Consistency Maintenance for Collaborative Real-Time Feature Modeling

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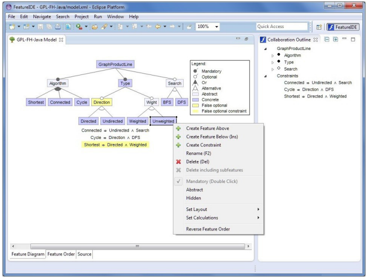
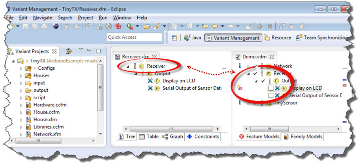
Bachelor Thesis

Advisors: Gunter Saake, Sebastian Krieter, Jacob Krüger

Motivation

- State of the Art: Single-User Feature Modeling
- No dedicated support for collaboration
- *Asynchronous Collaboration* with VCS
  But: not real-time; divergence





Why Real-Time?

- Engineers can discuss the feature model with domain experts
  $\Rightarrow$ Real-time feedback

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- Engineers can discuss the feature model with domain experts
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- Domain knowledge is spread across different collaborators
  $\Rightarrow$ Leverage group synergies for problem solving
- VCS does not allow tight collaboration (e.g., pair programming)
  $\Rightarrow$ Complements a VCS for short-term evolution

Motivation

Our Contribution:

- The Foundations of Collaborative Real-Time Feature Modeling, focusing on
  - Consistency Maintenance
  - Conflict Detection & Resolution

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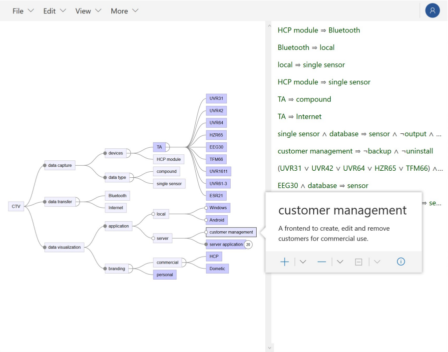
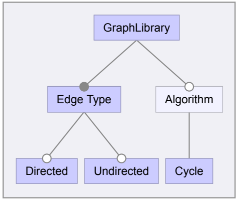
- The Foundations of Collaborative Real-Time Feature Modeling, focusing on
    - Consistency Maintenance
    - Conflict Detection & Resolution
- Open-Source Research Prototype



Running Example



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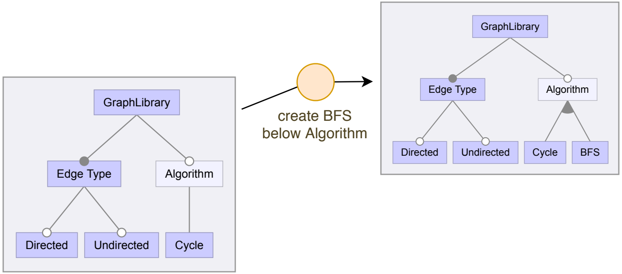

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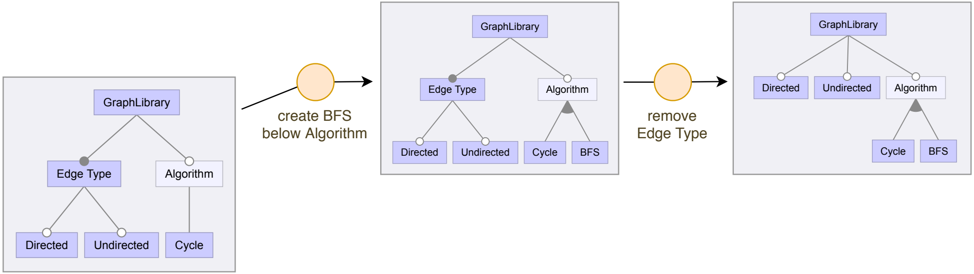

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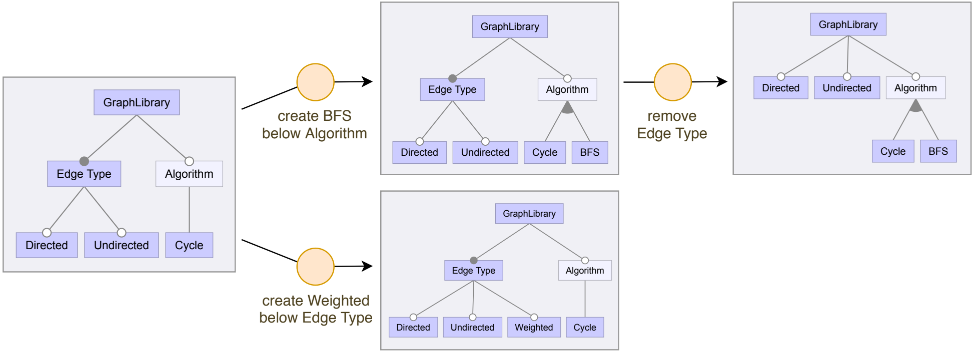

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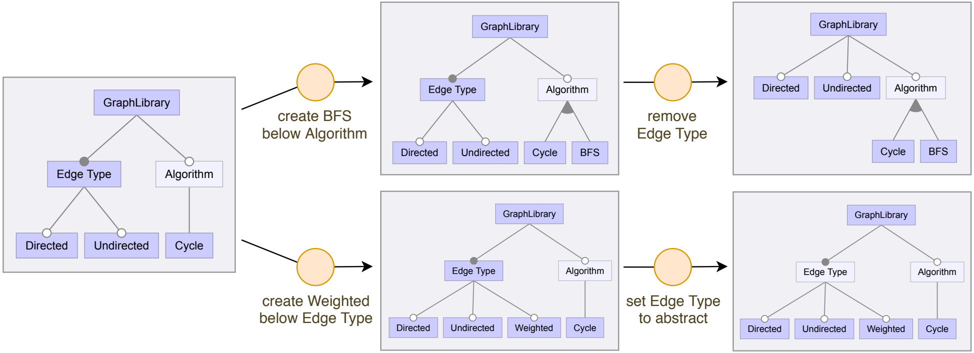

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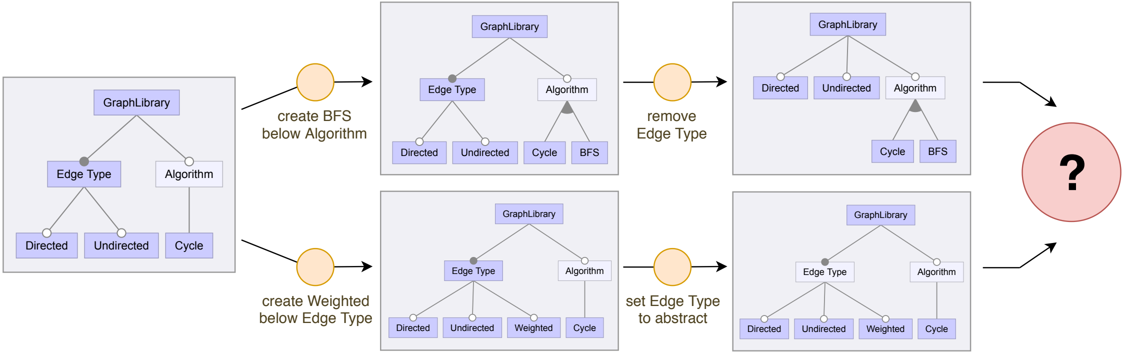
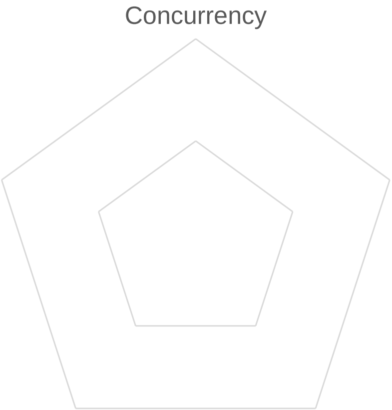


Requirements



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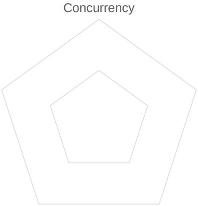
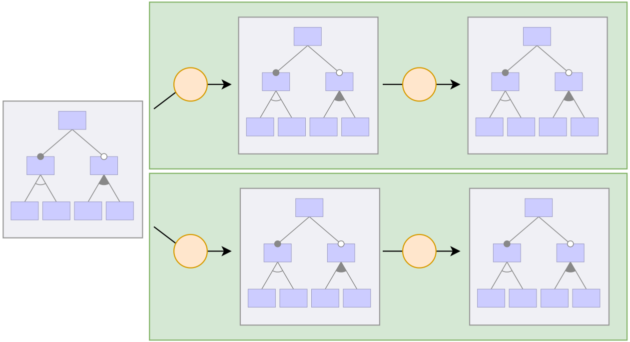
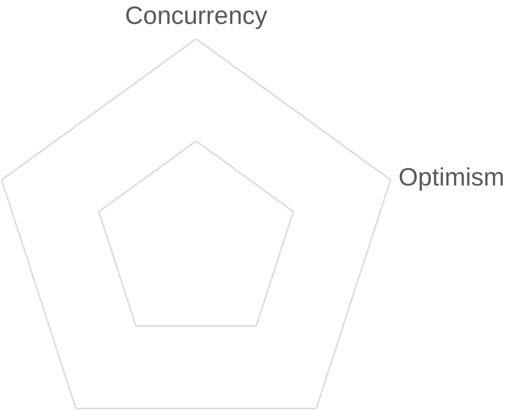




Concurrent Operation Chains

Requirements



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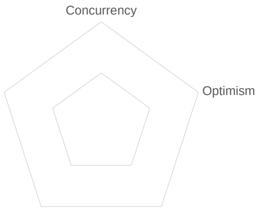
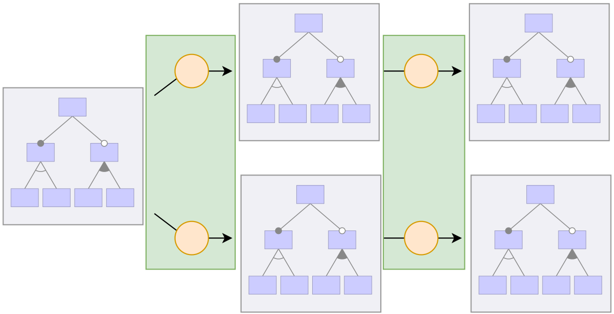
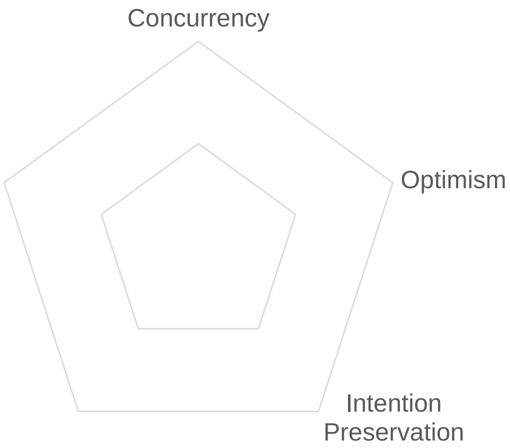




Immediate Operation Execution

Requirements



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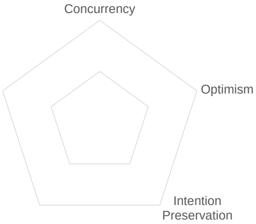
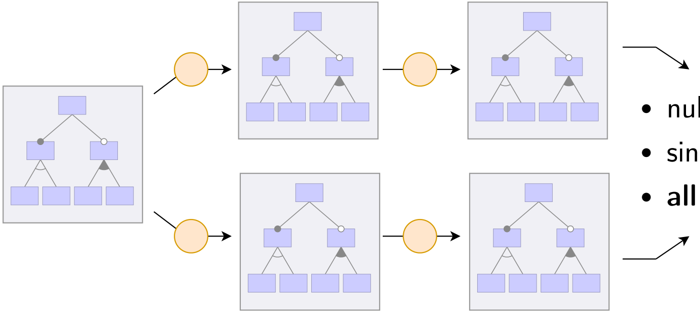
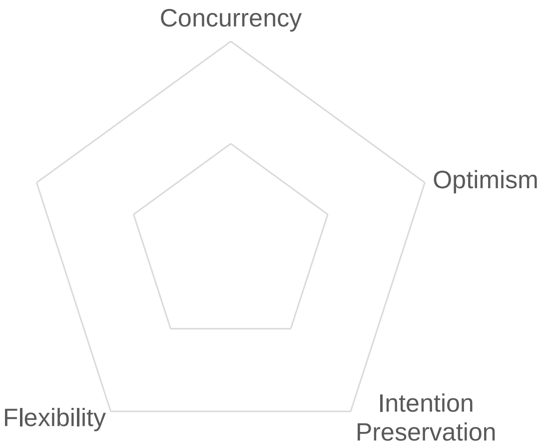




- null
- single op
- all ops

Requirements



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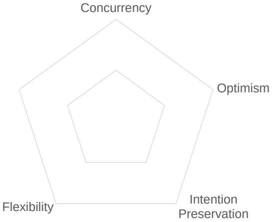
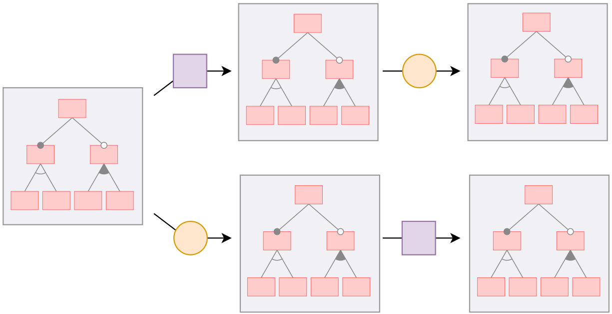
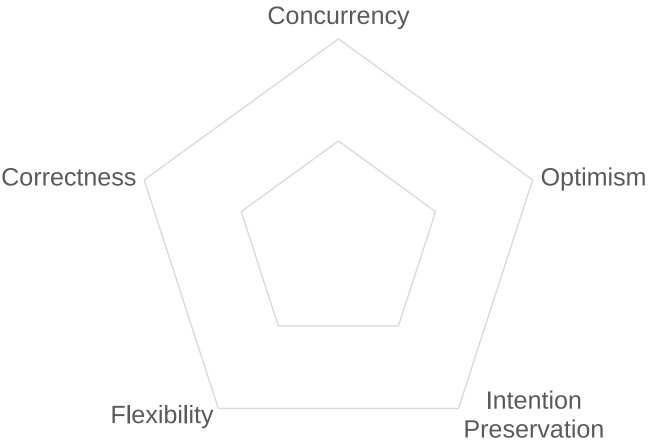




Additional Model Representations & Operations

Requirements



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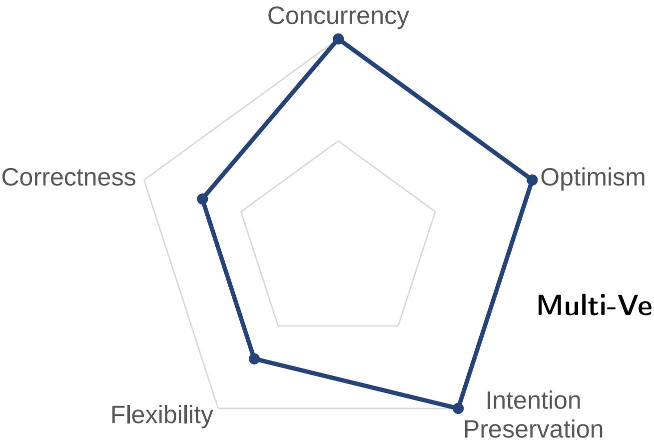

Multi-Version Multi-Display

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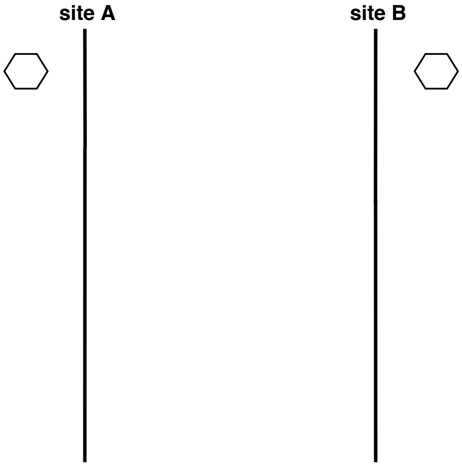

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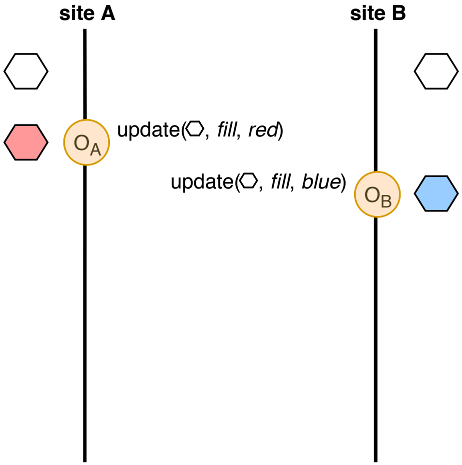

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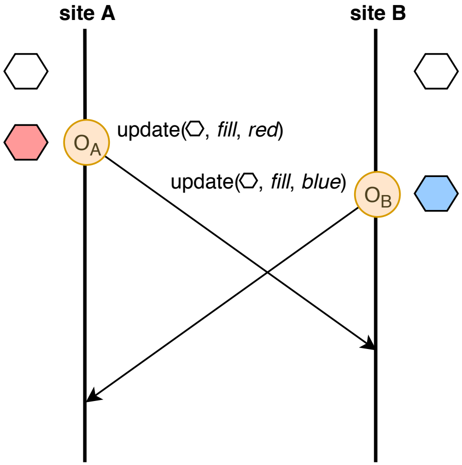

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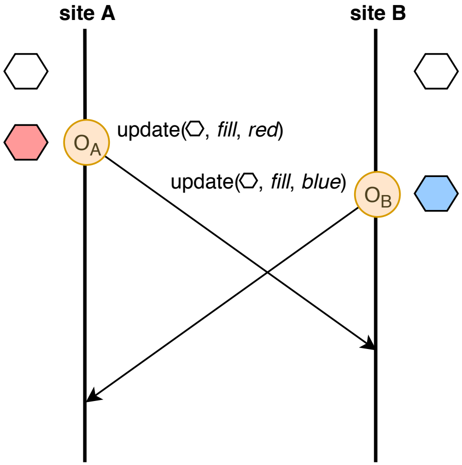
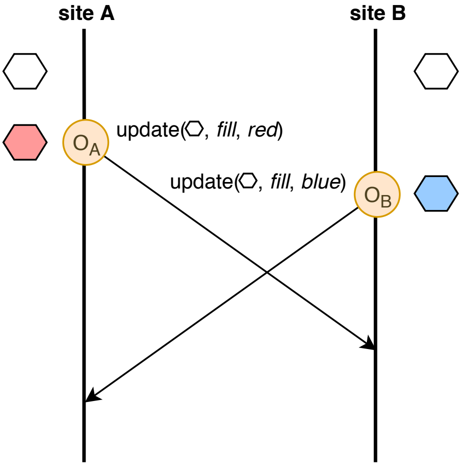


$O_A \otimes O_B$?

Multi-Version Multi-Display



$O_A \otimes O_B$? **Yes.**

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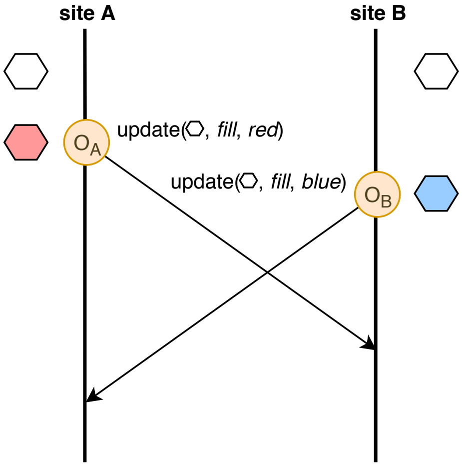

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$\{\{O_A\}, \{O_B\}\}$

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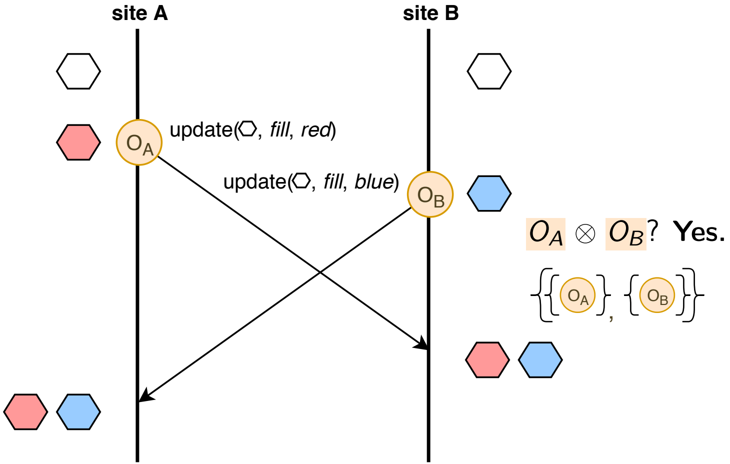

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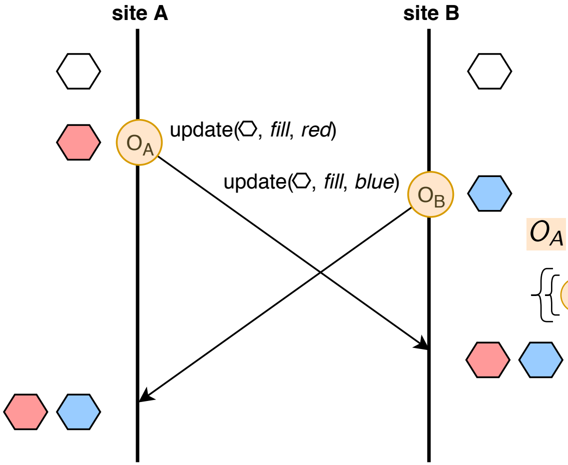
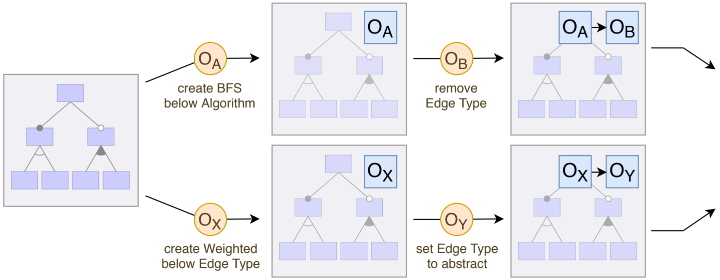


$O_A \otimes O_B$? **Yes.**

$\{\{O_A\}, \{O_B\}\}$ ⇐ guarantees min #versions

Feature Modeling Conflicts



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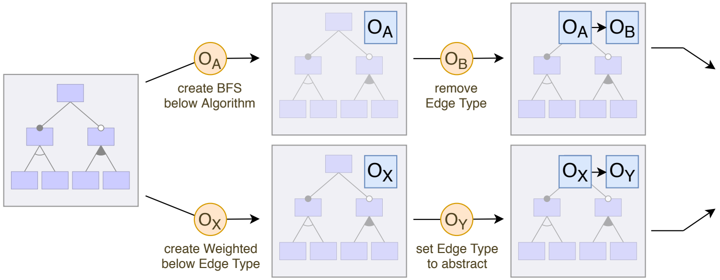

$O_A \otimes O_X$?

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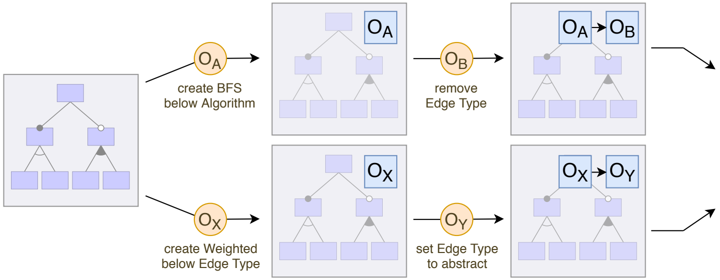
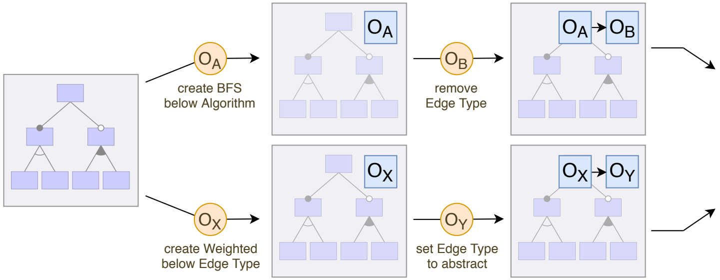


$O_A \otimes O_X$? No.

Feature Modeling Conflicts



$O_A \otimes O_X$? **No.**

$O_A \otimes O_Y$, based on O_X?

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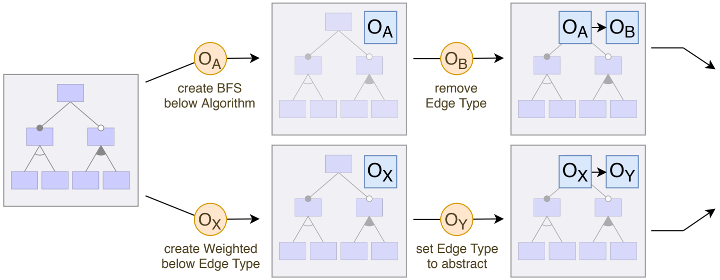

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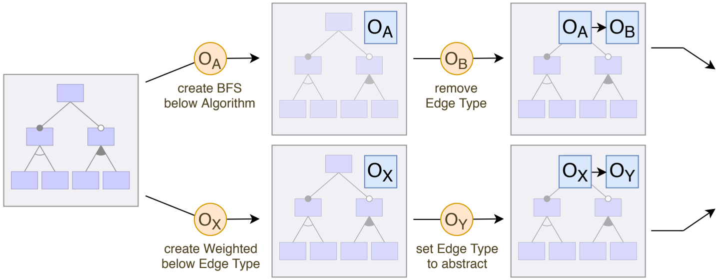

$O_A \otimes O_X$? **No.**

$O_A \otimes O_Y$, based on O_X? **No.**

$O_X \otimes O_B$, based on O_A?

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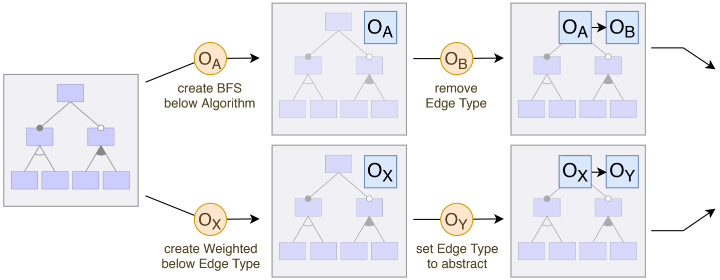

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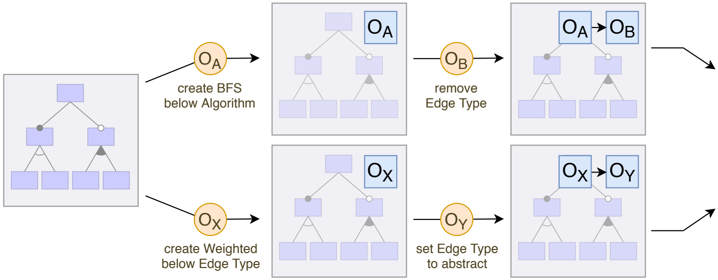
$O_A \otimes O_Y$, based on O_X? **No.**

$O_X \otimes O_B$, based on O_A? **Yes.**

Feature Modeling Conflicts



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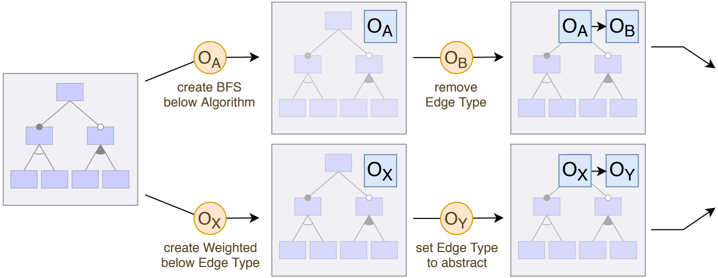
$O_A \otimes O_Y$, based on O_X? **No.**
$O_X \otimes O_B$, based on O_A? **Yes.**
Thus, also $O_Y \otimes O_B$.

Feature Modeling Conflicts



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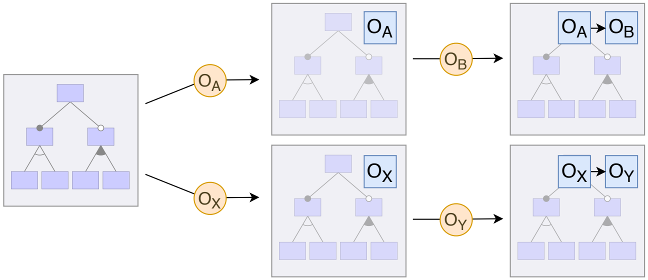
Thus, also $O_Y \otimes O_B$.

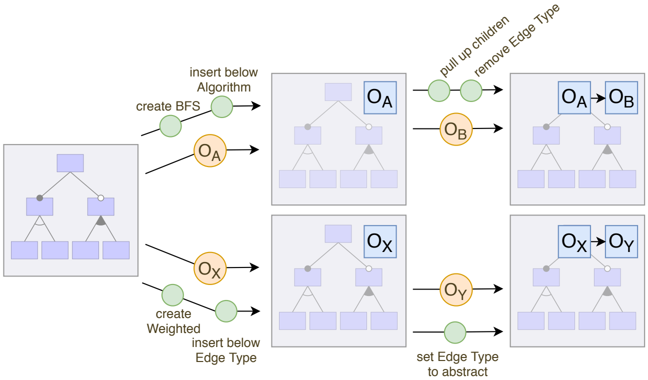
$\{\{O_A, O_B\}, \{O_A, O_X, O_Y\}\}$

Feature Modeling Conflicts



Decompose into Primitive Operations.

Feature Modeling Conflicts



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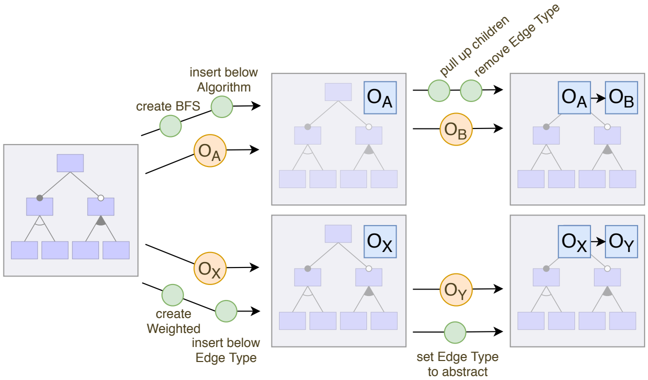
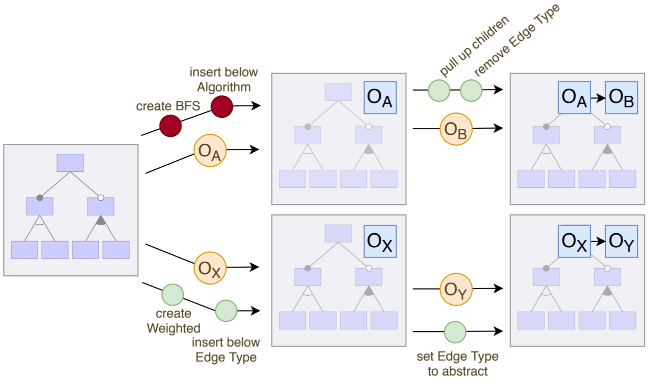


Decompose into Primitive Operations.
$O_X \otimes O_B$ because:

Feature Modeling Conflicts

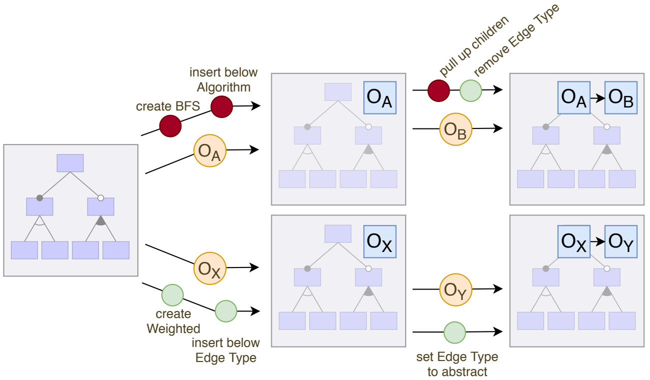


Decompose into Primitive Operations.

$O_X \otimes O_B$ because:

Based on O_A,

Feature Modeling Conflicts

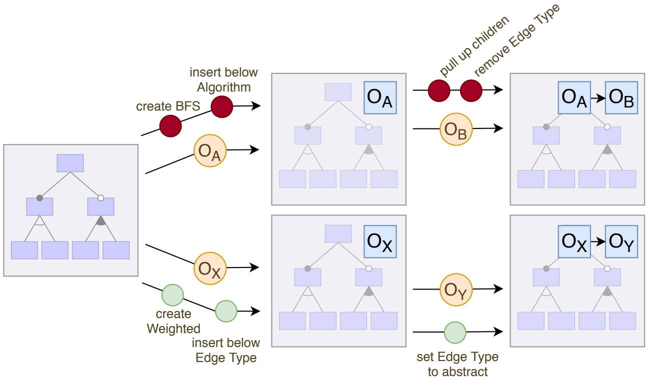


Decompose into Primitive Operations.

$O_X \otimes O_B$ because:

Based on O_A, apply O_B.

Feature Modeling Conflicts



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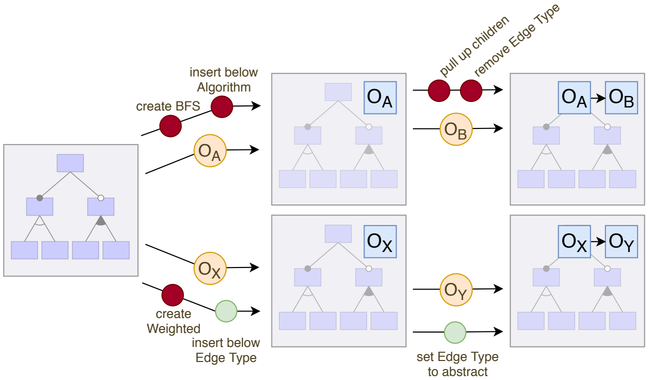


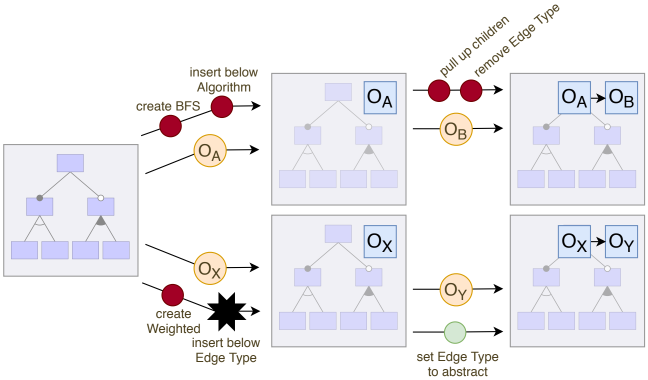
Decompose into Primitive Operations.

$O_X \otimes O_B$ because:

Based on O_A, apply O_B.

Now apply O_X ...

Feature Modeling Conflicts



Decompose into Primitive Operations.

$O_X \otimes O_B$ because:

Based on O_A, apply O_B.

Now apply O_X ...

...but a conflict rule applies.

Conflict Detection Rules

- No writes to removed features.

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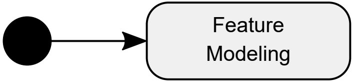
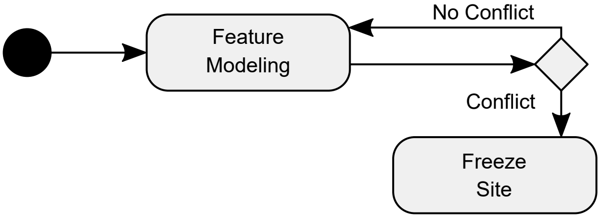
- No writes to removed features.
- No writes to the same feature attribute.
- May not introduce cycles.
- No mandatory/optional writes to group children.
- ... (cross-tree constraints, semantic properties)


Feature
Modeling

Resolution Process



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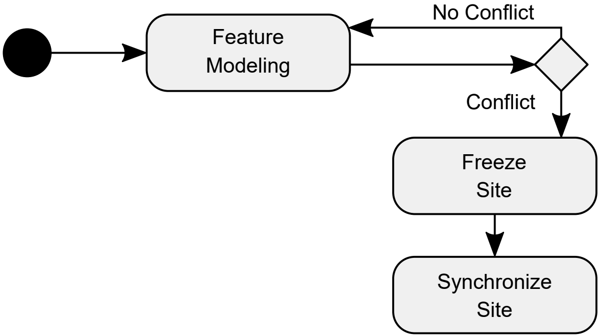

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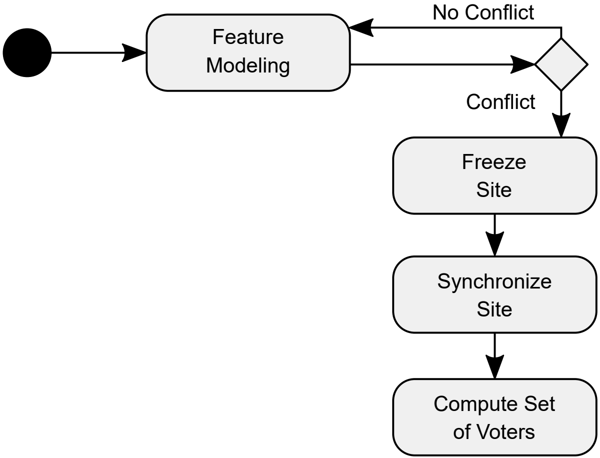

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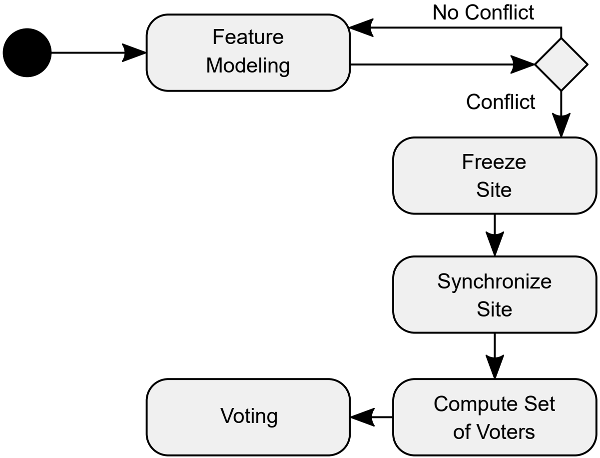

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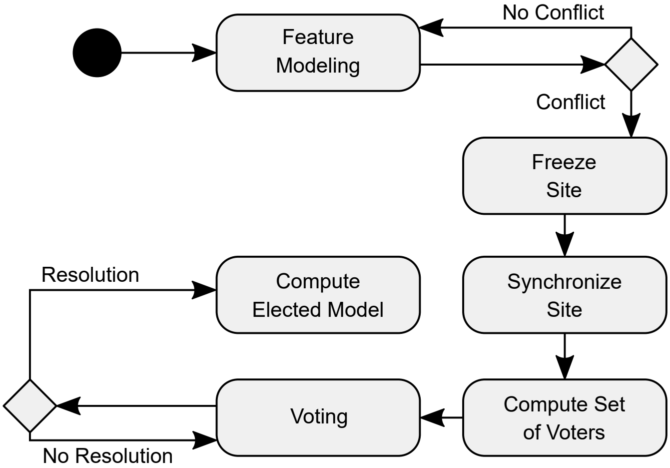

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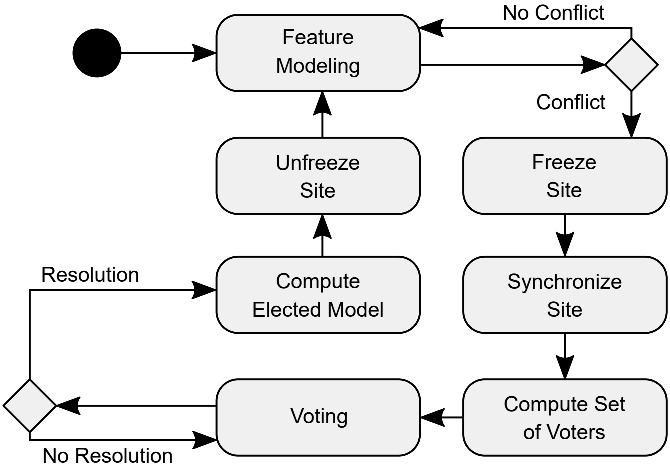

Correctness

- Convergence
- Causality Preservation
- Intention Preservation

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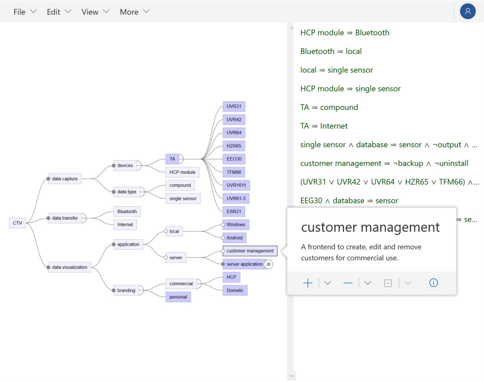
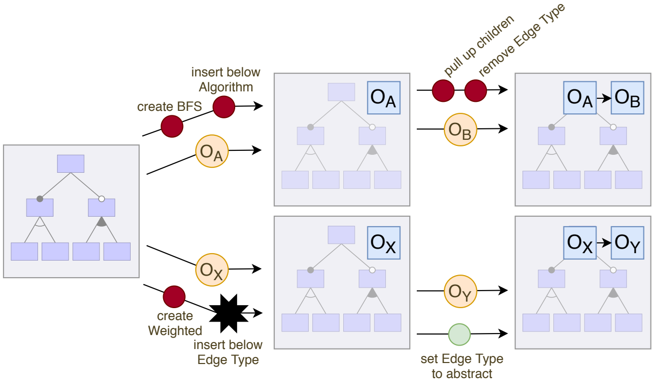
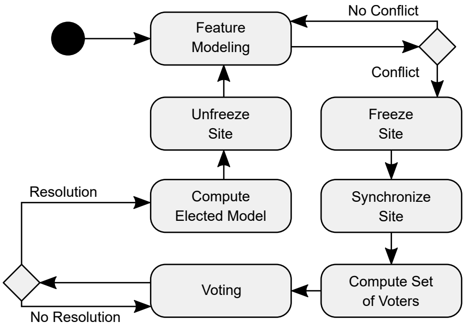
Prototype + Tests



Conclusion

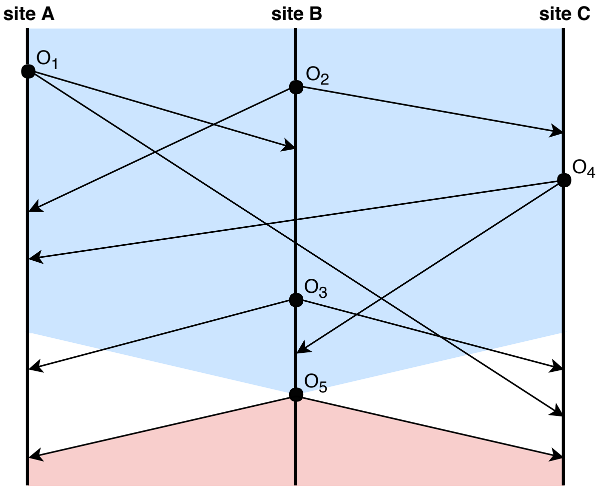


Conflict Detection



Conflict Resolution

CCI Model



- Convergence
- Causality Preservation
- Intention Preservation

Concurrency Control

	Turn-Taking	Locking	CRDTs	Serialization	OT	MVSD	MVMD
Concurrency	○	◐	●	●	●	●	●
Optimism	◐	○	●	●	●	●	●
Intention Preservation	●	○	○	○	○	◐	●
Flexibility	●	○	○	○	○	○	◐
Correctness	●	◐	◐	●	○	○	◐

Architecture (Demo)