



[Magdeburger Dom]

variED

An Editor for Collaborative, Real-Time Feature Modeling

SE 2023 (EMSE 2021) — February 22–24 — Paderborn

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University of Magdeburg¹, Ulm², Eindhoven³, Wernigerode⁴, supported by pure-systems GmbH*



universität
ulm

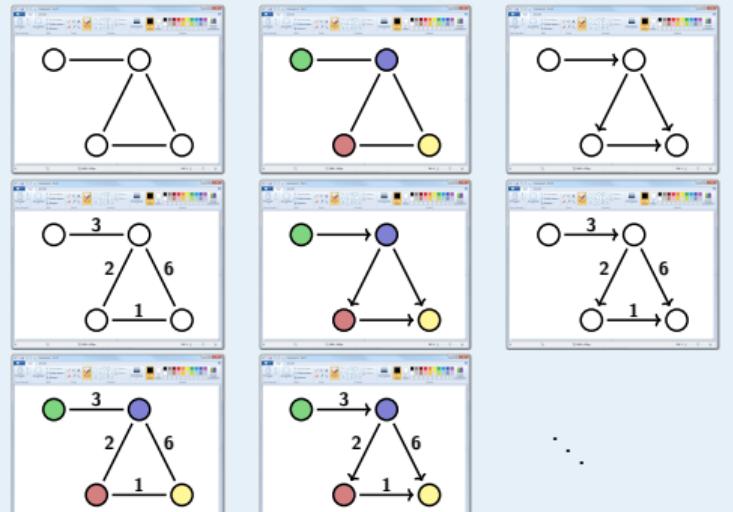
TU/e EINDHOVEN
UNIVERSITY OF
TECHNOLOGY

▲ Hochschule Harz
Harz University of Applied Sciences

 **pure**
systems

variED – An Editor for Collaborative, Real-Time Feature Modeling

A Family of Graph Applications

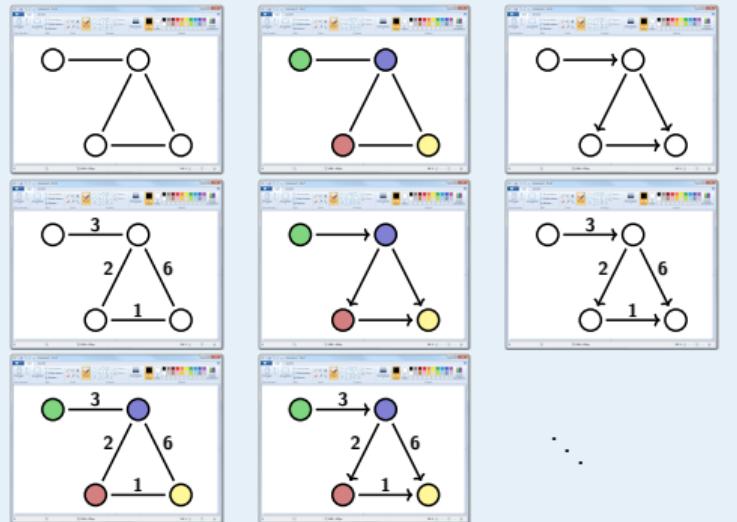


Product-Oriented Perspective

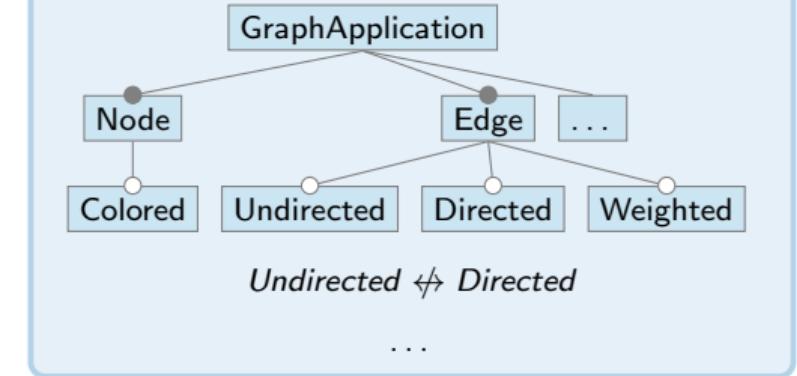
con: usually grows exponentially

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A Family of Graph Applications



Feature Model: Describes Variability Concisely



Feature-Oriented Perspective

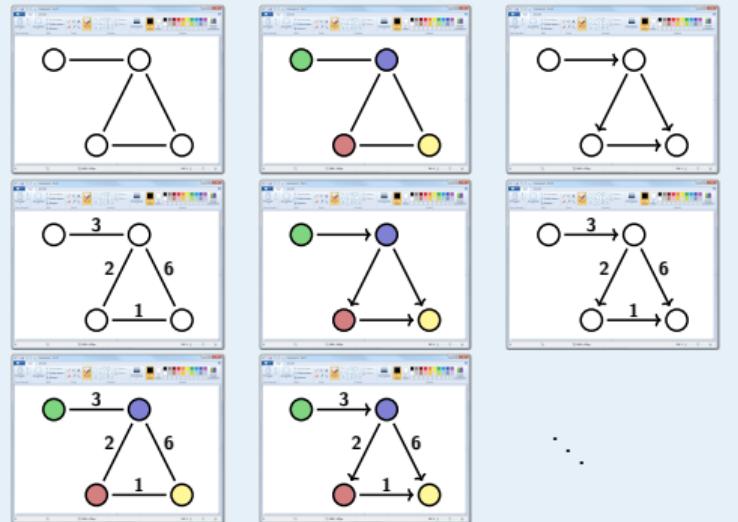
pros: analyzable, management-friendly, ...

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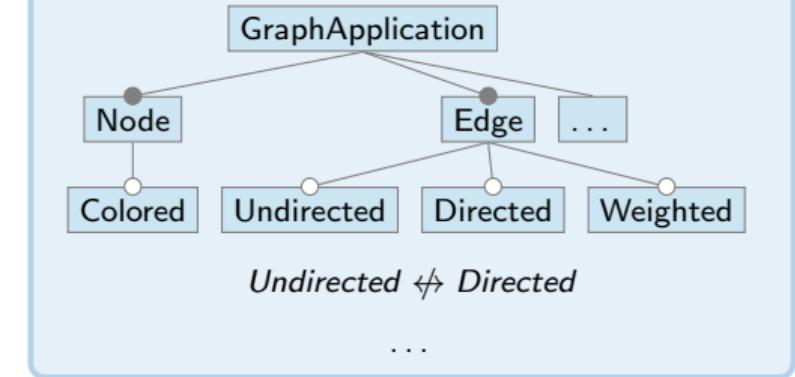
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Feature-Oriented Perspective

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Feature Modeling

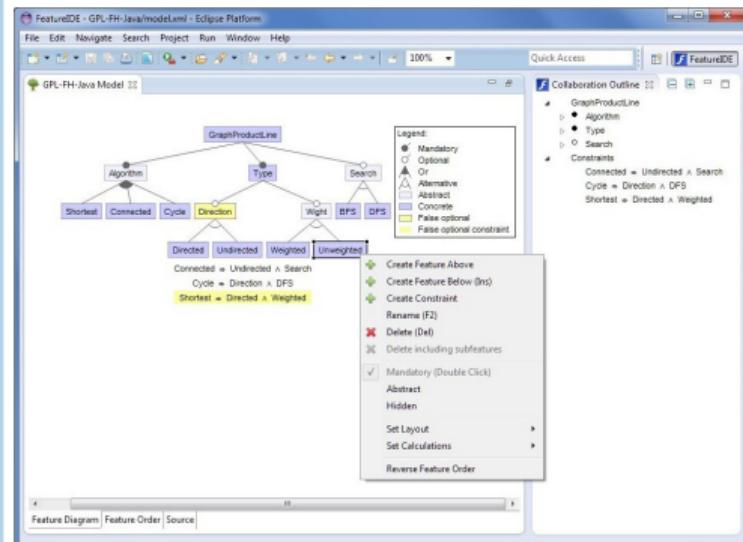
creating, maintaining, and evolving a feature model

variED – An Editor for Collaborative, Real-Time Feature Modeling

Single-User Feature Modeling

- state-of-the-art tools are **single-user only**
- multi-user editing only possible with
 - synchronous **turn-taking**
con: requires coordination
 - asynchronous **version control**
cons: not real-time, promotes divergence

FeatureIDE: A Single-User Feature-Model Editor



variED – An Editor for Collaborative, Real-Time Feature Modeling

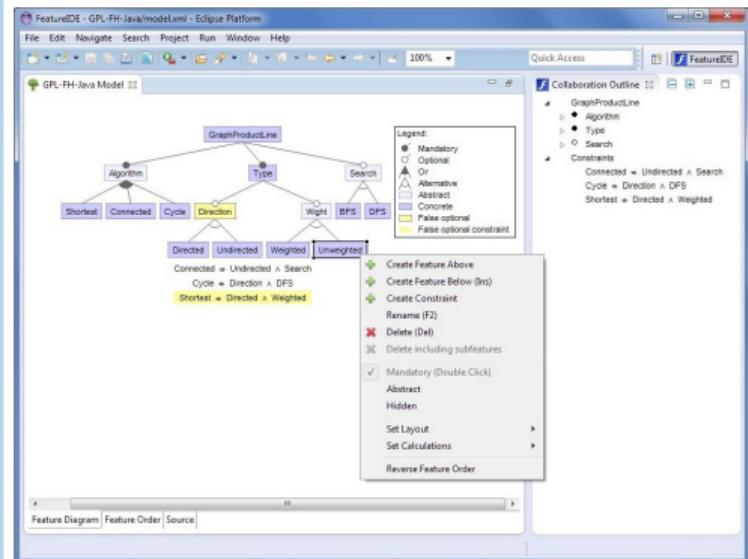
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Collaborative, Real-Time Feature Modeling

- why **collaborative**?
⇒ domain knowledge is often **spread** across team members
- why **real-time**?
⇒ hands-on discussion with domain experts
⇒ allows for “pair-programming”

FeatureIDE: A Single-User Feature-Model Editor



variED – An Editor for Collaborative, Real-Time Feature Modeling

Our Contributions

[Kuiter'19, FOSD'19, SPLC'19, EMSE'21]

- formal foundations for
collaborative, real-time feature modeling
 - requirements analysis
 - operation model
 - conflict detection
 - conflict resolution
- open-source research prototype
variED (the **variability editor**)
- evaluation
 - formal proofs of correctness
 - qualitative user study

variED – An Editor for Collaborative, Real-Time Feature Modeling

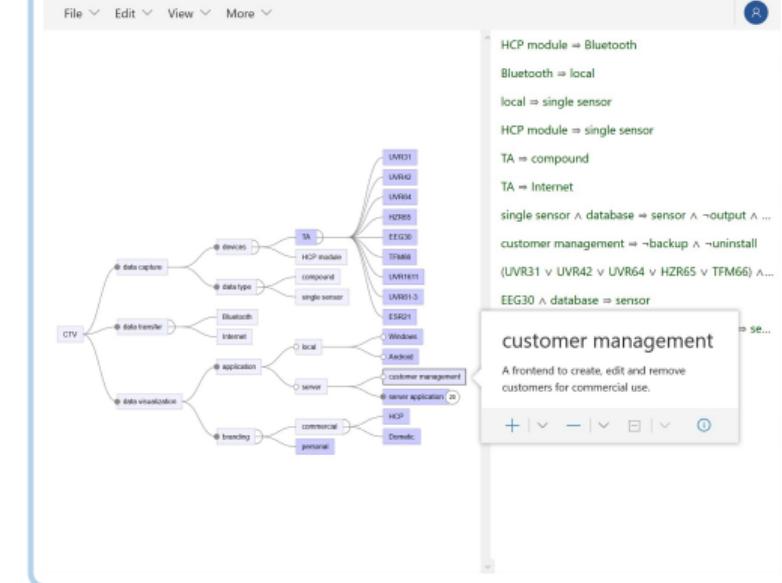
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- evaluation
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variED: A Collaborative, Real-Time Feature-Model Editor



Requirements for Collaborative, Real-Time Feature Modeling

Assumptions

Requirements for Collaborative, Real-Time Feature Modeling

Assumptions

- concurrent feature-model edits
⇒ i.e., **conflicts** may occur

Requirements

- concurrency control
⇒ i.e., we need **conflict detection** and **resolution**

Requirements for Collaborative, Real-Time Feature Modeling

Assumptions

- concurrent feature-model edits
⇒ i.e., **conflicts** may occur
- small group of 2–4 collaborators
⇒ i.e., conflicts are **rare** and unexpected

Requirements

- concurrency control
⇒ i.e., we need **conflict detection** and **resolution**
- correctness
⇒ i.e., we need proofs of **intention preservation**

Requirements for Collaborative, Real-Time Feature Modeling

Assumptions

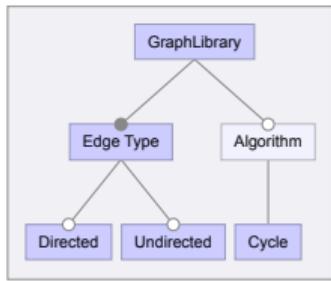
- concurrent feature-model edits
⇒ i.e., **conflicts** may occur
- small group of 2–4 collaborators
⇒ i.e., conflicts are **rare** and unexpected
- remotely connected
⇒ i.e., there is **latency**

Requirements

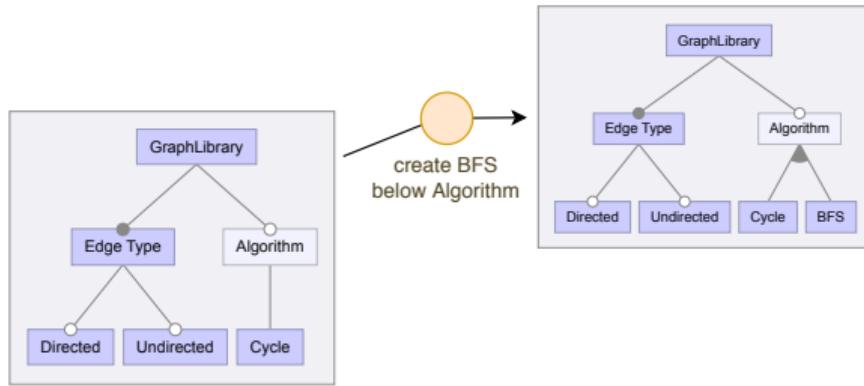
- concurrency control
⇒ i.e., we need **conflict detection** and **resolution**
- correctness
⇒ i.e., we need proofs of **intention preservation**
- efficiency
⇒ i.e., we need **optimism**

⇒ chosen technique: **multi-version multi-display**

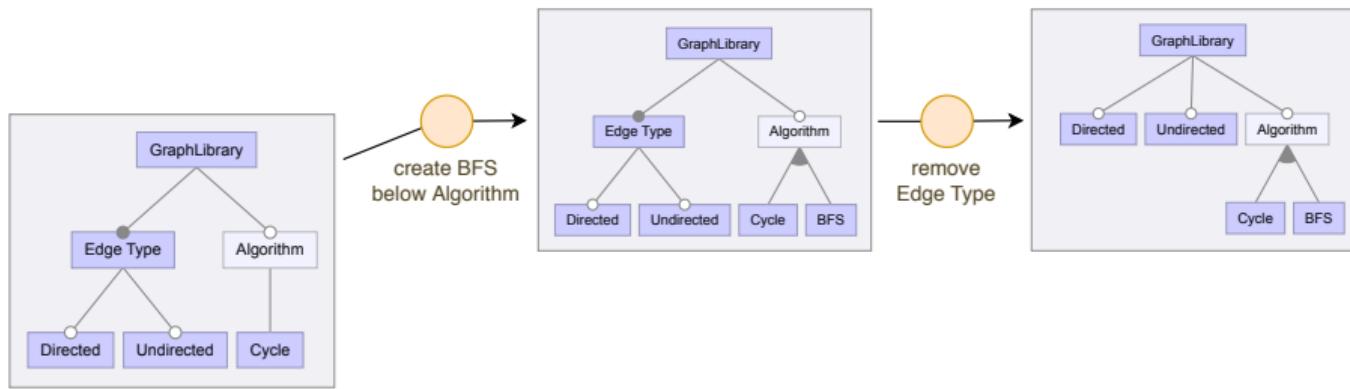
Concurrent Feature-Model Edits – Example



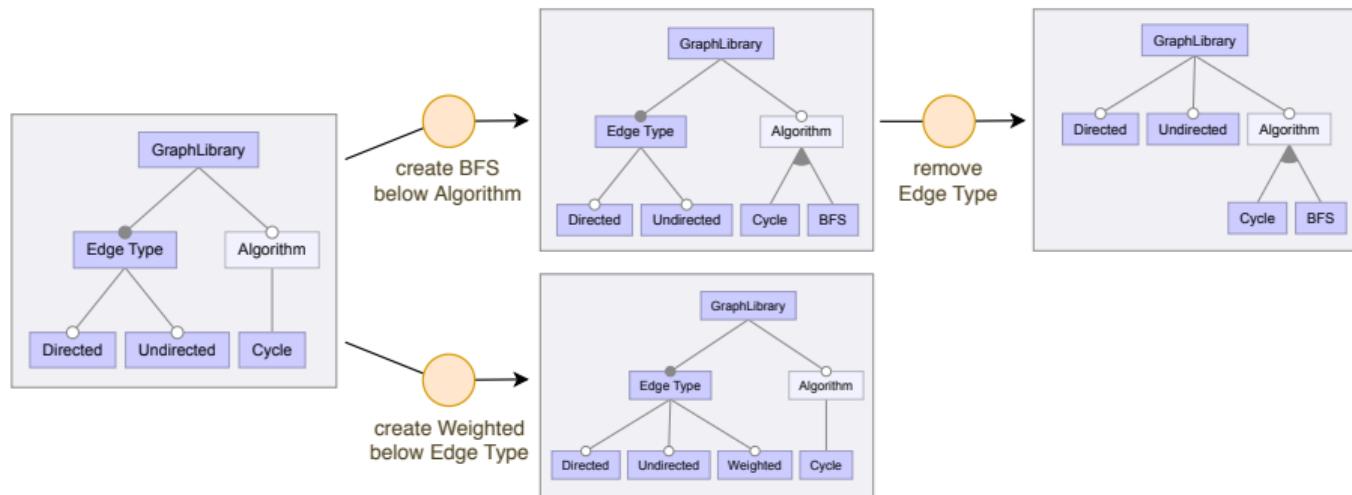
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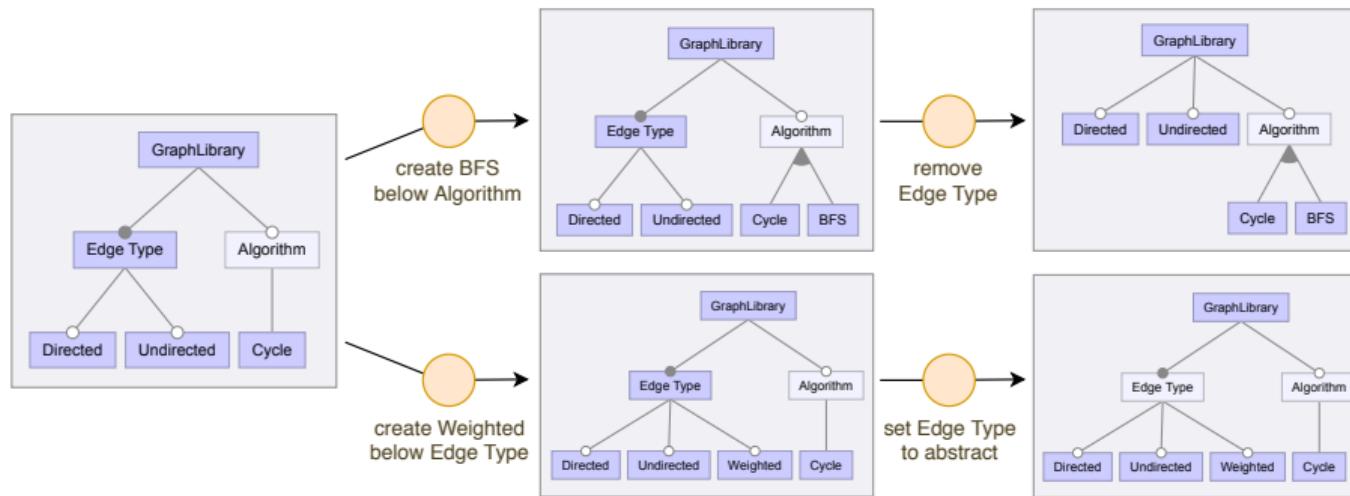
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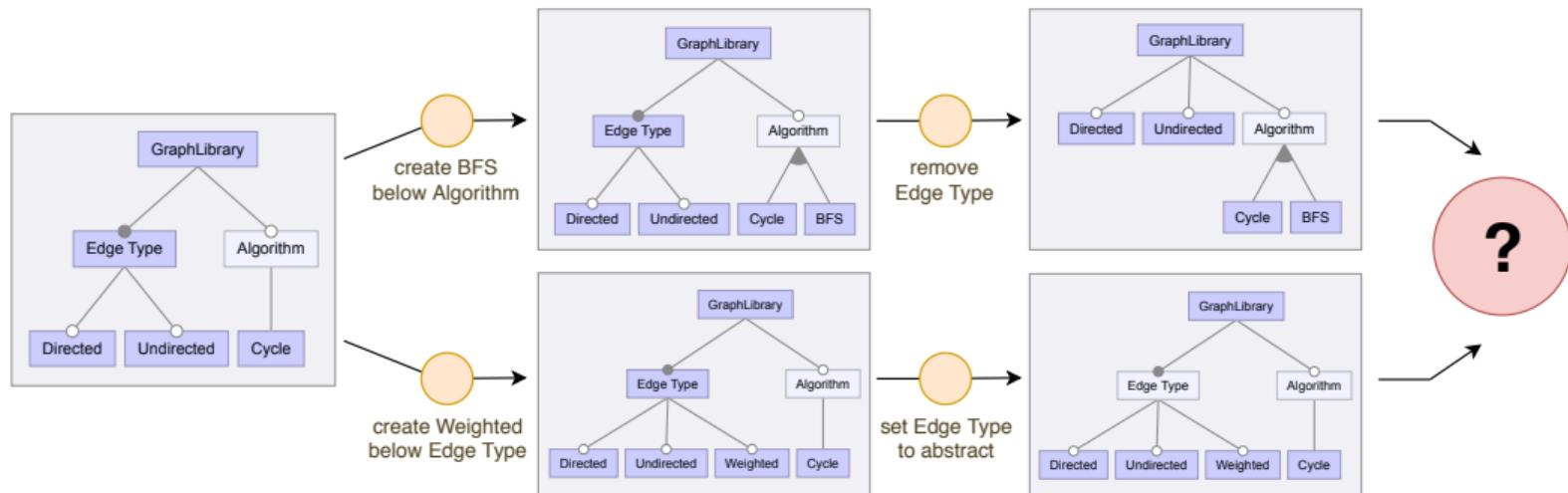
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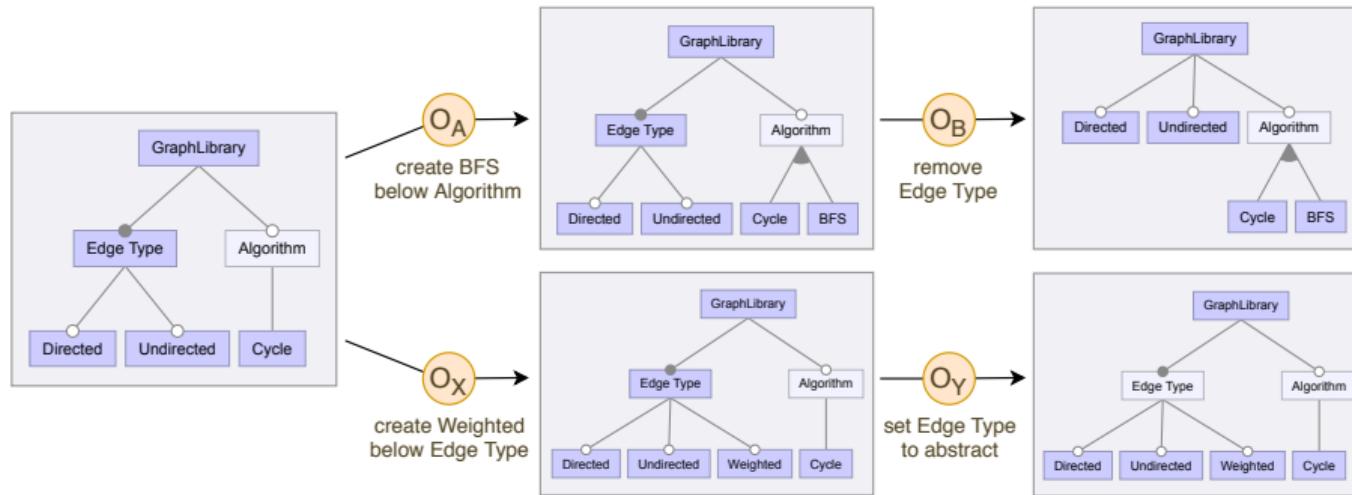
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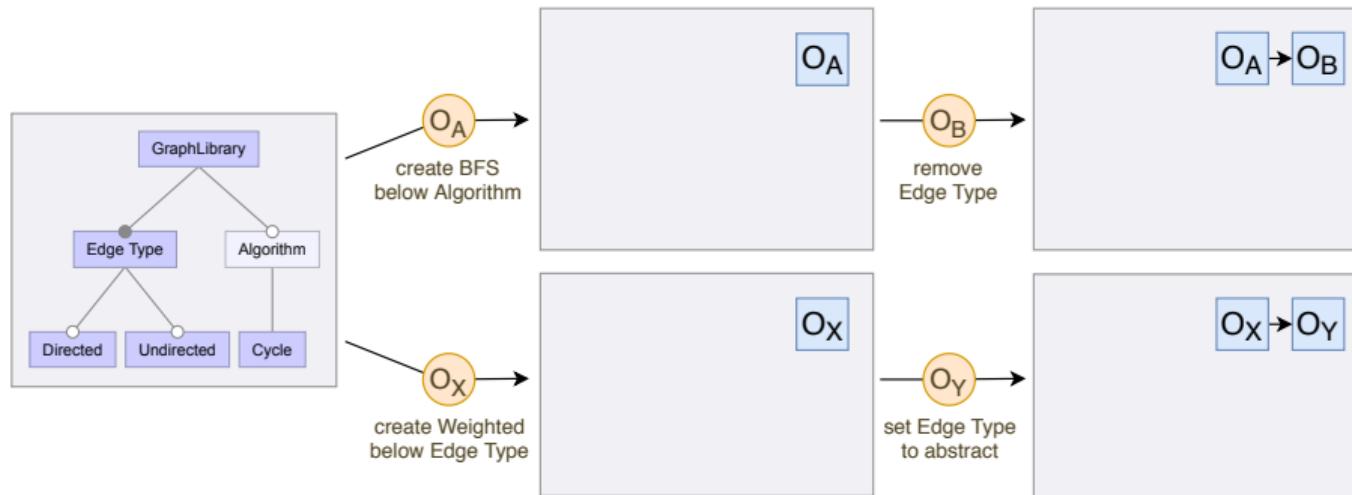
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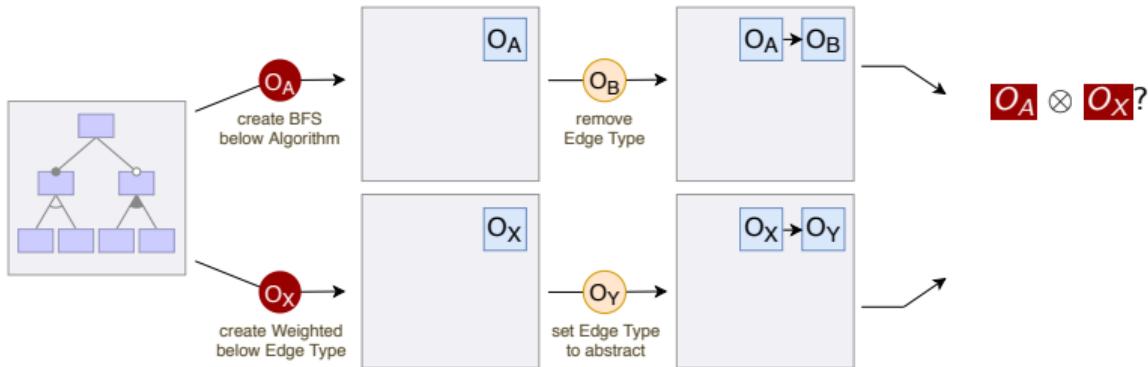
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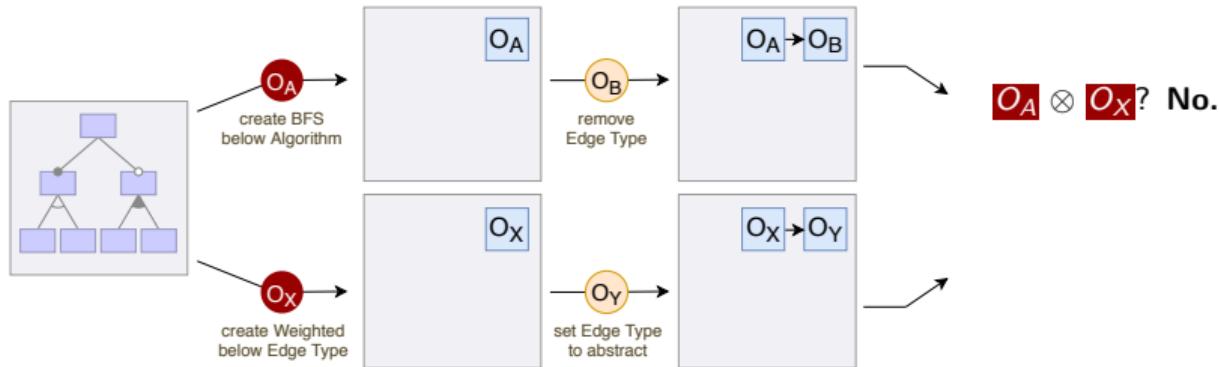
Concurrent Feature-Model Edits – Conflict Detection



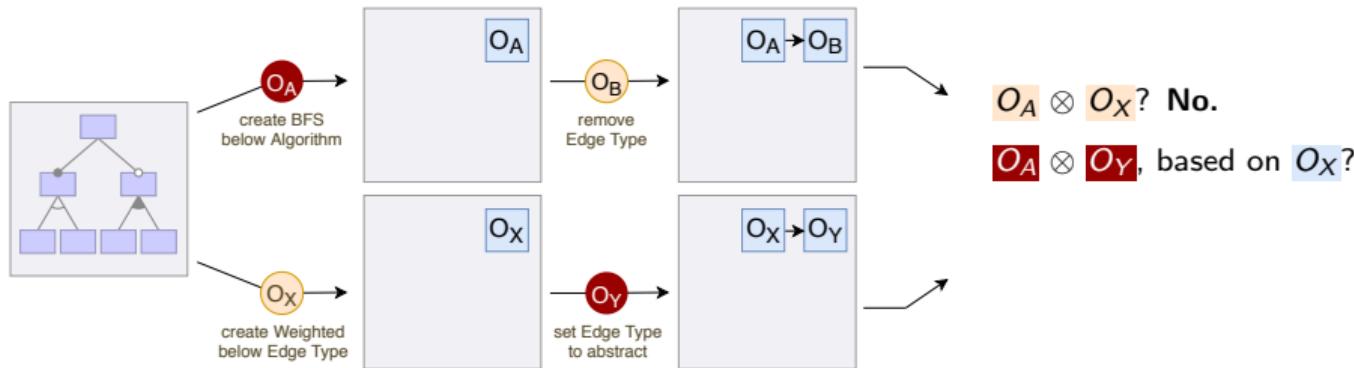
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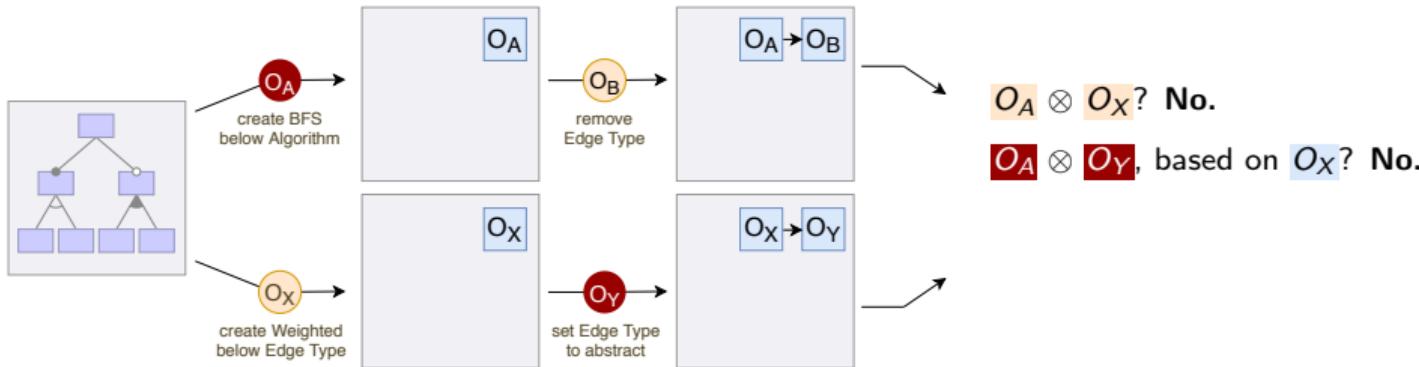
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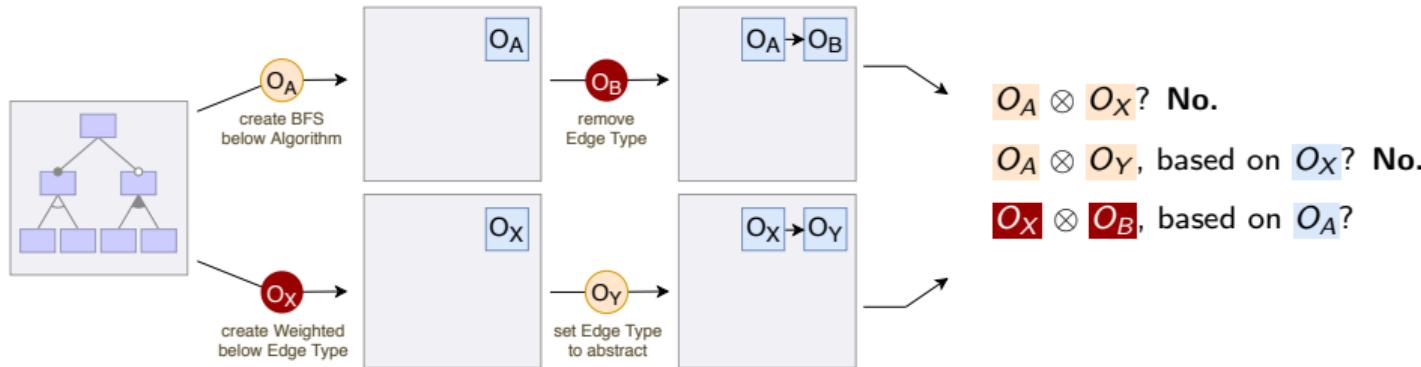
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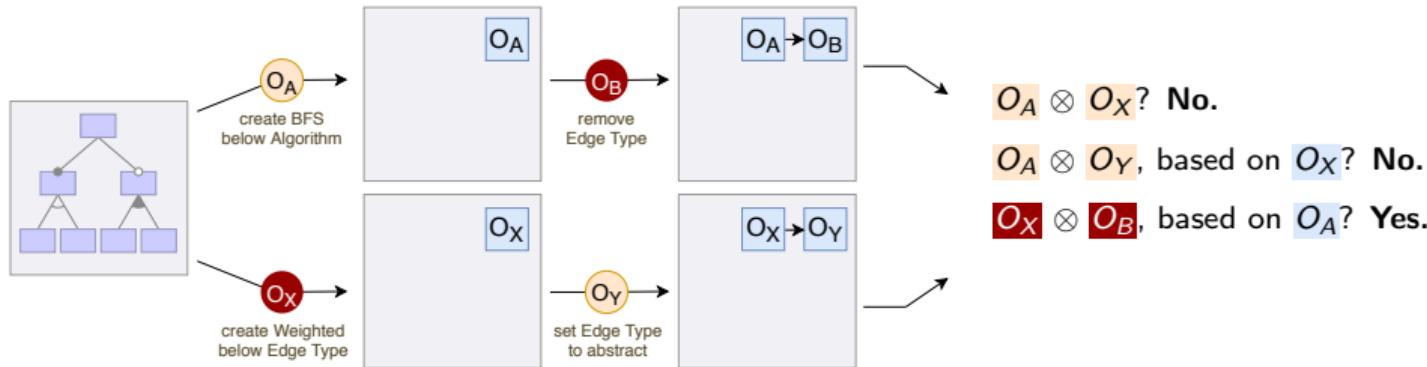
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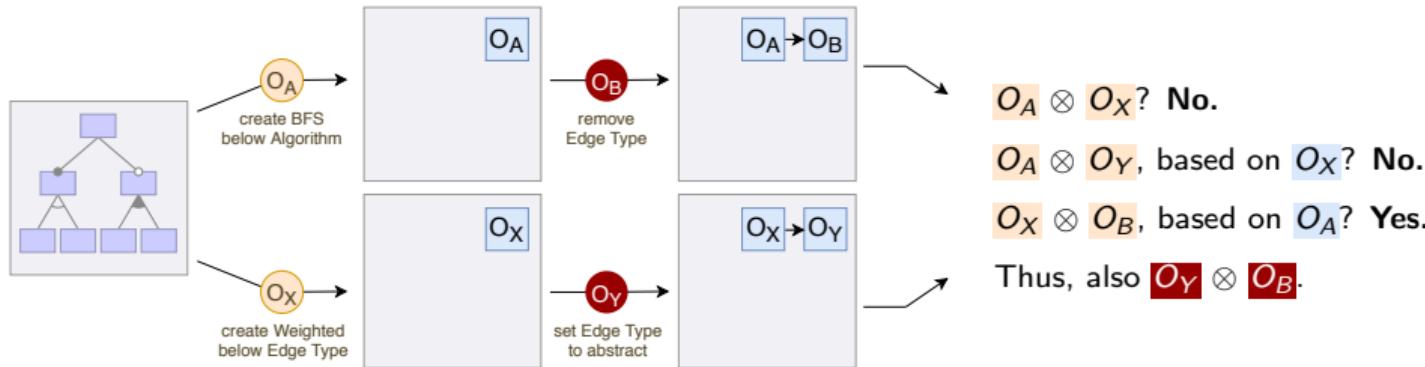
Concurrent Feature-Model Edits – Conflict Detection



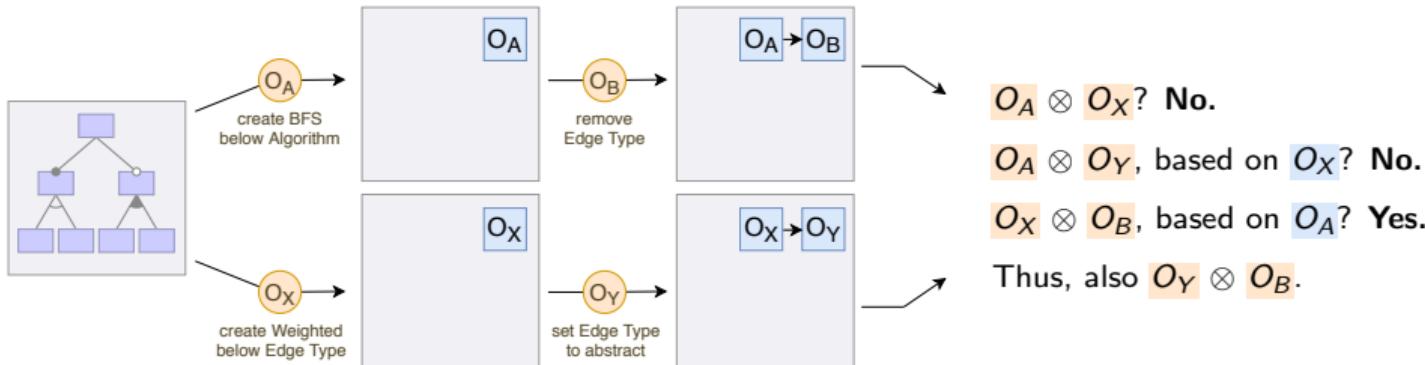
Concurrent Feature-Model Edits – Conflict Detection



Concurrent Feature-Model Edits – Conflict Detection



Concurrent Feature-Model Edits – Conflict Detection



multi-version multi-display yields:

$$\left\{ \left[O_A, O_B \right], \left[O_A, O_X, O_Y \right] \right\}$$

(min. #versions, max. #operations)

Concurrent Feature-Model Edits in variED

The screenshot shows the variED interface with two versions of a feature model side-by-side.

Version A

- Floral Truth has removed the feature BFS.
7 minutes ago
- + Floral Truth has created a feature below Algorithm.
5 minutes ago
 - + You have created a feature below Edge Type.
Conflict: The new parent feature **Edge Type** targeted by one operation is removed by the other.
6 minutes ago
 - (Floral Truth has set name of the feature New Feature to BFS.
5 minutes ago)
 - (You have set name of the feature New Feature to Weighted.
Conflict: The new parent feature **Edge Type** targeted by one operation is removed by the other.
6 minutes ago)
 - (You have set abstract? of the feature Edge Type to true.
Conflict: The new parent feature **Edge Type** targeted by one operation is removed by the other.
5 minutes ago)

Version B

- Floral Truth has removed the feature BFS.
7 minutes ago
- + Floral Truth has created a feature below Algorithm.
5 minutes ago
 - (Floral Truth has set name of the feature New Feature to BFS.
5 minutes ago)
 - Floral Truth has removed the feature Edge Type.
3 conflicts: The new parent feature **Edge Type** targeted by one operation is removed by the other. The new parent feature **Edge Type** targeted by one operation is removed by the other. The new parent feature **Edge Type** targeted by one operation is removed by the other.
5 minutes ago

Bottom Buttons:

- Vote
- Vote

Concurrent Feature-Model Edits in variED

The screenshot shows the variED interface with two columns of edits:

Version A

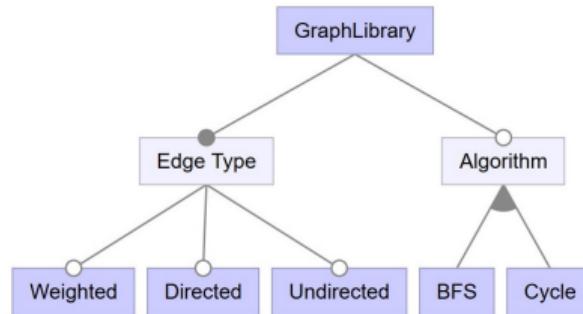
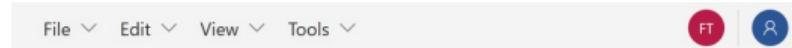
- You have removed the feature **BFS**.
9 minutes ago
- + **Damp Dew** has created a feature below **Edge Type**.
Conflict: The children features of the feature **Edge Type** have changed unexpectedly.
8 minutes ago
- + You have created a feature below **Algorithm**.
8 minutes ago
- / **Damp Dew** has set **name** of the feature **New Feature** to **Weighted**.
Conflict: The children features of the feature **Edge Type** have changed unexpectedly.
8 minutes ago
- / You have set **name** of the feature **New Feature** to **BFS**.
7 minutes ago
- / **Damp Dew** has set **abstract?** of the feature **Edge Type** to **true**.
Conflict: The children features of the feature **Edge Type** have changed unexpectedly.
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Version B

- You have removed the feature **BFS**.
9 minutes ago
- + You have created a feature below **Algorithm**.
8 minutes ago
- / You have set **name** of the feature **New Feature** to **BFS**.
7 minutes ago
- You have removed the feature **Edge Type**.
3 conflicts: The children features of the feature **Edge Type** have changed unexpectedly. The children features of the feature **Edge Type** have changed unexpectedly. The children features of the feature **Edge Type** have changed unexpectedly.
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Vote

Concurrent Feature-Model Edits in variED



Evaluation – Methodology

Survey Design

- gain **qualitative insights** on collaboration from feature-modeling experts
- gain feedback on the **usability** of the tool
- **survey** with 15 questions
- tool tested freely and with predefined tasks

General Feature Modeling Experience

- Q₁ What have been your involvements in feature modeling?
 Developer Modeler Researcher Domain Expert Student Lecturer Other
- Q₂ What is your experience in feature modeling in the following roles?
Likert scale (0 - no experience, 5 expert) for roles: teaching, studying, academic, industrial
- Q₃ How many features do your feature models contain, on average?
 <50 50–100 100–500 500+
- ### Collaborative Feature Modeling Practices
- Q₄ What is your experience in collaborative feature modeling?
 Personally involved Observing/studying Second-hand None Other
- Q₅ For what use cases do you use collaborative feature modeling and why?
Free text
- Q₆ How often do you edit feature models collaboratively?
Likert scale (0 - never, 5 - frequently)
- Q₇ With how many people do you edit a feature model in a collaborative fashion, on average?
Free text
- Q₈ What strategy do you employ for collaborative feature modeling and what systems do you use?
Free text
- Q₉ How satisfied are you with the implemented strategy?
 Very <un->satisfied <Un->Satisfied Slightly <un->satisfied Not applicable
- Q₁₀ What problems do you face during collaborative feature modeling?
Free text
- Q₁₁ In what use cases do you not apply collaborative feature modeling and why?
Free text
- ### Tool
- Q₁₂ How satisfied are you with the tool?
 Very <un->satisfied <Un->Satisfied Slightly <un->satisfied
- Q₁₃ What functionalities of the tool could be improved or are missing with regard to collaborative feature modeling?

Evaluation – Methodology

Survey Design

- gain **qualitative insights** on collaboration from feature-modeling experts
- gain feedback on the **usability** of the tool
- **survey** with 15 questions
- tool tested freely and with predefined tasks

Survey Responses

- 8 supervised participants (in 4 live sessions)
- 9 unsupervised participants
- **17 responses** in total (from Austria, Brazil, France, Germany, Spain, Sweden, and the United States)

General Feature Modeling Experience

Q1 What have been your involvements in feature modeling?
 Developer Modeler Researcher Domain Expert Student Lecturer Other

Q2 What is your experience in feature modeling in the following roles?

Likert scale (0 - no experience, 5 expert) for roles: teaching, studying, academic, industrial

Q3 How many features do your feature models contain, on average?

<50 50–100 100–500 500+

Collaborative Feature Modeling Practices

Q4 What is your experience in collaborative feature modeling?

Personally involved Observing/studying Second-hand None Other

Q5 For what use cases do you use collaborative feature modeling and why?

Free text

Q6 How often do you edit feature models collaboratively?

Likert scale (0 - never, 5 - frequently)

Q7 With how many people do you edit a feature model in a collaborative fashion, on average?

Free text

Q8 What strategy do you employ for collaborative feature modeling and what systems do you use?

Free text

Q9 How satisfied are you with the implemented strategy?

Very <un->satisfied <Un->Satisfied Slightly <un->satisfied Not applicable

Q10 What problems do you face during collaborative feature modeling?

Free text

Q11 In what use cases do you not apply collaborative feature modeling and why?

Free text

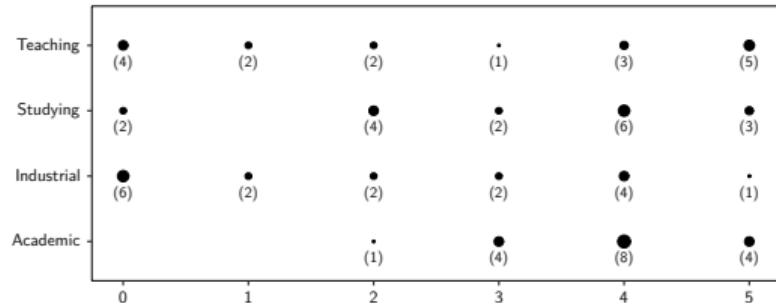
Tool

Q12 How satisfied are you with the tool?

Very <un->satisfied <Un->Satisfied Slightly <un->satisfied

Q13 What functionalities of the tool could be improved or are missing with regard to collaborative feature modeling?

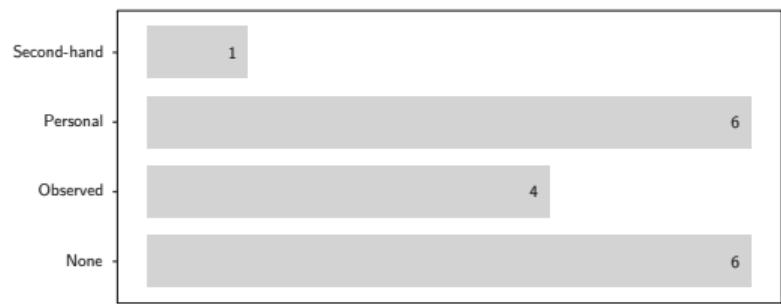
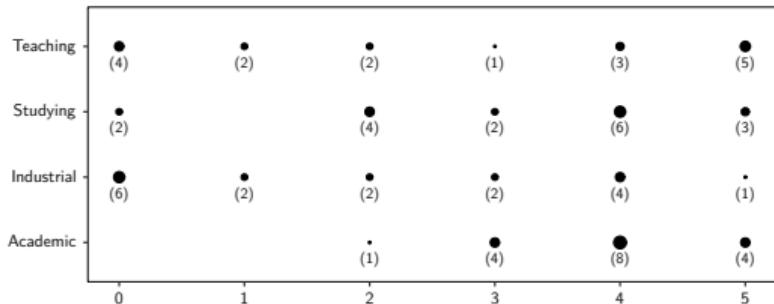
Evaluation – Participants



Experiences with Feature Modeling

- everyone had **academic** experience
- 9 also had **industrial** experience
- 9 edited small feature models (< 50 features)
- 7 had experience with 50 – 500 features

Evaluation – Participants



Experiences with Feature Modeling

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Experiences with Collaborative Feature Modeling

- 11 had experience ⇒ **collaboration insights**
- 6 had no experience ⇒ **usability feedback**

Evaluation – Results

Identified Use Cases

- step-wise refinement, brainstorming, requirements analysis, on-the-fly changes
- teaching, customer support, workshops
- collaboration may not occur frequently
- up to 10 stakeholders

Identified Collaboration Strategies

- face-to-face collaboration, pair-modeling
- version-control systems

⇒ aligns with the literature and our expectations

Evaluation – Results

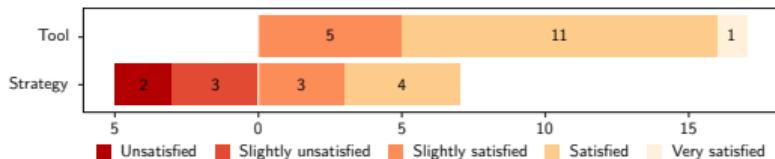
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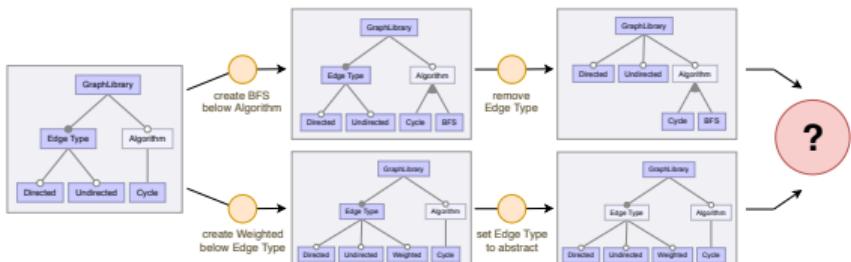
Feedback on Usability

- **positive feedback**, but there are limitations
- suited for sketching a feature model, discussing changes, remote work, ...
- less suited for offline work, versioning, ...
- lacks convenience features (e.g., undo/redo)

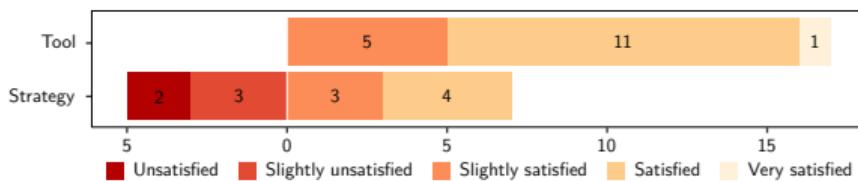
⇒ aligns with pros/cons of Google Docs and Overleaf

Conclusion

Conflict Detection for Concurrent Feature-Model Edits



Usability Study



Open-Source Prototype variED

The screenshot shows a graphical user interface for the variED prototype. The top menu includes File, Edit, View, More, and Help. The main area displays a feature model tree with nodes like 'Graph module', 'Bluetooth', 'local', 'single sensor', 'HCP module', 'compound', 'TA', 'Internet', and 'customer management'. A legend on the right defines symbols: blue square for HCP module, blue triangle for Bluetooth, blue circle for local, blue diamond for single sensor, blue hexagon for HCP module, blue square with a dot for compound, blue square with a triangle for TA, blue square with a circle for Internet, and blue square with a plus sign for customer management. A tooltip for 'customer management' explains it as a frontend to create, edit, and remove customers for commercial use. A status bar at the bottom right shows '59...'.

live demo at:



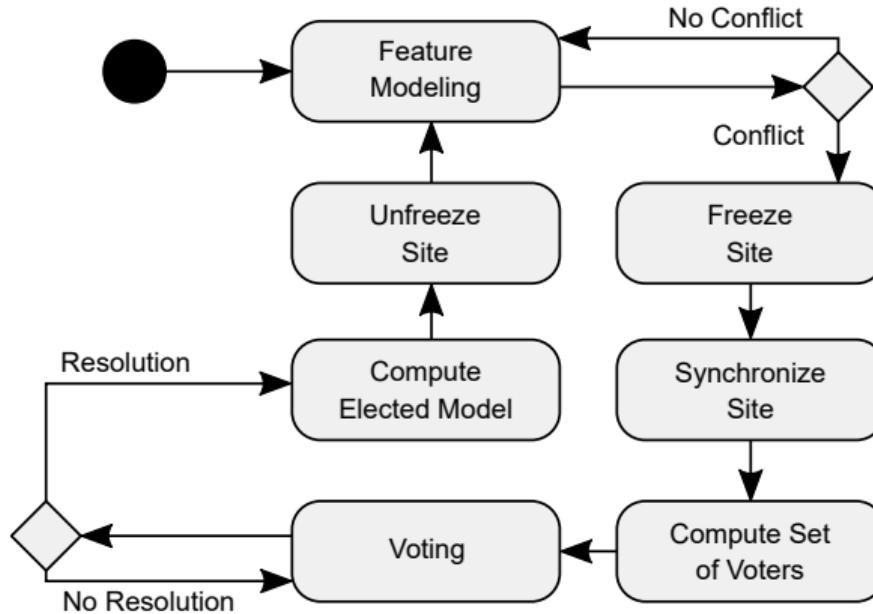
varied.herokuapp.com

find out more:

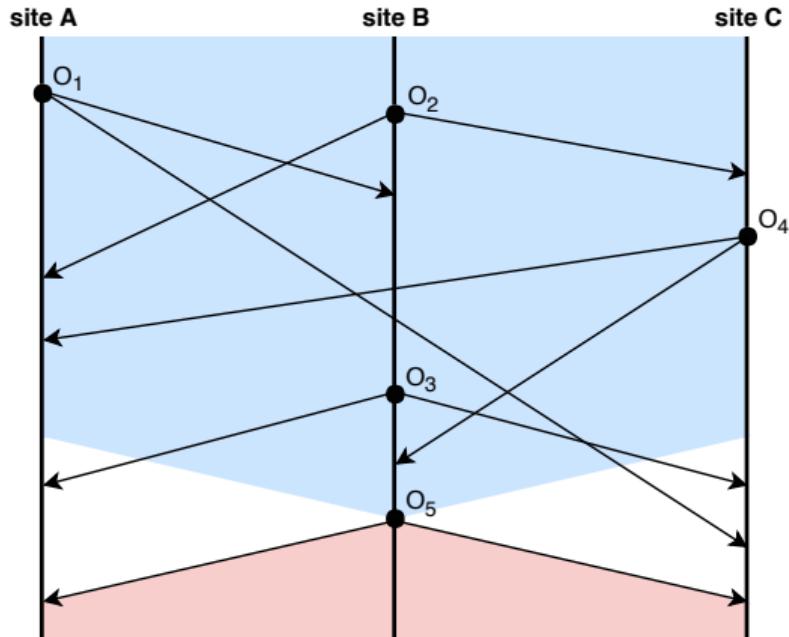


github.com/ekuiter/variED

Conflict Resolution



CCI Model

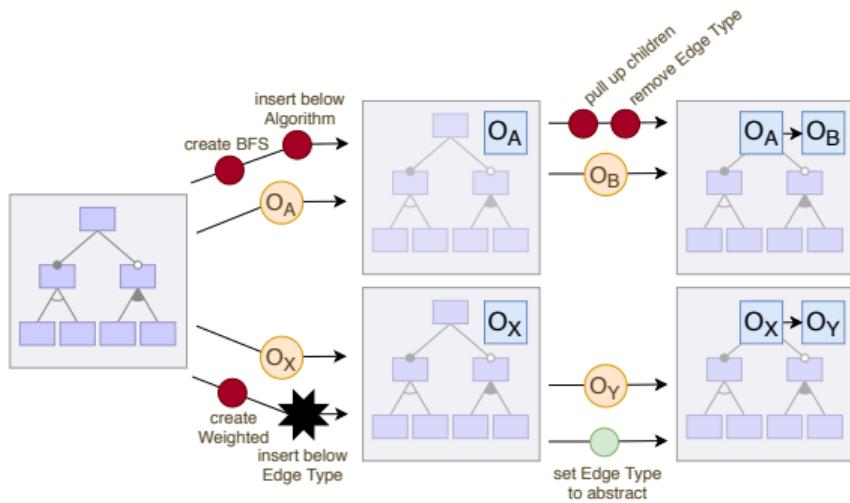


- Convergence
- Causality Preservation
- Intention Preservation

Concurrency Control

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

Primitive Operations



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.

Prototype Architecture

