

[Magdeburger Dom]

variED

An Editor for Collaborative, Real-Time Feature Modeling

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



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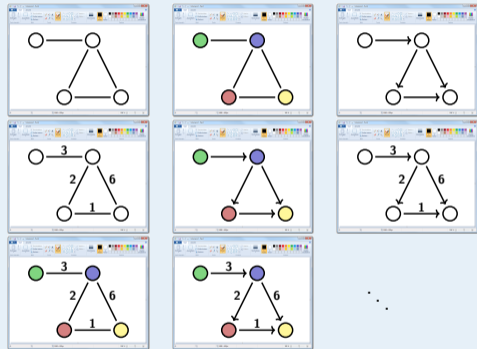
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▲ Hochschule Harz
Harz University of Applied Sciences

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

A Family of Graph Applications

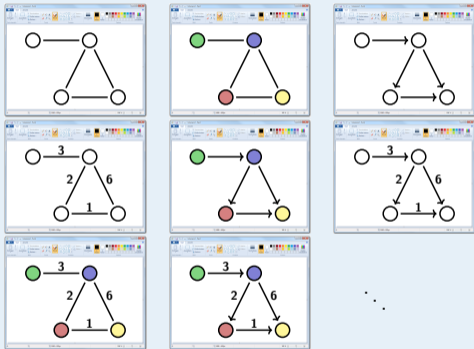


Product-Oriented Perspective

con: usually grows exponentially

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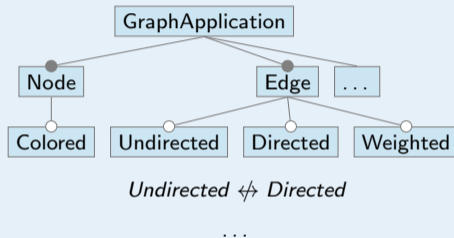
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Feature Model: Describes Variability Concisely

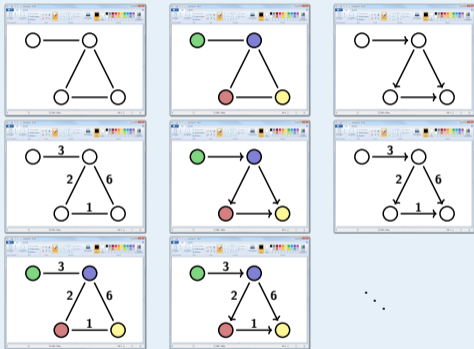


Feature-Oriented Perspective

pros: analyzable, management-friendly, ...

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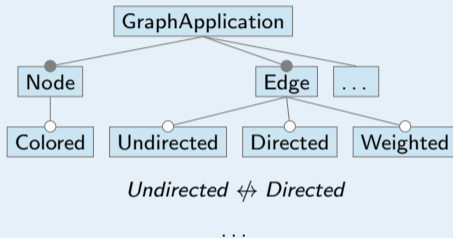
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Feature Modeling

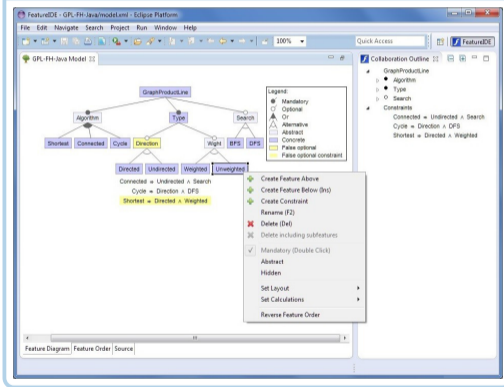
creating, maintaining, and evolving a feature model

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

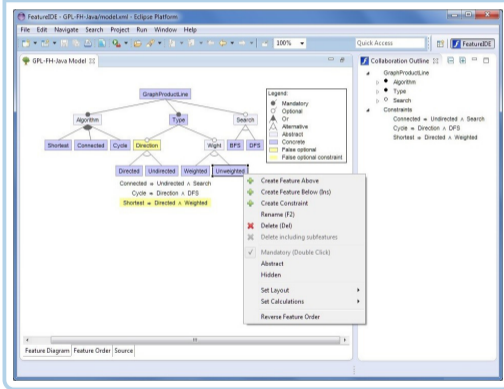
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Collaborative, Real-Time Feature Modeling

- 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

[Kuitert'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

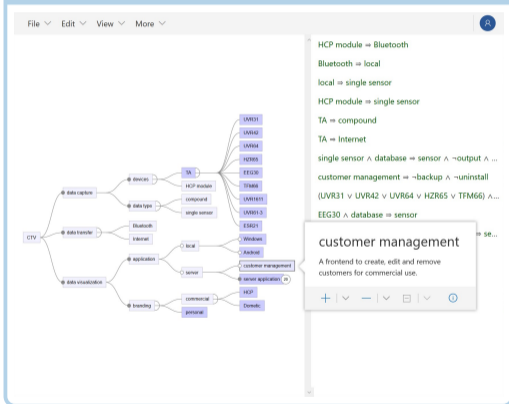
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variED: A Collaborative, Real-Time Feature-Model Editor



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

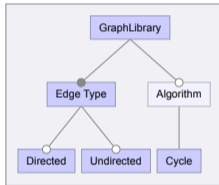
Assumptions

- 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**

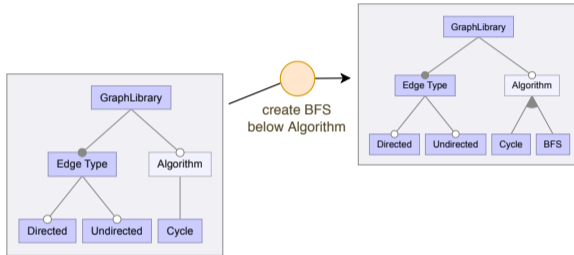
Requirements

- 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**

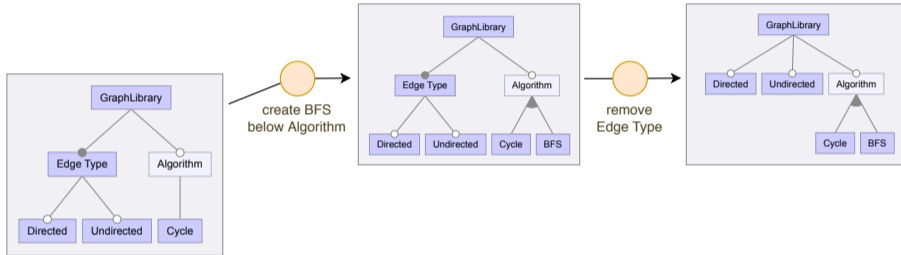
Concurrent Feature-Model Edits – Example



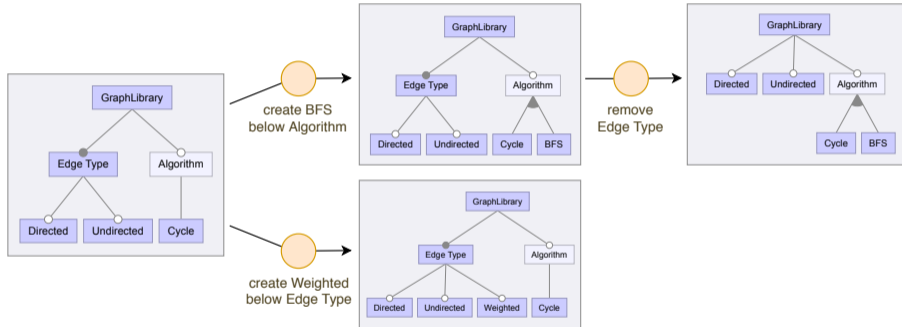
Concurrent Feature-Model Edits – Example



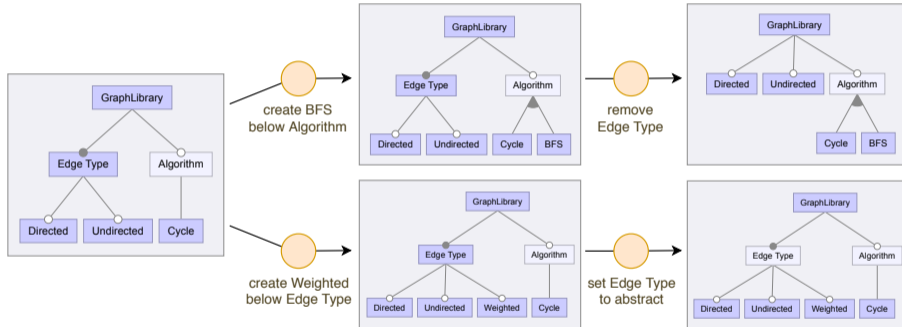
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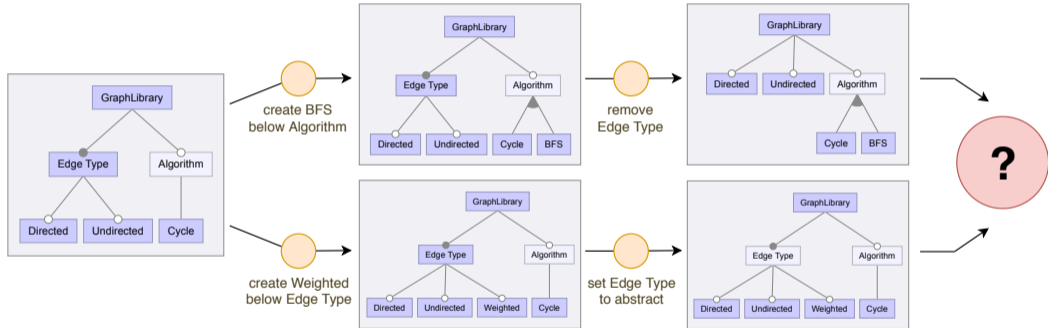
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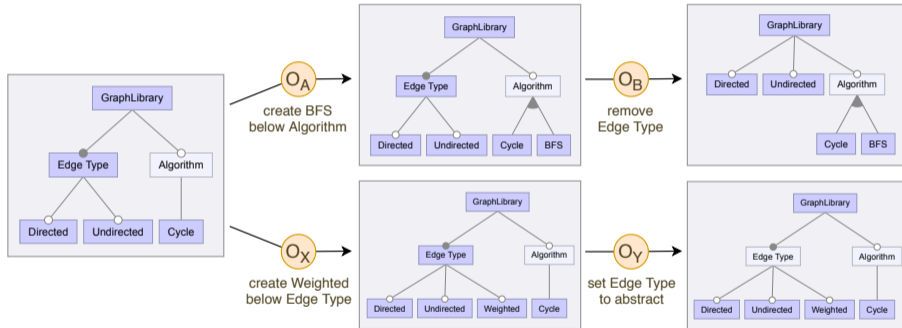
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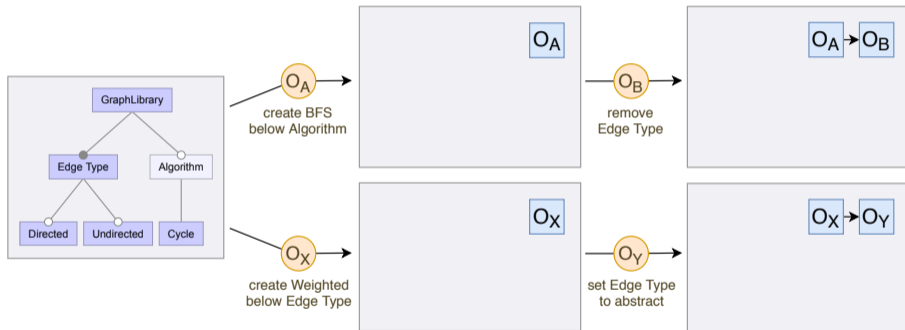
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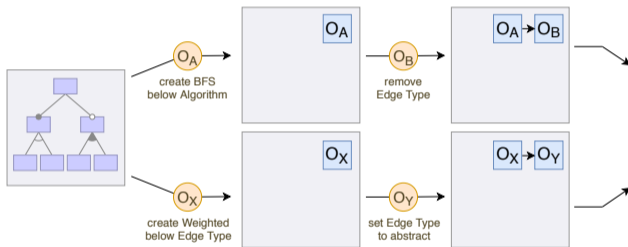
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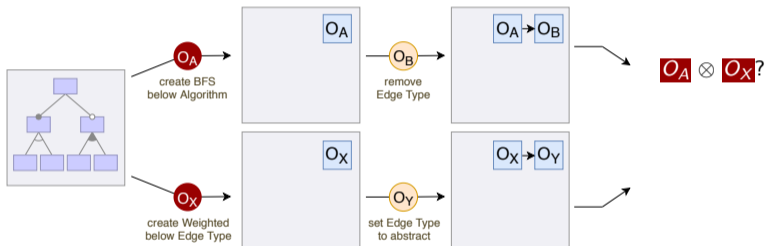
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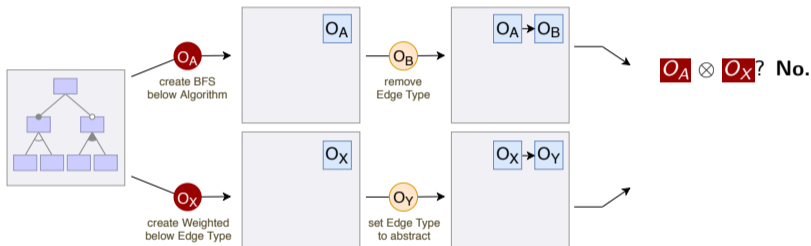
Concurrent Feature-Model Edits – Conflict Detection



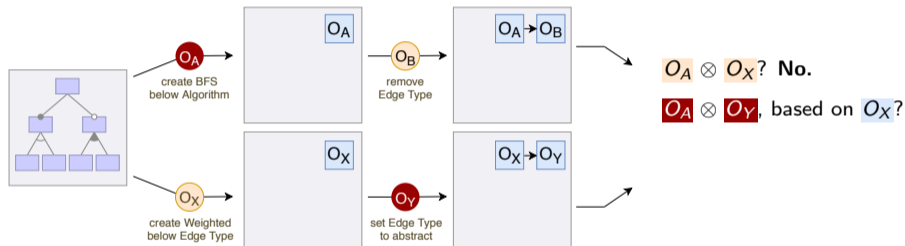
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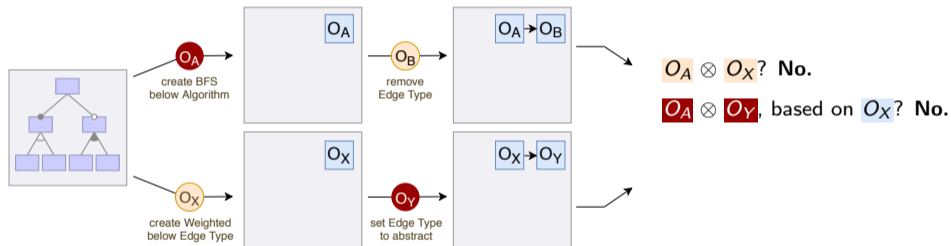
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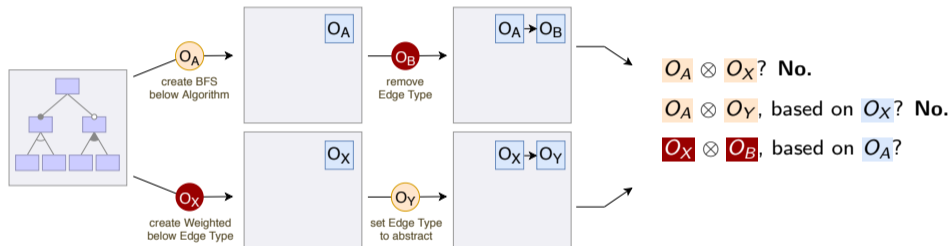
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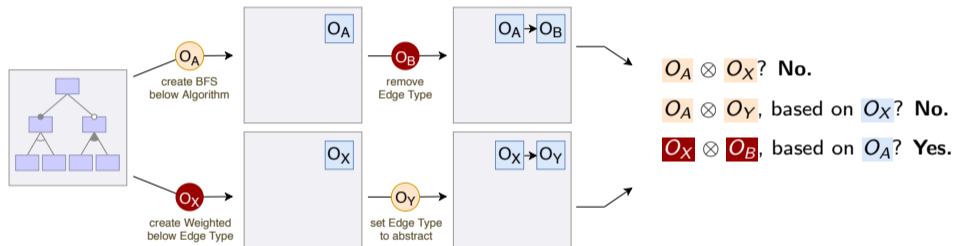
Concurrent Feature-Model Edits – Conflict Detection



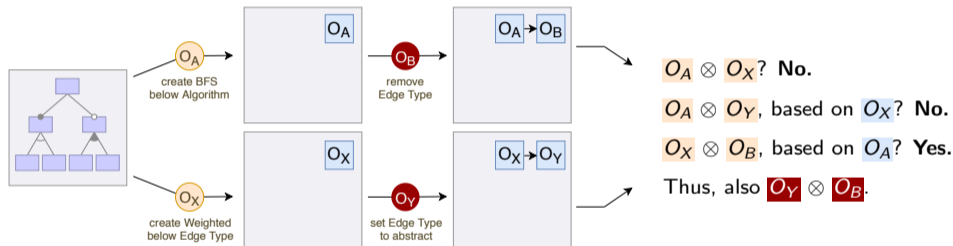
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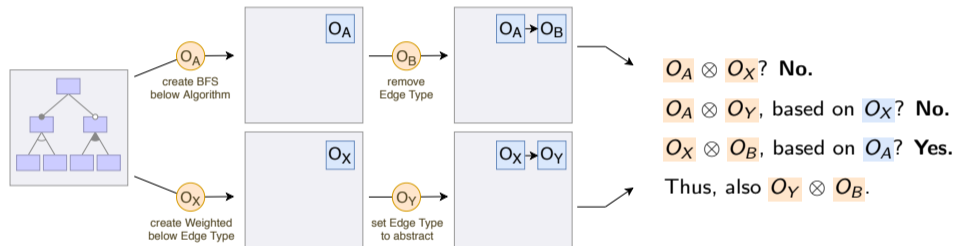
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Concurrent Feature-Model Edits – Conflict Detection



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 displays the variED interface with a top menu bar containing 'File' and 'Tools' dropdowns, and user profile icons for 'FT' and another user. The main content area is titled 'Conflicts detected!' and features a 'Discard all conflicts' button. It is divided into two columns: 'Version A' and 'Version B'. Each column lists several changes made by 'Floral Truth', such as removing or creating features and setting names. Three specific conflicts are highlighted in pink boxes, each with a pencil icon and a 'Conflict' message explaining that a new parent feature is being removed by another operation. At the bottom of each column is a 'Vote' button with a ballot icon.

File ▾ Tools ▾ FT [User Icon]

Conflicts detected!

✕ Discard all conflicts

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

✎ Vote

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

✎ Vote

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The screenshot displays the variED interface with a top navigation bar containing 'File' and 'Tools' menus, and user avatars for 'DD' and another user. The main content area is titled 'Conflicts detected!' and includes a 'Discard all conflicts' button. It is divided into two columns: 'Version A' and 'Version B'. Each column lists several changes and conflicts. A 'Vote' button is present at the bottom of each column, with the 'Vote' button in the 'Version A' column circled in blue. The interface also shows a vertical scrollbar on the right side.

File ▾ Tools ▾

DD [Avatar]

Conflicts detected!

✕ Discard all conflicts

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**.
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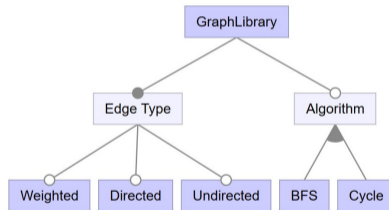
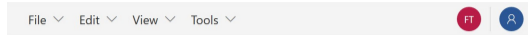
Vote

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**.
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7 minutes ago

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?
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Tool

- Q12 How satisfied are you with the tool?
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- Q13 What functionalities of the tool could be improved or are missing with regard to collaborative feature modeling?

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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)

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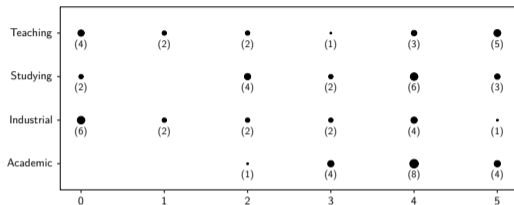
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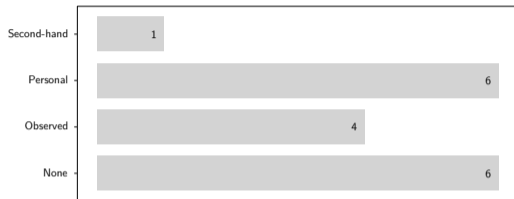
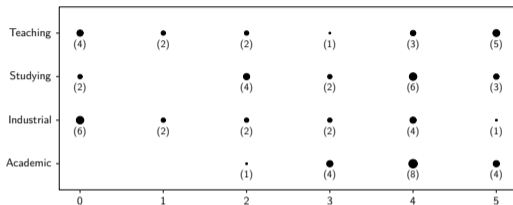
Evaluation – Participants



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



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Experiences with Collaborative Feature Modeling

- 11 had experience \Rightarrow **collaboration insights**
- 6 had no experience \Rightarrow **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

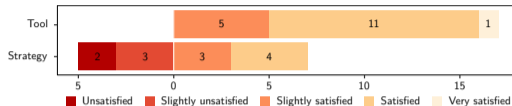
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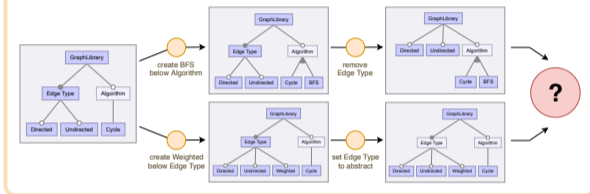
Feedback on Usability

- **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)

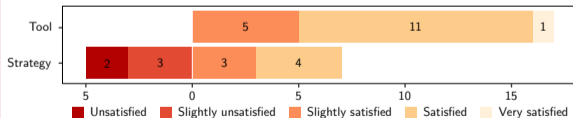
⇒ aligns with pros/cons of Google Docs and Overleaf

Conclusion

Conflict Detection for Concurrent Feature-Model Edits



Usability Study



Open-Source Prototype variED

The screenshot shows the **variED** interface with a hierarchical tree view on the left and a list of feature constraints on the right. The constraints include:

- HCP module = Bluetooth
- Bluetooth = local
- local = single sensor
- HCP module = single sensor
- TA = compound
- TA = Internet
- single sensor ^ database = sensor ^ ~output A ...
- customer management = ~backup ^ ~uninstall
- (UVR31 v UVR42 v UVR64 v H2865 v TF666) A ...
- EGG30 ^ database = sensor

The interface also shows a search bar and a list of feature names like **customer management**.

live demo at:



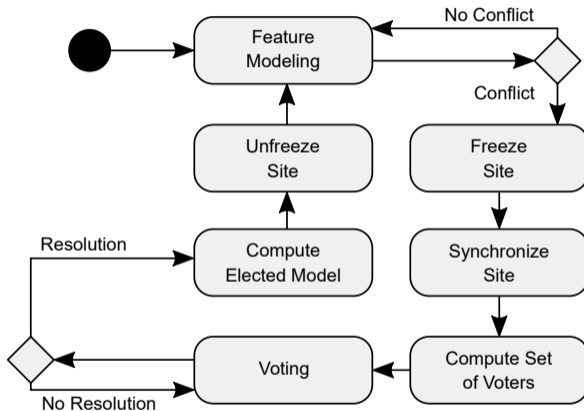
`varied.herokuapp.com`

find out more:

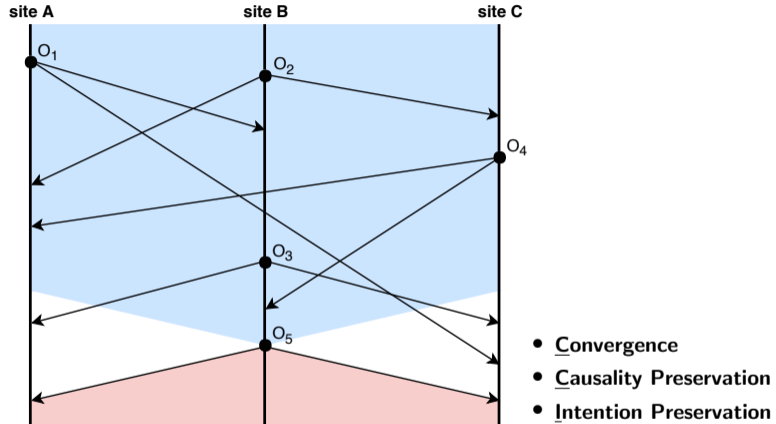


`github.com/ekuiter/variED`

Conflict Resolution



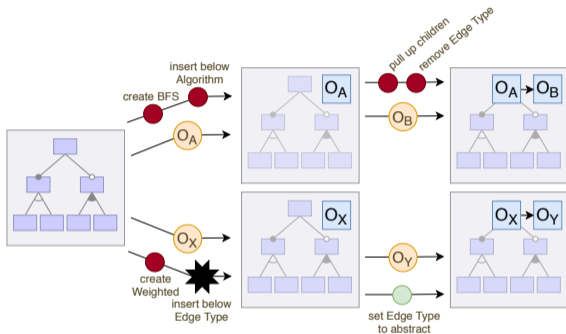
CCI Model



Concurrency Control

	<i>Turn-Taking</i>	<i>Locking</i>	<i>CRDTs</i>	<i>Serialization</i>	<i>OT</i>	<i>MVSD</i>	<i>MVMD</i>
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

