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Universal Language Server Protocol and Debugger Adapter Protocol for Modular Language Workbenches

Federico Bruzzone

Università degli Studi di Milano
Computer Science Department
PhD Candidate in Computer Science

22/07/2024
Cyclus 40th

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Programming Language Implementation

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The implementation of a programming language is a complex task that involves several implementation aspects, such as:

- Syntax and semantics definition
- Type system definition
- Code generation
- Error handling
- IDE support
- Documentation

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- Syntax and semantics definition
- Type system definition
- Code generation
- Error handling
- IDE support
- Documentation

It is usually done in a monolithic way with a top-down approach, where all the aspects are tightly coupled.

This makes the maintainability, extensibility and reusability of the implementation difficult.

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In 2016, Microsoft in collaboration with Red Hat introduced the Language Server Protocol (LSP) and the Debugger Adapter Protocol (DAP).

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The LSP and DAP are JSON-RPC based protocols that allow the communication between a Language Server and an IDE.

LSP and DAP
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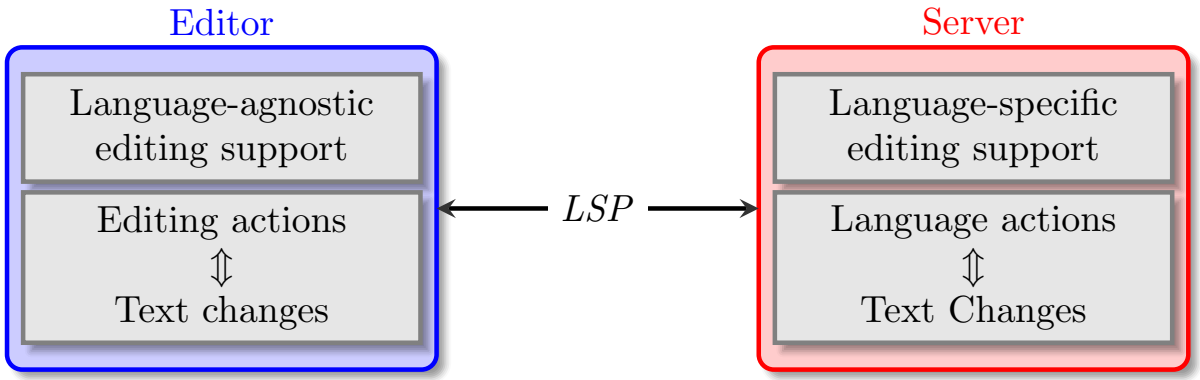

Intrinsic properties:

- Language-agnostic
- IDE-agnostic
- Asynchronous
- Text-based

Features:

- Diagnostics
- Hover
- Go to definition
- Find references

LSP and DAP
The Reduction of Combinations

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Initially implemented for Visual Studio Code, the LSP and DAP have been adopted by several IDEs and programming languages.

Universal LSP and DAP for Modular LWs
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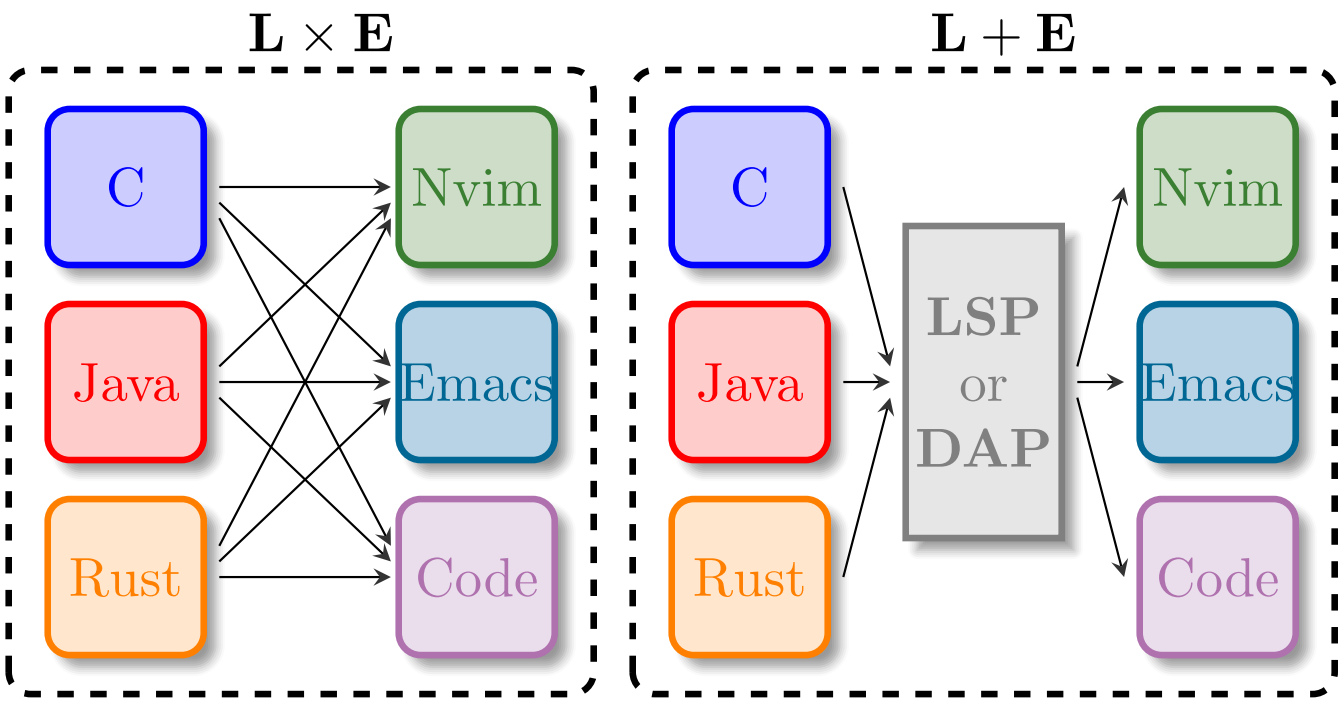

LSP and DAP
What would be an important achievement?

Universal LSP and DAP for Modular LWs

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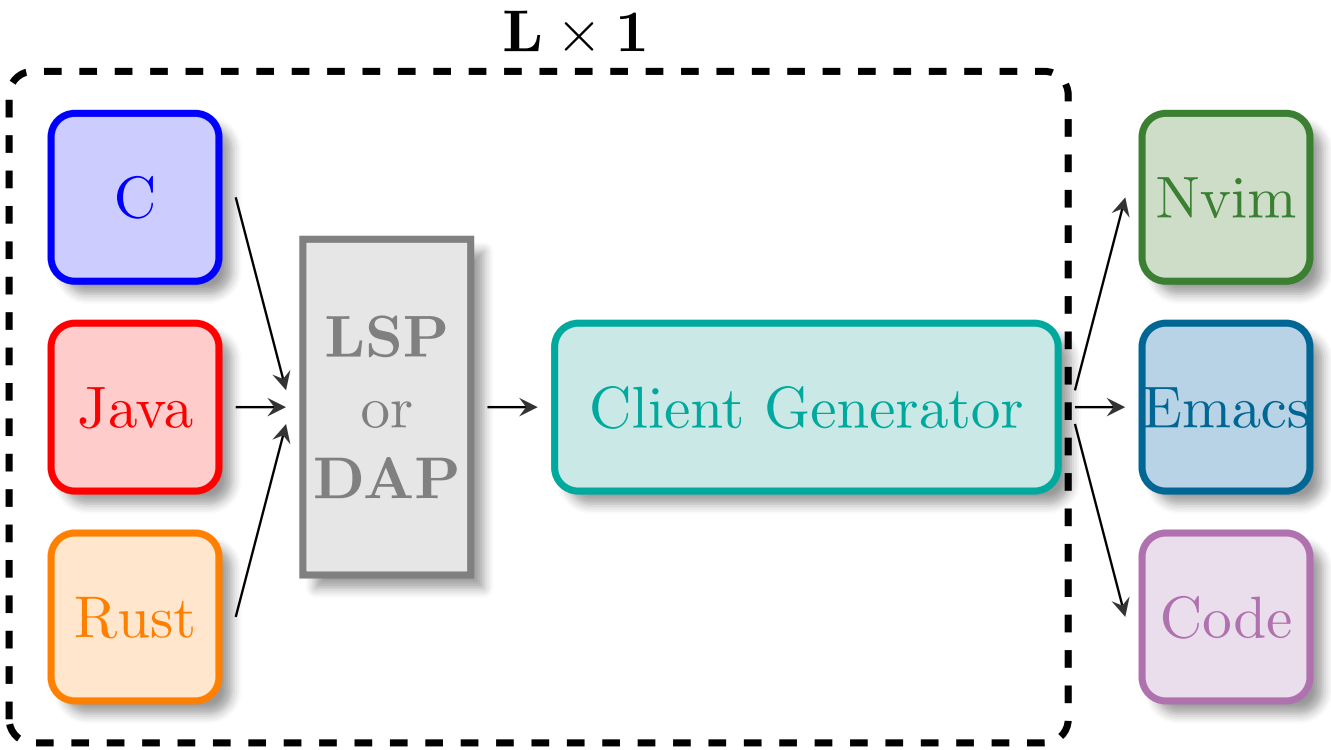
Reducing the number of combinations between Language Servers and IDEs.

LSP and DAP

What would be an important achievement?

Reducing the number of combinations between Language Servers and IDEs.



RO 1: Reduce to **L × 1** the number of combinations to support **L** languages

Feature-Oriented Programming

Universal LSP and DAP for Modular LWs

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Feature-Oriented Programming (FOP) is a programming paradigm that allows the development of software product lines (SPLs).

Feature-Oriented Programming

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Feature-Oriented Programming (FOP) is a programming paradigm that allows the development of software product lines (SPLs).

- Feature is a unit of functionality that satisfies a requirement.
- Feature Model is a model that represents the variability of the SPL.
- Feature Configuration is a set of features that compose a product.

RO 2: Facilitate LSP and DAP Modularization

Feature-Oriented Programming

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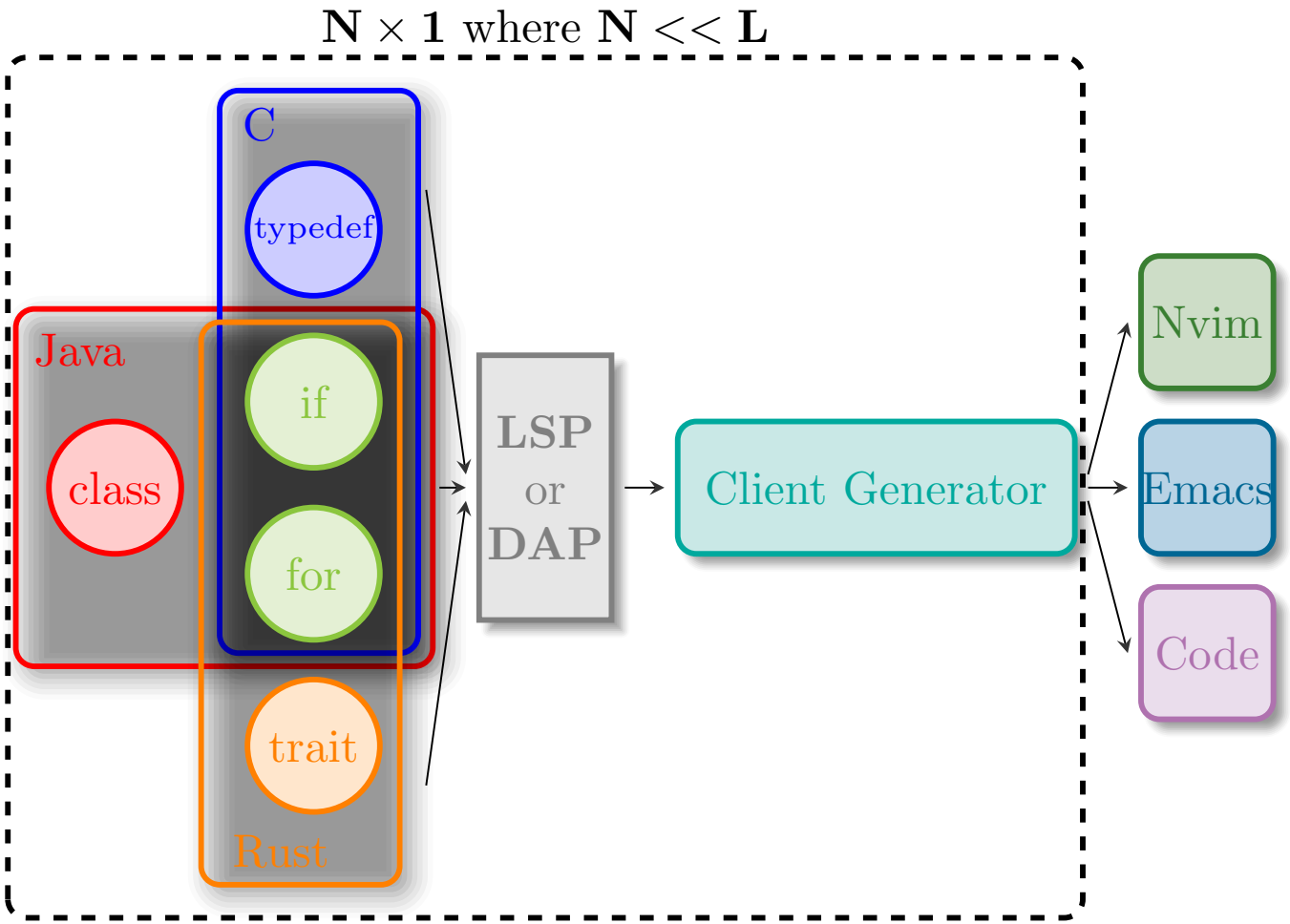

Language Workbenches

Language Workbenches (LWs) are tools that allow the development of programming languages, both GPLs and DSLs.

Language Workbench	Modularization Supp.	Precompiled Feature Supp.	Native IDE gen.	LSP & DAP Gen.	LSP & DAP Mod.
JustAdd	◐	○	○	○	○
Melange	◬	○	3rd p.	☆	☆
MontiCore	◐	◐	●	○	○
MPS	◬	○	●	☆	☆
Rascal	○	○	●	○	○
Spoofax	◬	◐	●	☆	☆
Xtext	○	◐	●	●	○
Neverlang	◊	●	○	★	★

- ● Full support
- ○ No support
- ◐ Limited support
- ◊ Fine-grained mod.
- ◬ Coarse-grained mod.
- ★ My expected contribution
- ☆ Extended contribution
- 3rd p. Third-party

RO 3: Improve IDE and LSP Generation

Scientific Contribution

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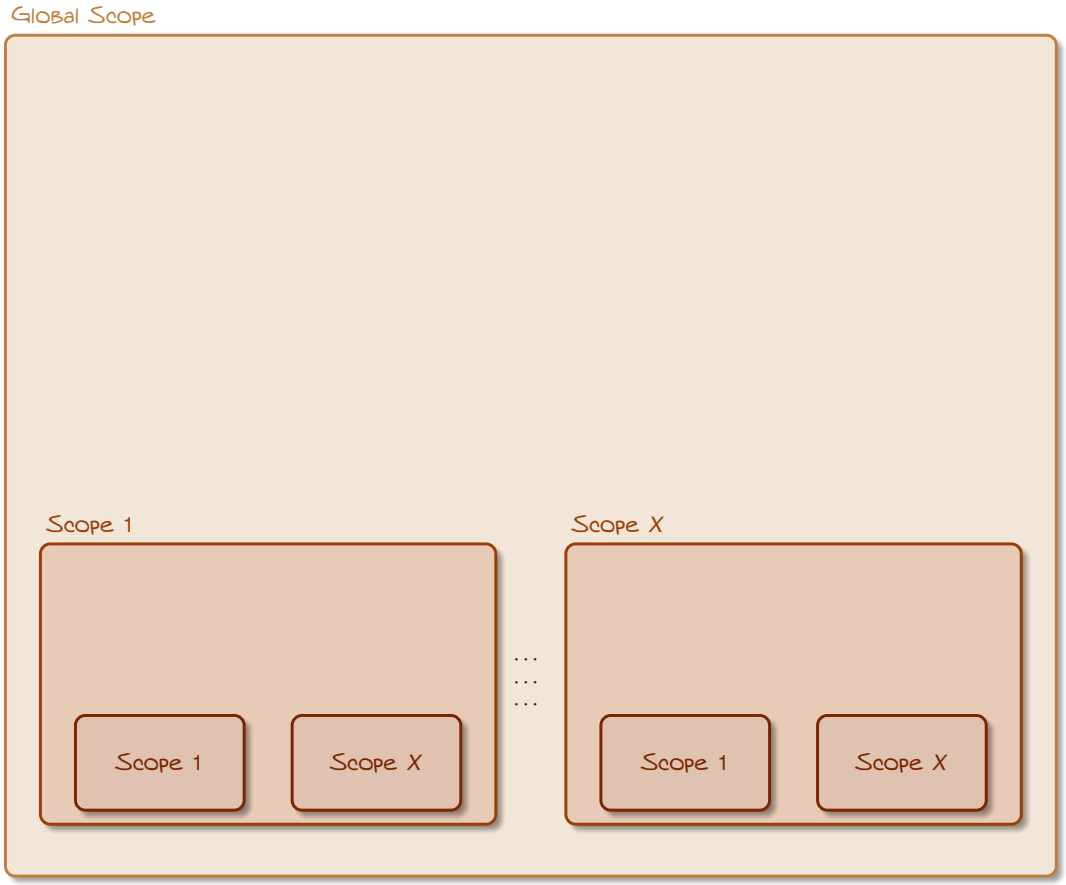
- Methodology for whole LWs that support at least component modularization.
- Type System, LSP and DAP Modularization.
- DSL for Type System definition.
- LSP and DAP generation for Neverlang languages.
- Clients and Syntax Highlighting generation reducing the number of combinations.
- Implementation of a Java Library for Neverlang to support the type system, LSP and DAP for every language developed with Neverlang.
- 3 use cases to show the effectiveness of the methodology.

RO 4: Leverage Neverlang for LSP and DAP in LPL Development

Scientific Contribution
Type System Components



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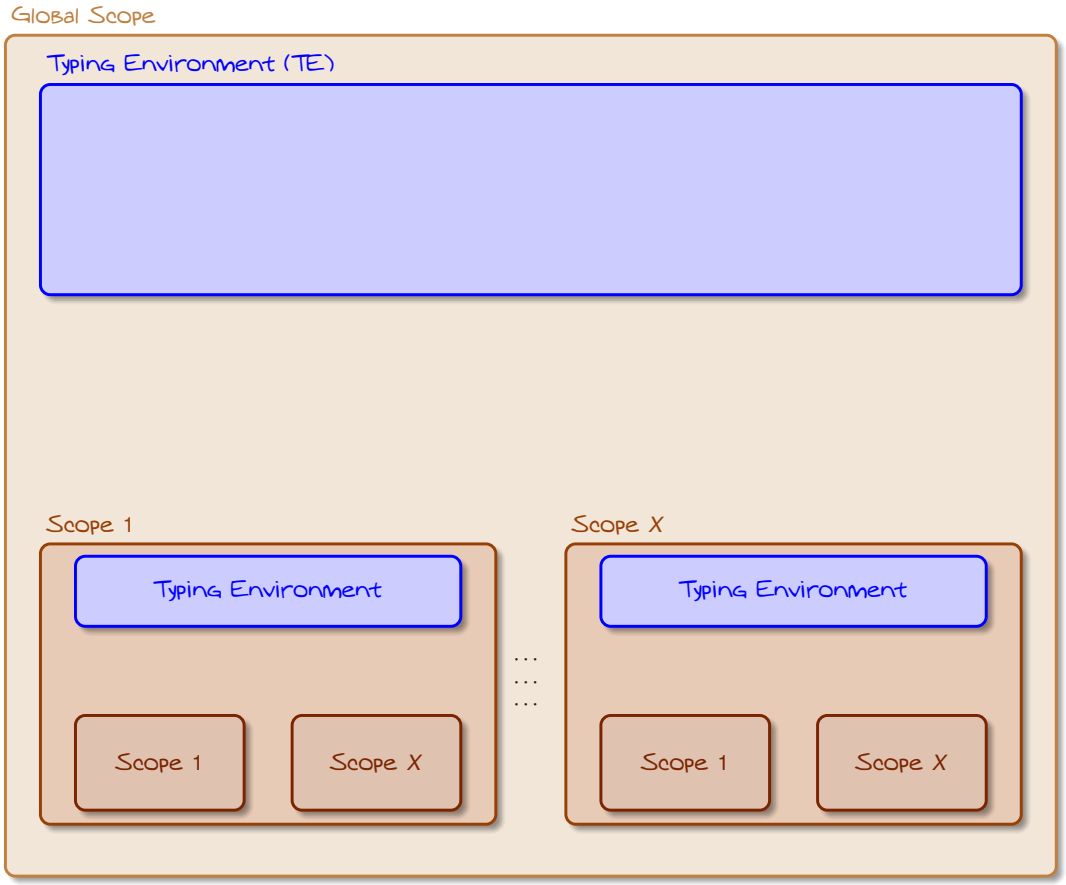

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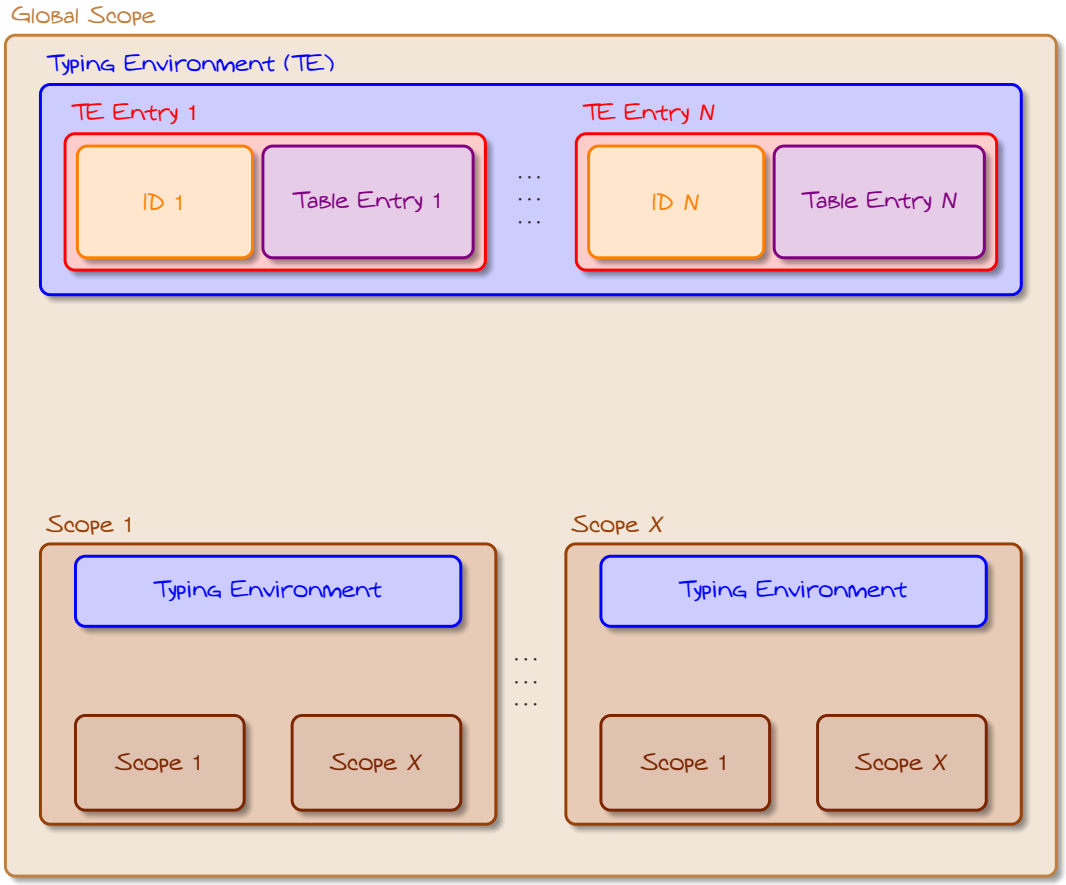

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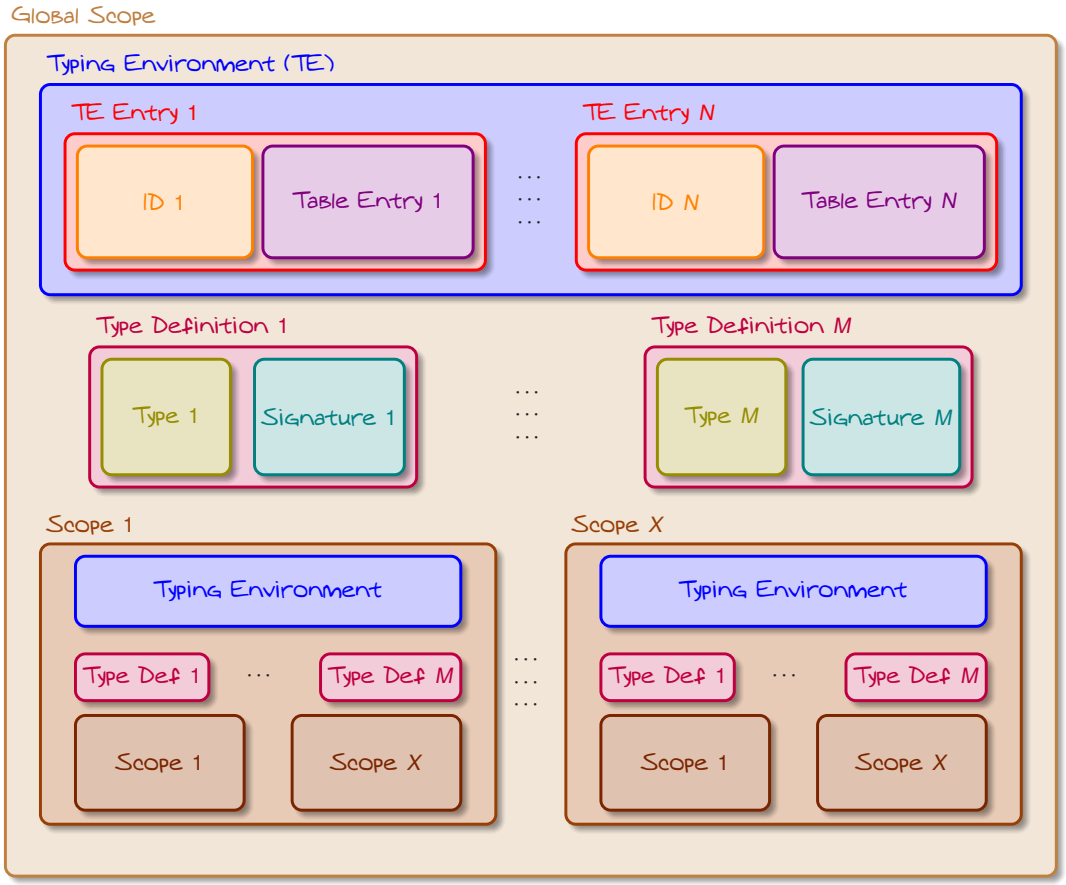

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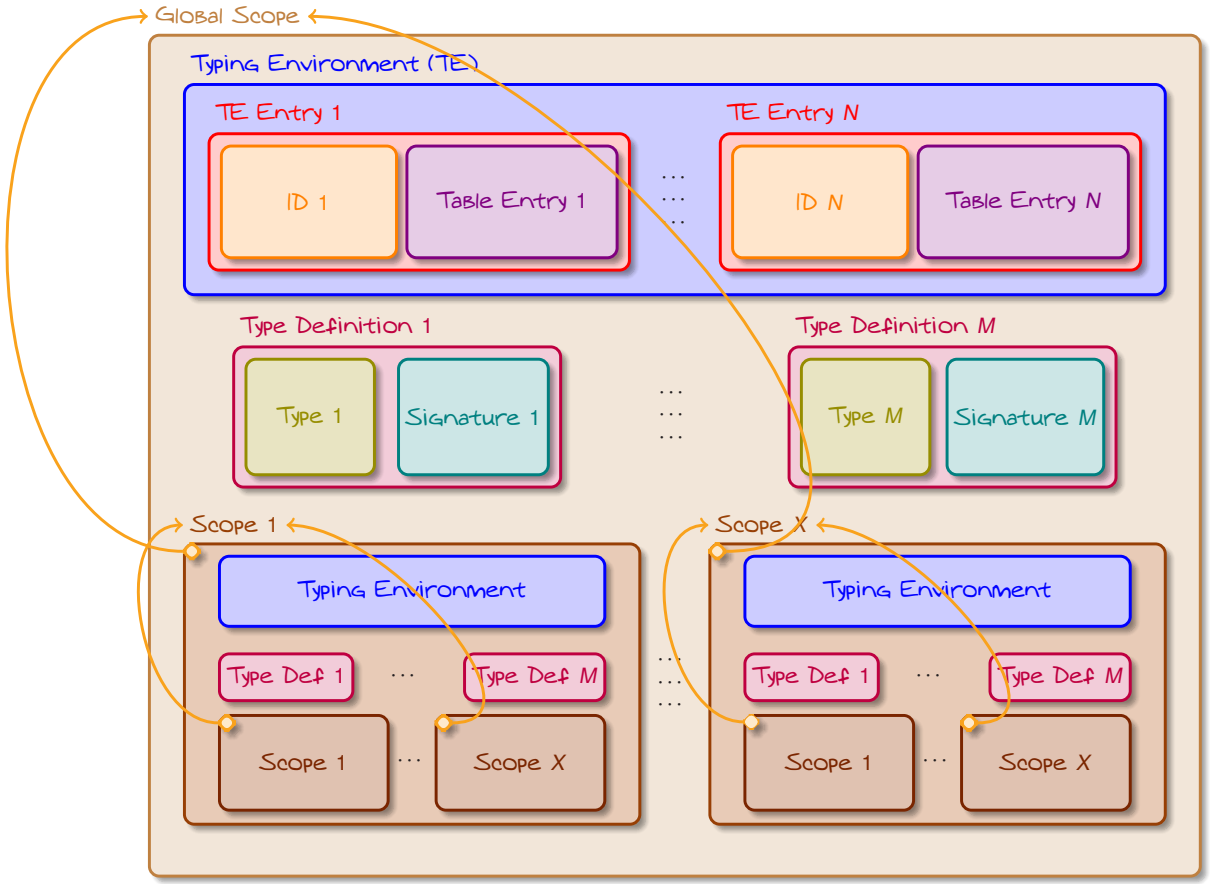

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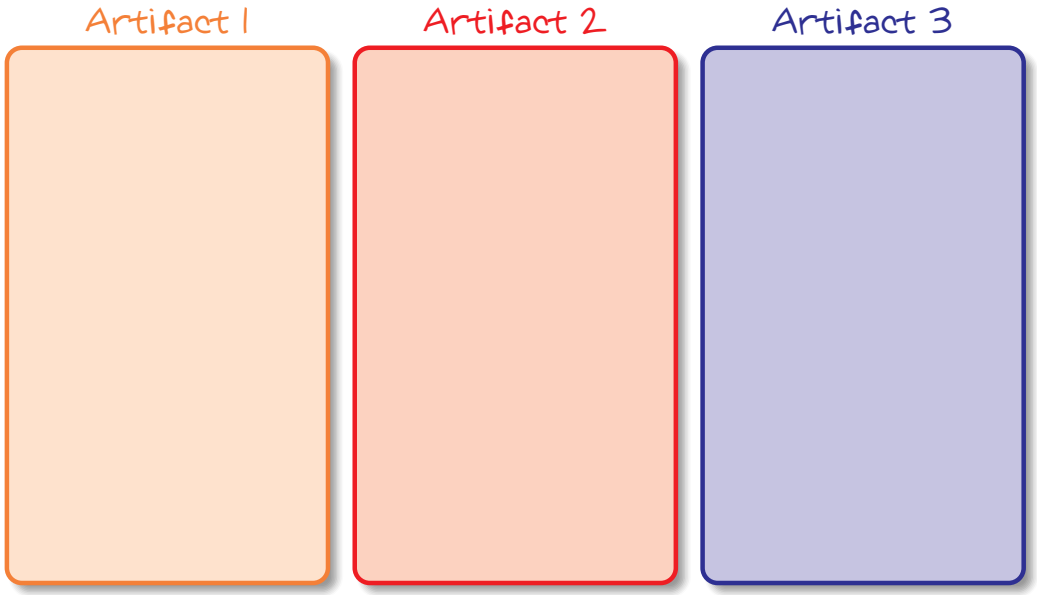

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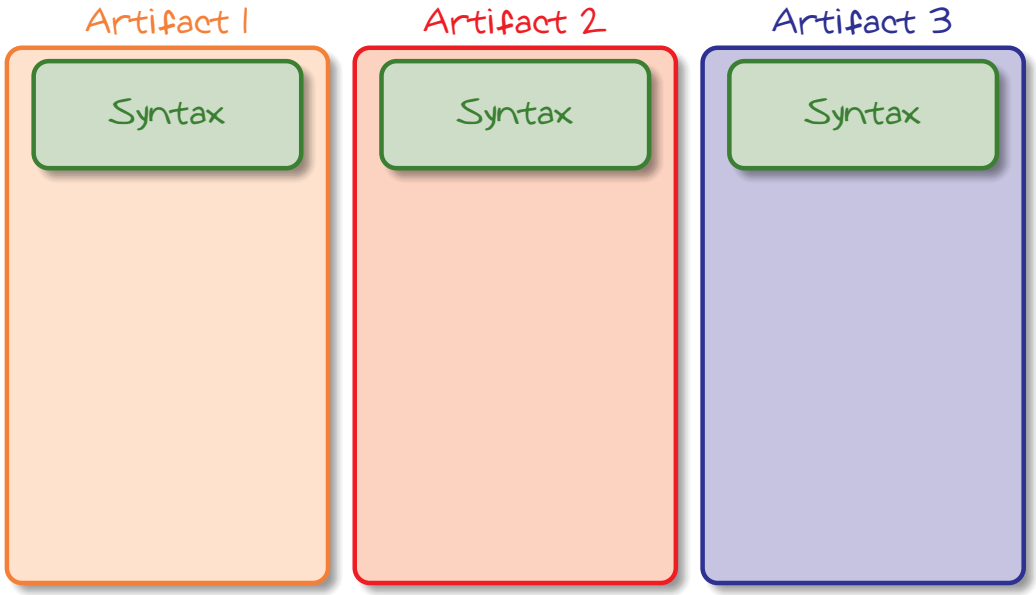

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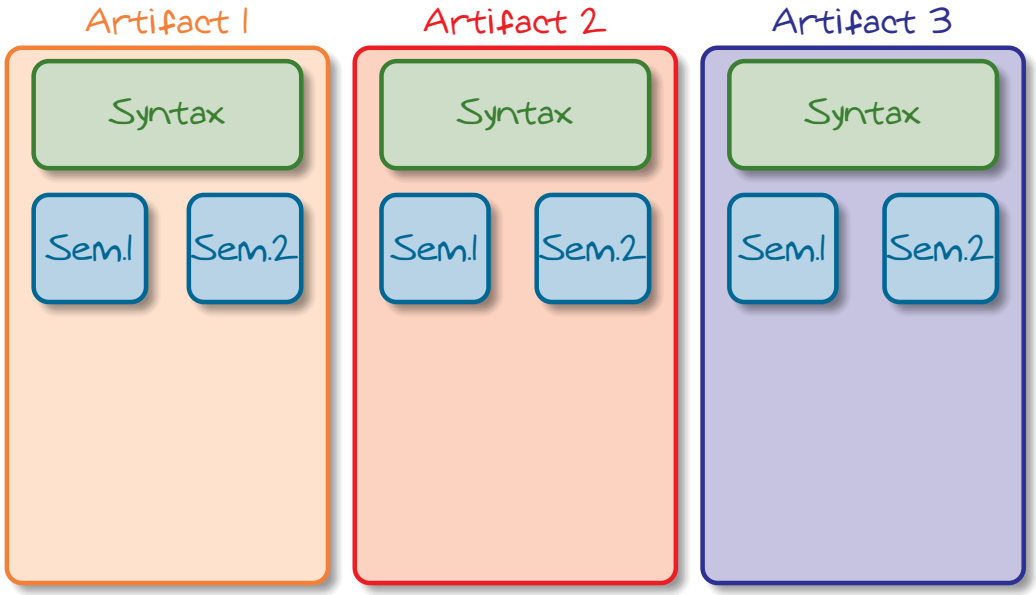

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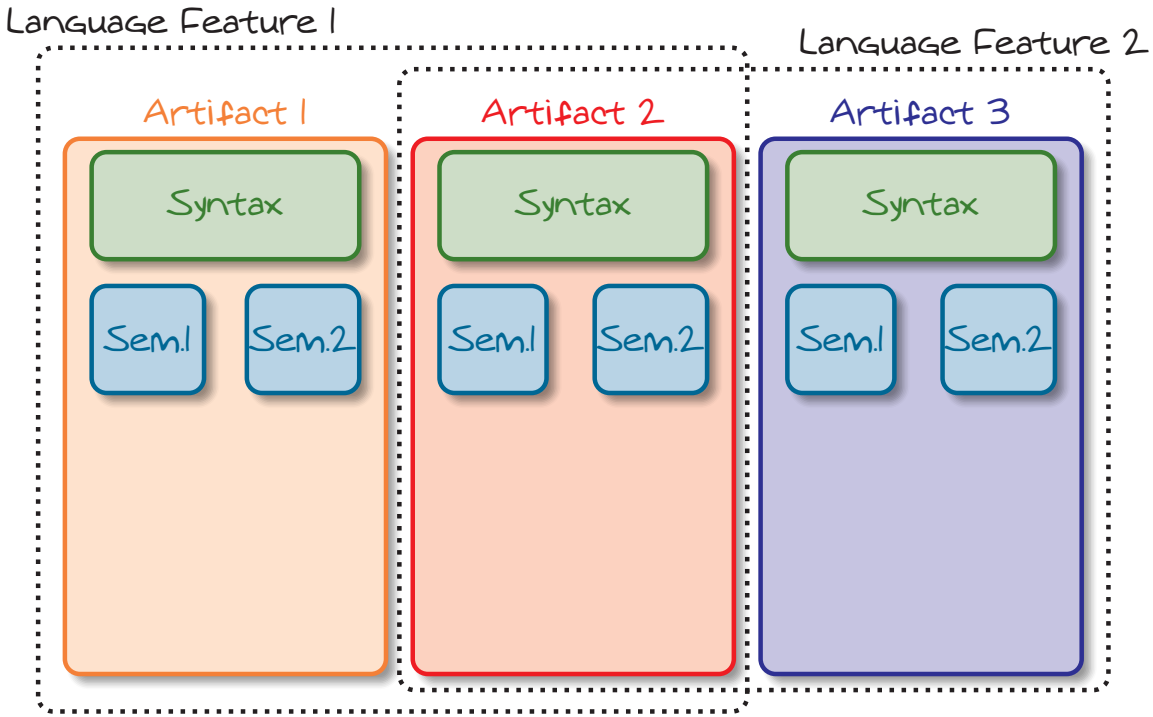

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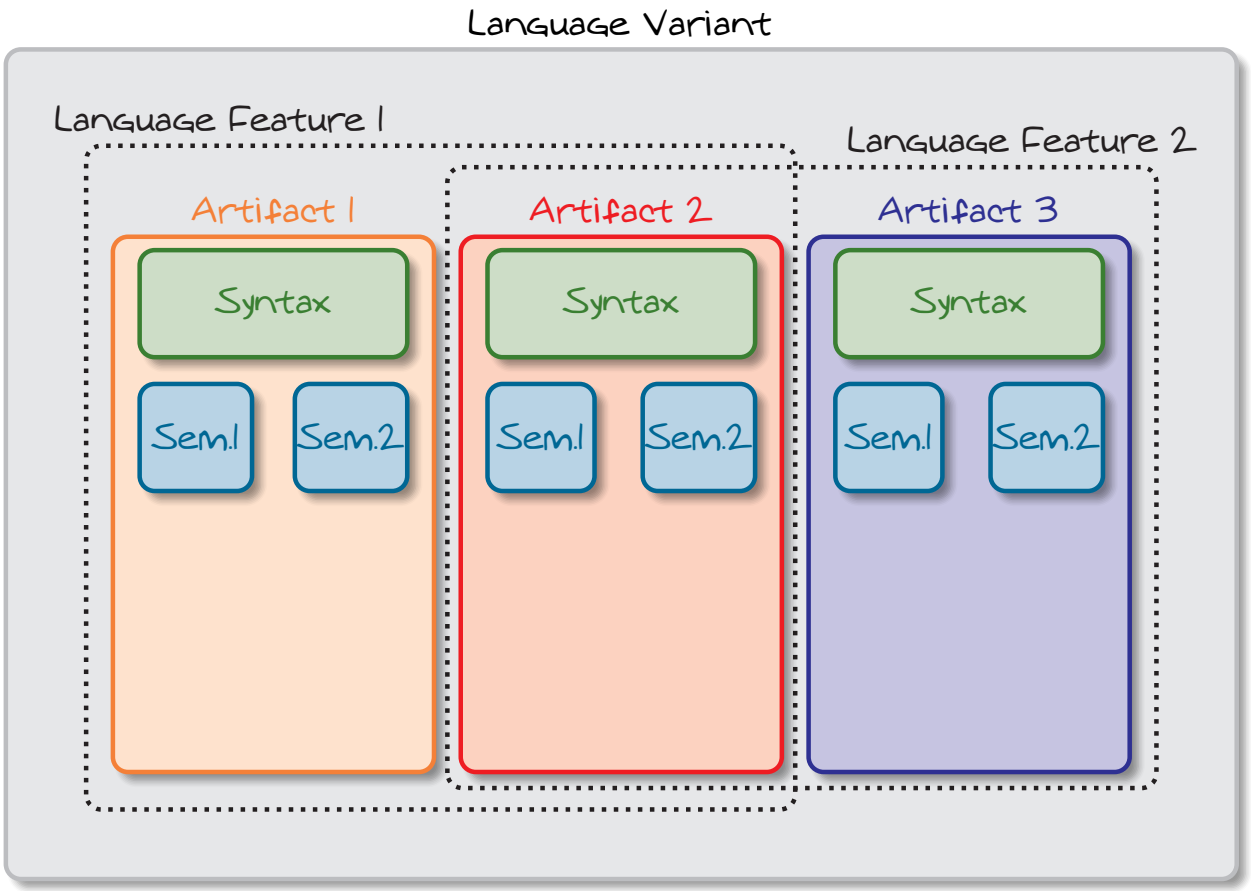

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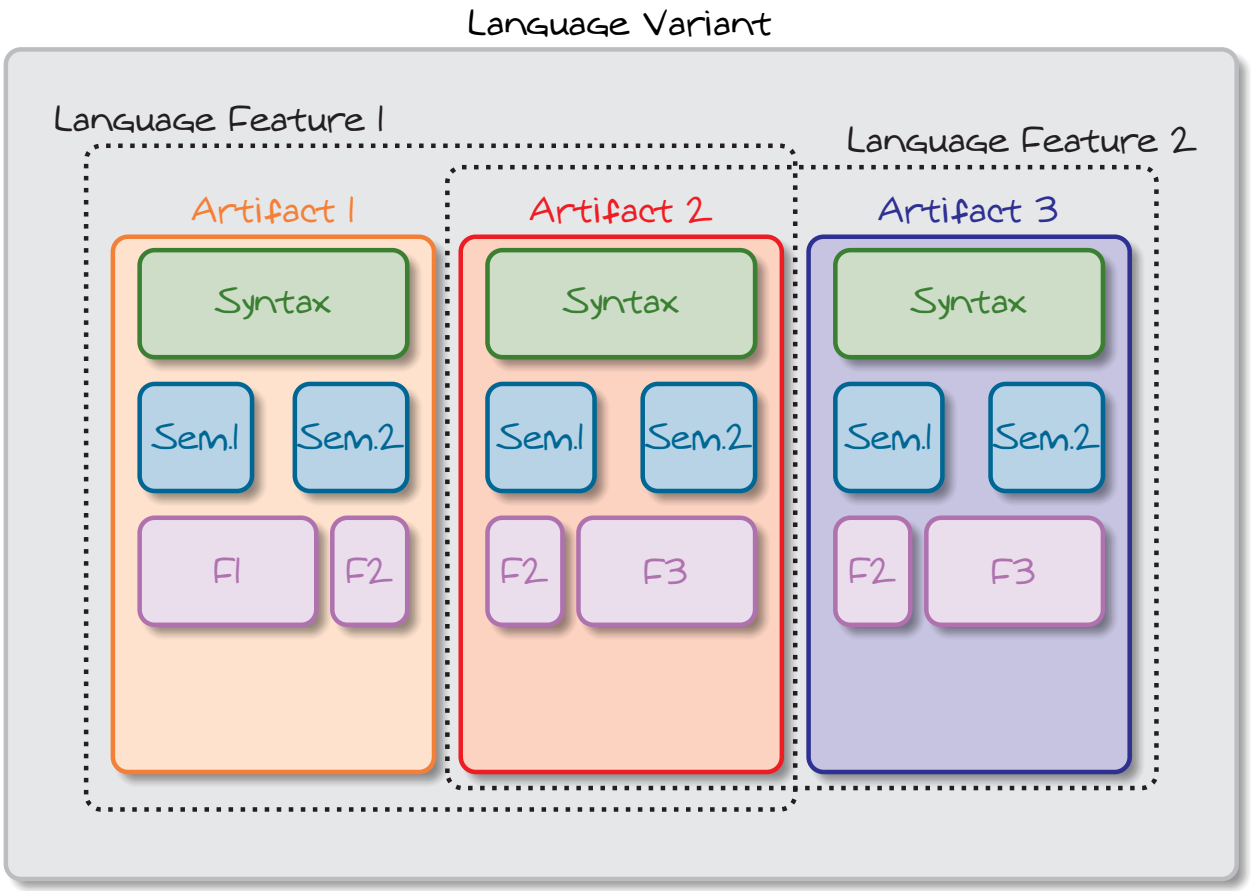

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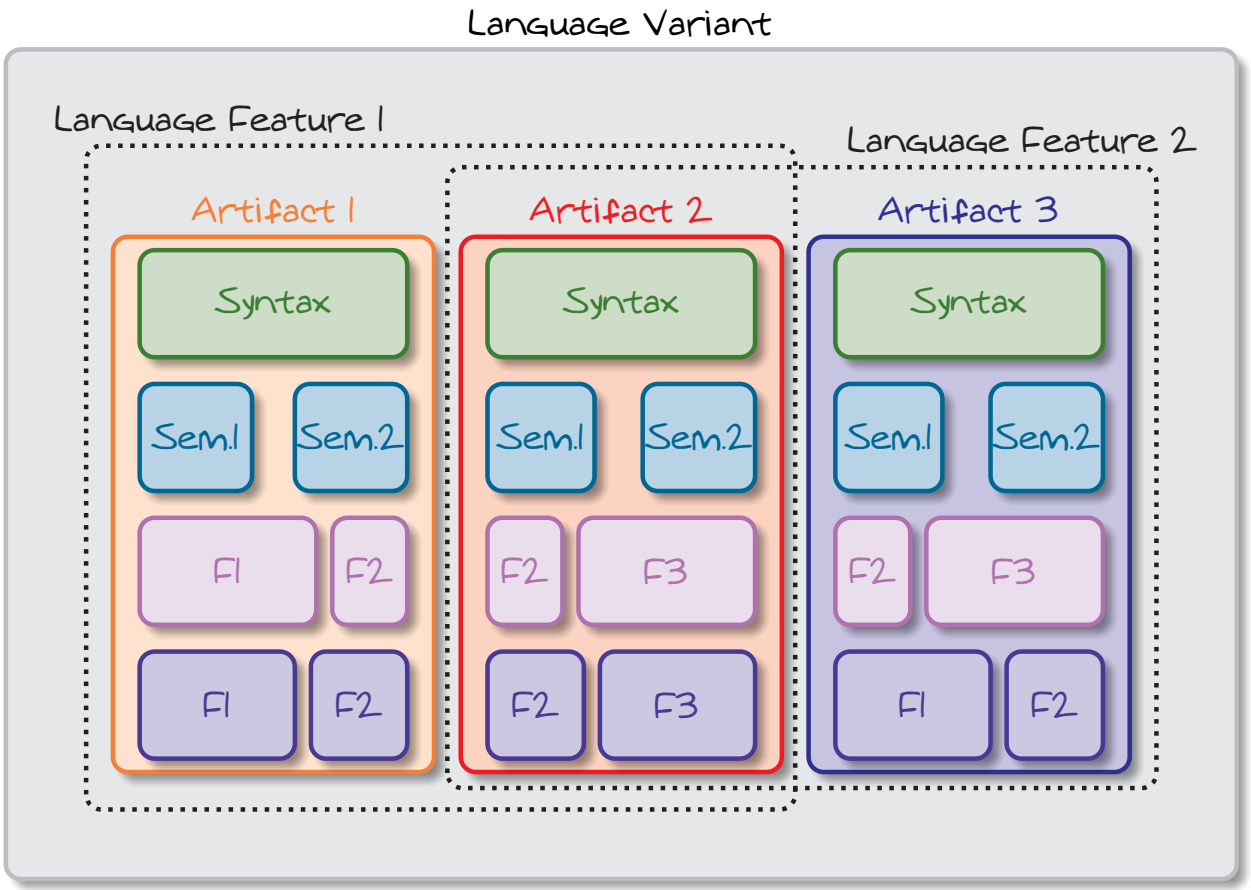

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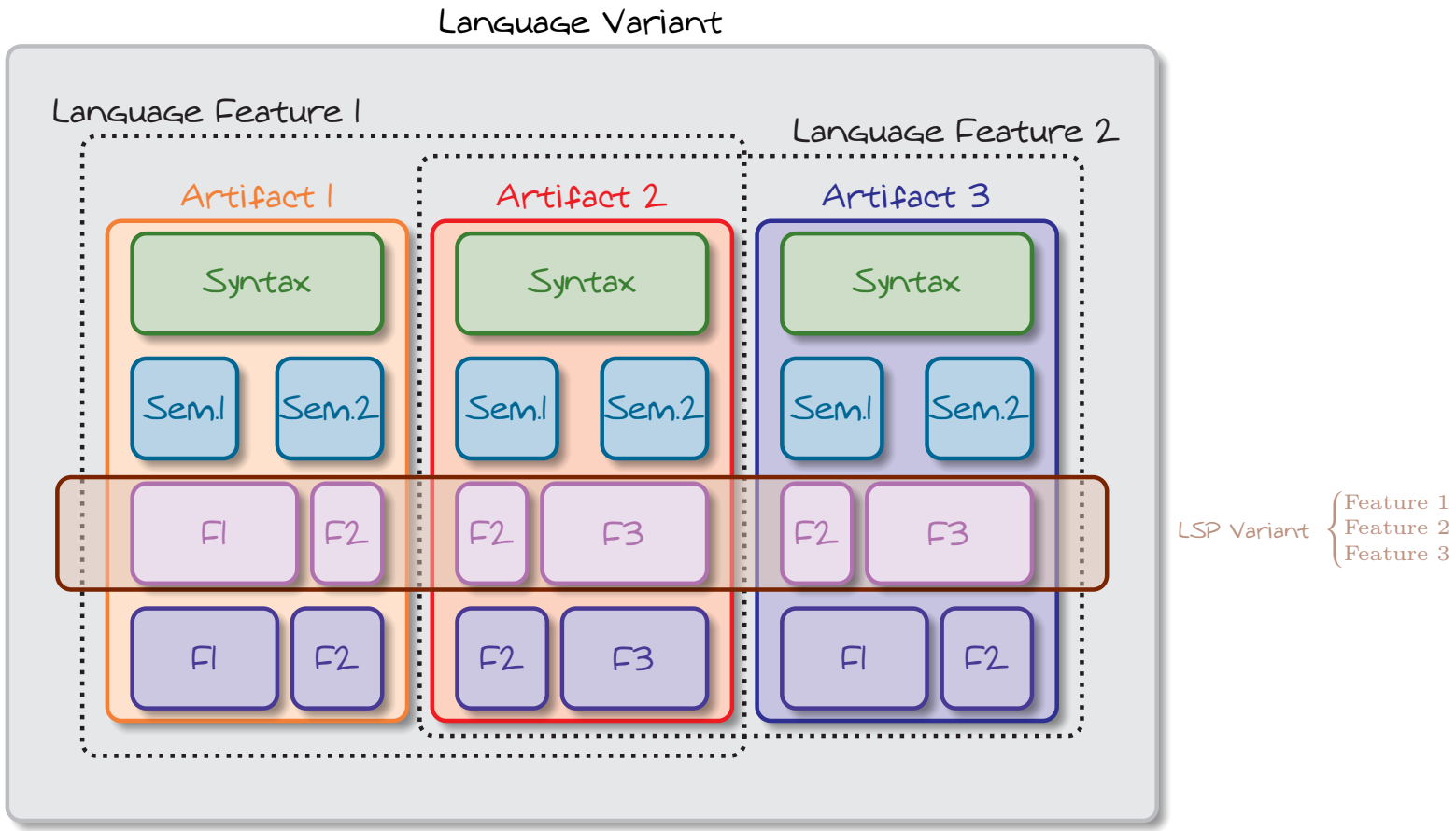

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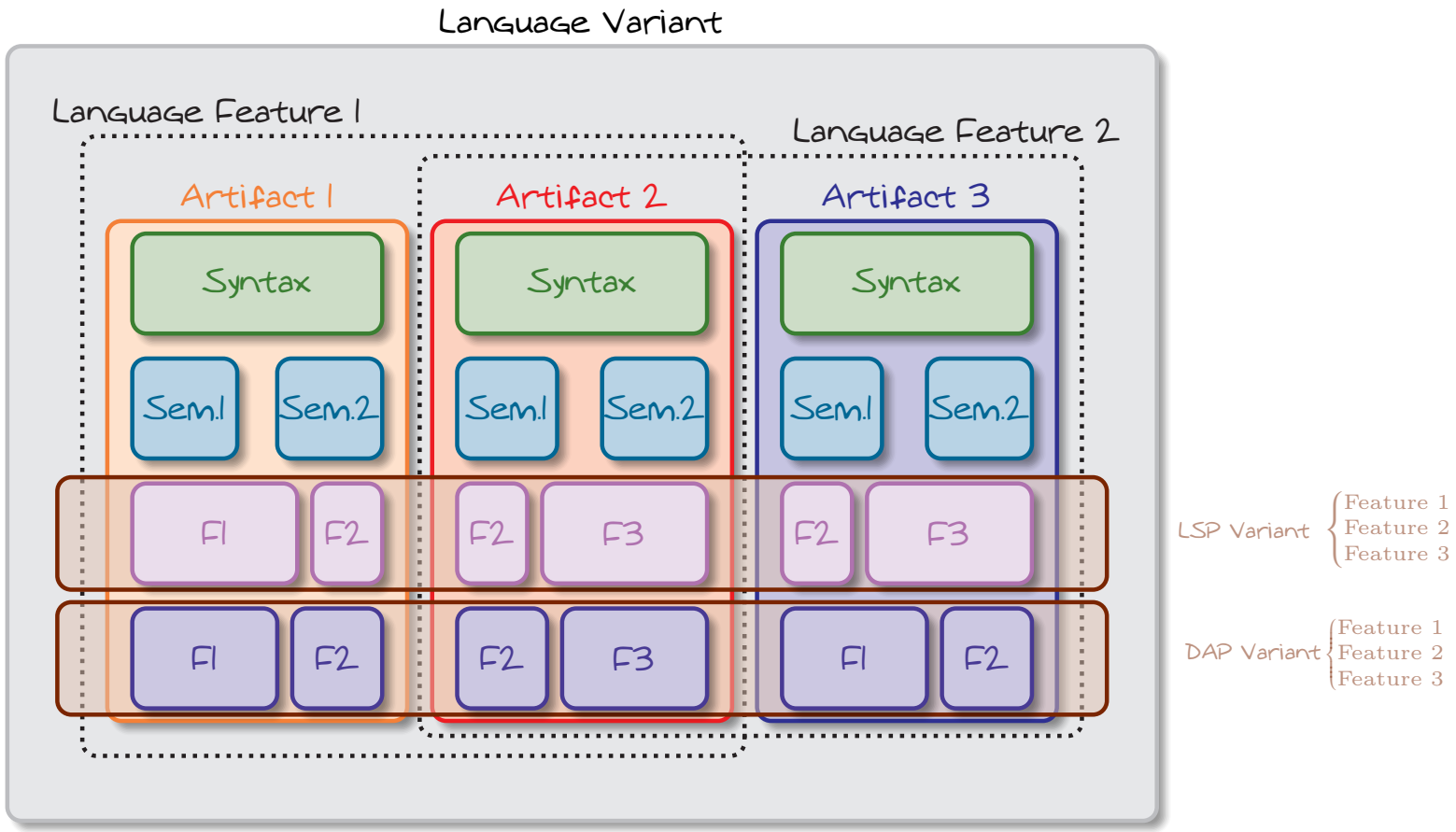

Conclusions
Master's Thesis Results

- We are writing an article (Code Less to Code More) to be submitted to JSS.
- Propose a feasibility study for the methodology.
- We prototyped the reduction of combinations.
- We prototyped the modularization of the type system.

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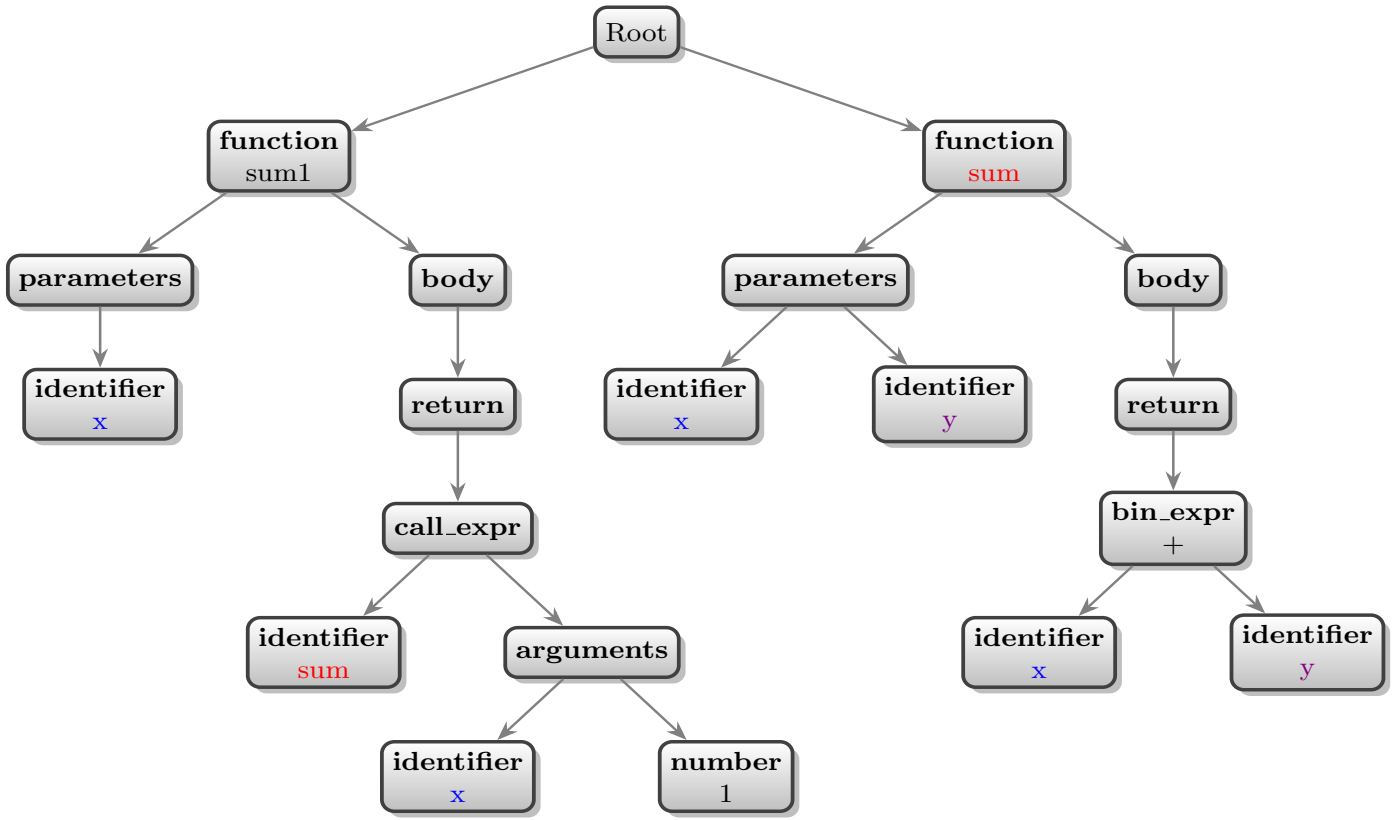
Thanks for your attention!

Type Checking and Type Inference


```
1  function sum1(x) {
2      return sum(x, 1);
3  }
5  function sum(x, y) {
6      return x + y;
7  }
```



Type Checking and Type Inference

```
1  function sum1(x) {
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```
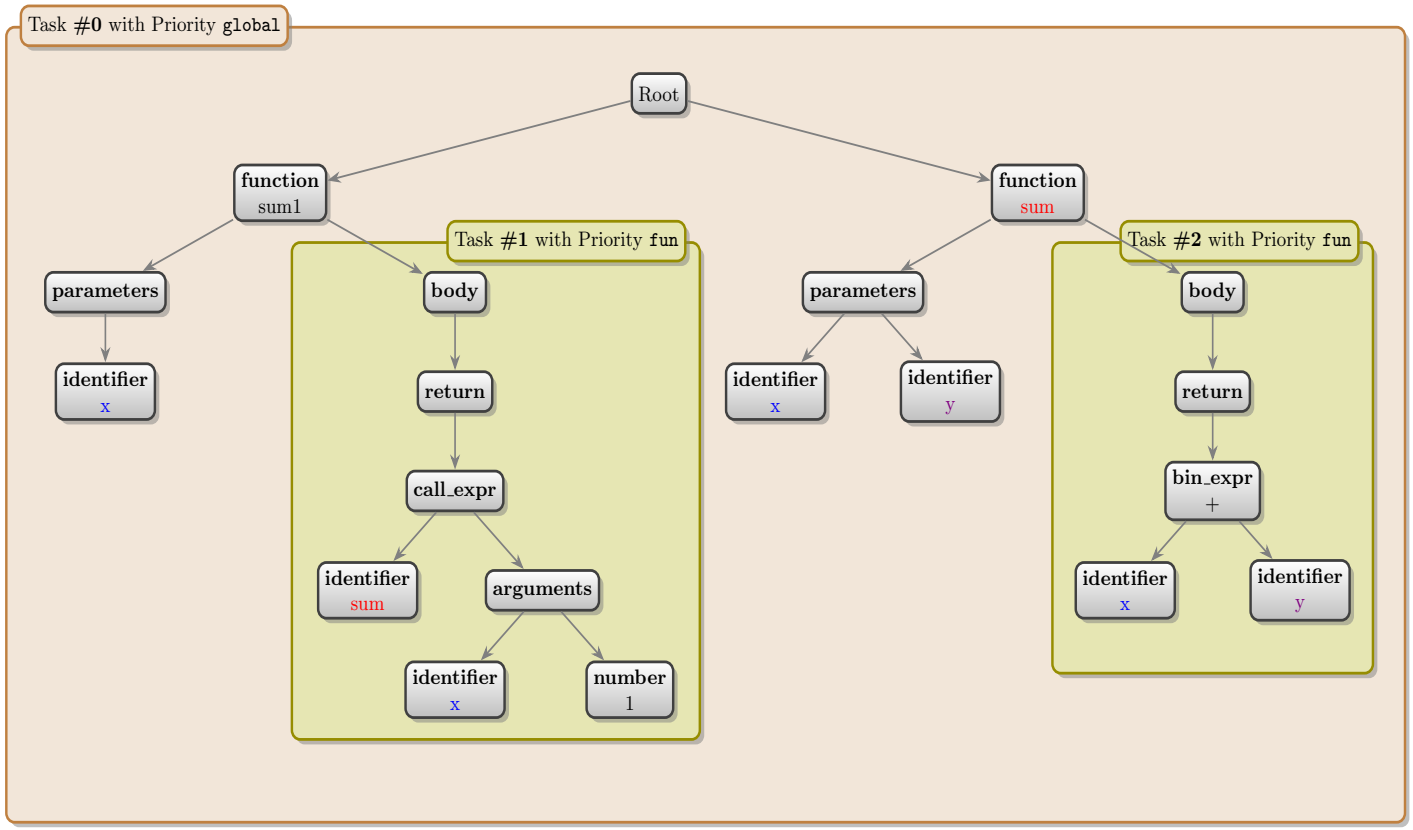

- Compilation Unit
- Compilation Unit Task
- Compilation Helper



Software Product Lines

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Since 1990s, researchers have been working on the concept of Software Product Lines (SPLs) to move towards a more modular world.

Software Product Lines

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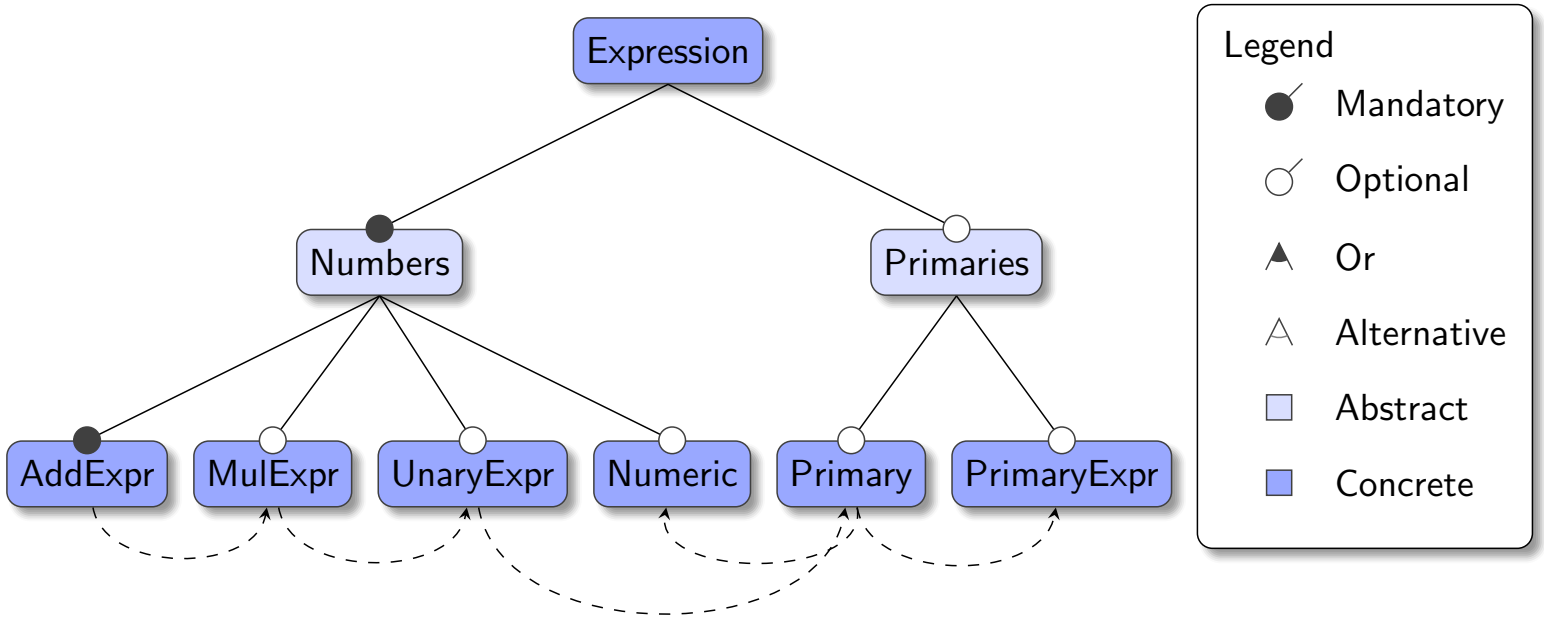
Since 1990s, researchers have been working on the concept of Software Product Lines (SPLs) to move towards a more modular world.

- SPLs defines a family of software products.
- SPLs is described by a Feature Model.
- A Feature Model describes the variability of the software.
- SPL variants are generated by selecting a set of features.
- A feature (or artifact) is a first-class entity in SPLs.

Language Product Lines

Applying the concept of SPLs to programming languages, we obtain the concept of Language Product Lines (LPLs).



Language Product Lines

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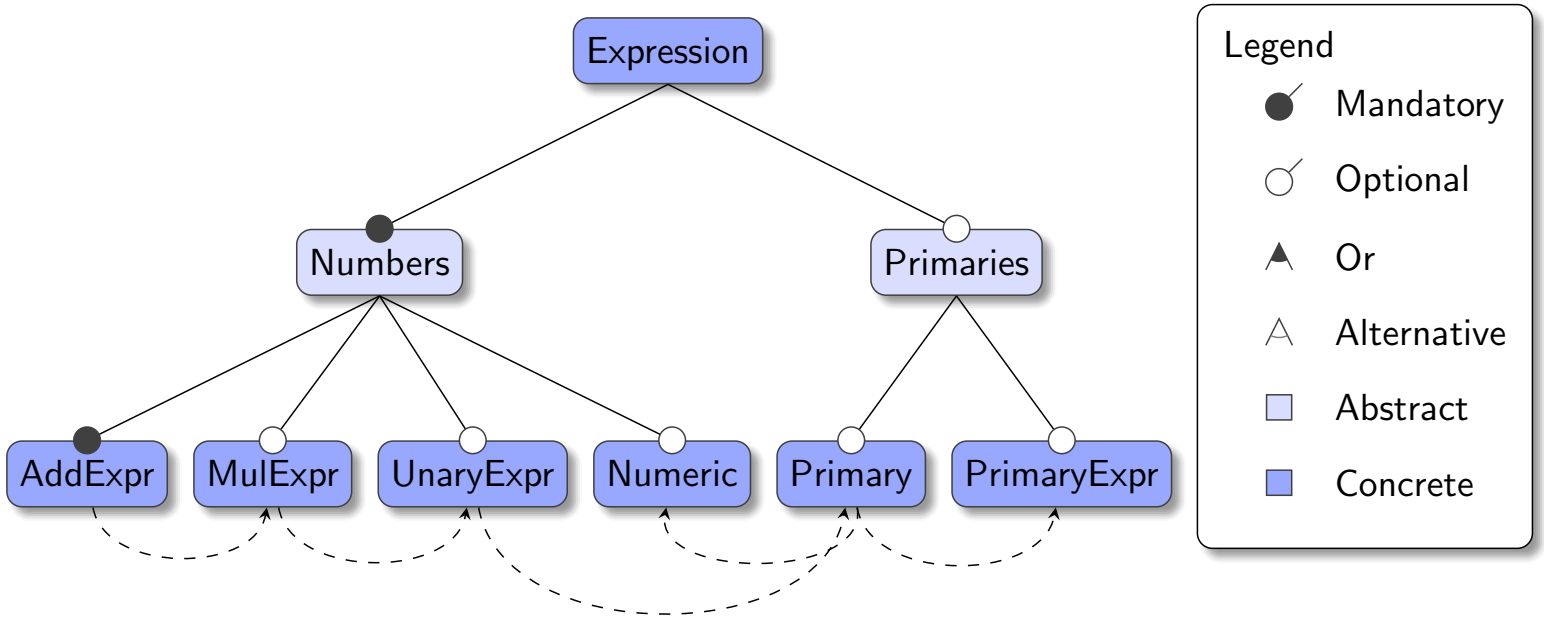

Some achievements:

- Bottom-up approach to language implementation
- Reusability of language artifacts
- Multiple variants of the same language
- Language Workbenches come to the rescue

Research Objective 1

Universal LSP and DAP for Modular LWs

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RO 1: Reduce to **L** × **1** the number of combinations to support **L** languages

RQ 1.1: How can IDE generation be improved to support LSP and DAP?

RQ 1.2: What are the key challenges in generating LSP and DAP for different programming languages?

RQ 1.3: How can a universal LSP and DAP be developed to support multiple languages and IDEs?

Research Objective 2

RO 2: Facilitate LSP and DAP Modularization

RQ 2.1: How can LSP and DAP modularization be facilitated in language workbenches?

RQ 2.2: What are the key challenges in modularizing LSP and DAP for different programming languages?

RQ 2.3: How can LSP and DAP modularization be integrated with existing language composition and modularization features in language workbenches?

Research Objective 3

Universal LSP and DAP for Modular LWs

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RO 3: Improve IDE and LSP Generation

RQ 3.1: How can the number of combinations required to support multiple languages be reduced to L × I?

RQ 3.2: In what ways does simplifying the development process for language support enhance efficiency?

RQ 3.3: How does reducing combinations impact the speed and effectiveness of creating language support?

Research Objective 4

RO 4: Leverage Neverlang for LSP and DAP in LPL Development

RQ 4.1: How can Neverlang's LPL development features be leveraged for creating a reusable core for LSP and DAP functionalities?

RQ 4.2: What are the key benefits of using Neverlang for LSP and DAP development in the context of LPLs?

RQ 4.3: How does leveraging Neverlang's LPL features enhance the scalability and efficiency of LSP and DAP development?

Journals and Conferences

Universal LSP and DAP for Modular LWs

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Journals

- JSS (Journal of Systems and Software)
- TSE (IEEE Transactions on Software Engineering)
- TOSEM (ACM Transactions on Software Engineering and Methodology)
- TOPLAS (ACM Transactions on Programming Languages and Systems)

Conferences

- ICSE (International Conference on Software Engineering)
- PLDI (Programming Language Design and Implementation)
- OOPSLA (Object-Oriented Programming, Systems, Languages, and Applications)
- SLE (Software Language Engineering)

Language Workbenches and Research Groups

- JustAdd → Computer Science department of the Lund University (Lund, Sweden)
- Melange → DiverSE research team at the Institut National de Recherche en Informatique et en Automatique (INRIA) (Paris, France)
- MontiCore → Software Engineering group at the RWTH Aachen University (Aquisgrana, Germany)
- MPS → JetBrains Research (Saint Petersburg, Russia)
- Rascal → Centrum Wiskunde & Informatica (CWI) (Amsterdam, Netherlands)
- Spoofax → Delft University of Technology (Delft, Netherlands)
- Xtext → Eclipse Foundation (Ottawa, Canada)

Language Workbenches and Research Groups

- **Martin Fowler:** Renowned for his work on software development methodologies. His book "Domain-Specific Languages" is a seminal work in the field.
- **Markus Voelter:** Known for his contributions to the development and promotion of language workbenches like JetBrains MPS.
- **Eelco Visser:** A professor at Delft University of Technology, Visser has made significant contributions to the field through his work on the Spoofax language workbench.
- **Gregor Kiczales:** Known for his work on aspect-oriented rogramming (AOP). Professor at the University of British Columbia.
- **Antonia Bertolino:** Known for her work on software testing and quality assurance.