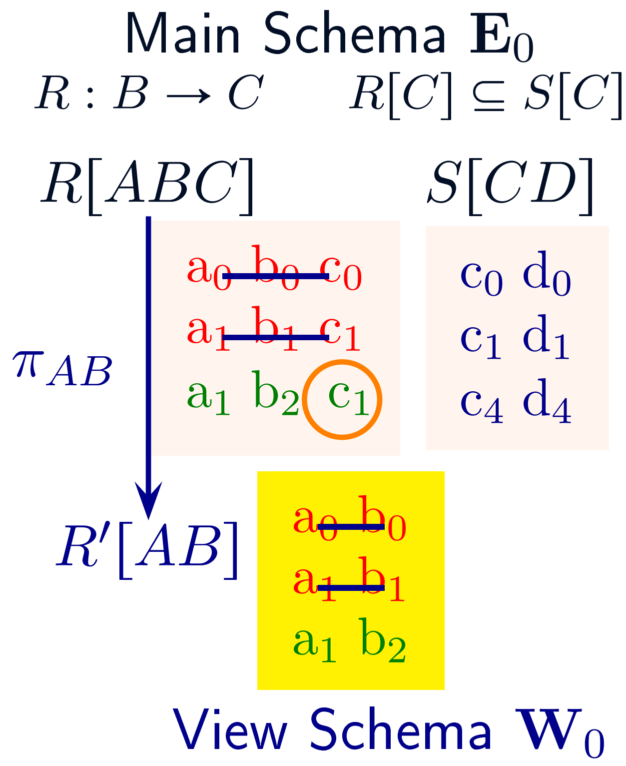
- Deletion optimality is possible only when the view update corresponds to changes in fields of tuples.



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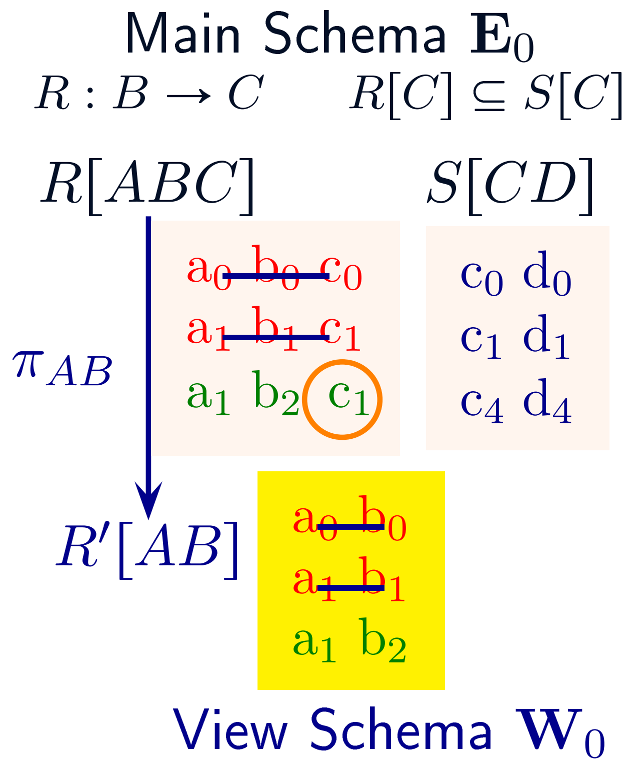
- There are two incomparable reflections which minimize $G_{\not\vdash}$.
  This one preserves $(\exists x)(\exists y)(R(x, y, \mathrm{c}_0))$. This one preserves $(\exists x)(\exists y)(R(x, y, \mathrm{c}_1))$.



- Deletion optimality is possible only when the view update corresponds to changes in fields of tuples.

- The insertion optimal realization of the previous slides is, however, *deletion optimal for tuples*.

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Further Directions:

- Classification of reflection type along *tuple update* versus *delete-insert* lines.
- Integration of this measure with more traditional syntactic ones.