TECHNISCHE UNIVERSITÄT DRESDEN

LUND UNIVERSITY

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Relational Reference Attribute Grammars

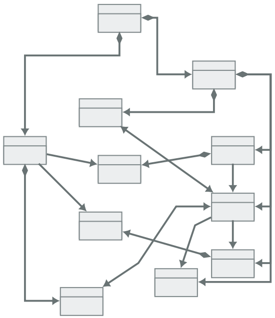
Dresden, January 21, 2021

From Model Refactoring to Relational RAGs

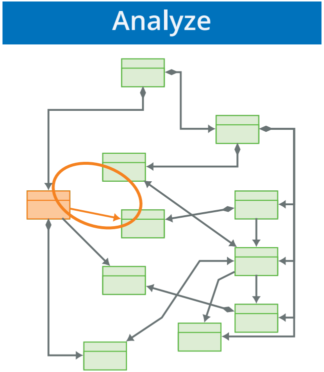
Continuously Changing Models

Models:

- **Analyze**
  Here: search for refactoring candidates
- **Modify**
  Here: apply refactoring



Continuously Changing Models



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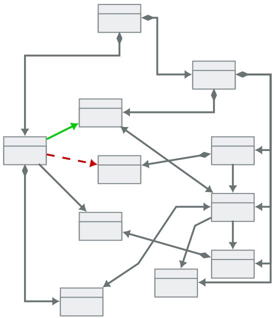

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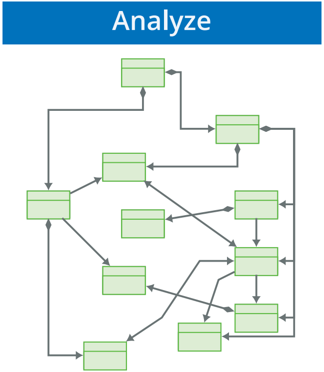

Continuously Changing Models

Models:

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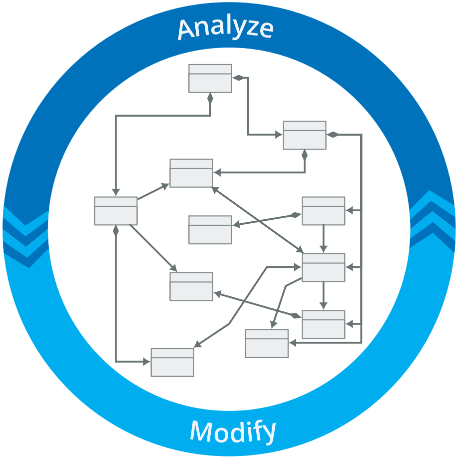
Models at runtime:

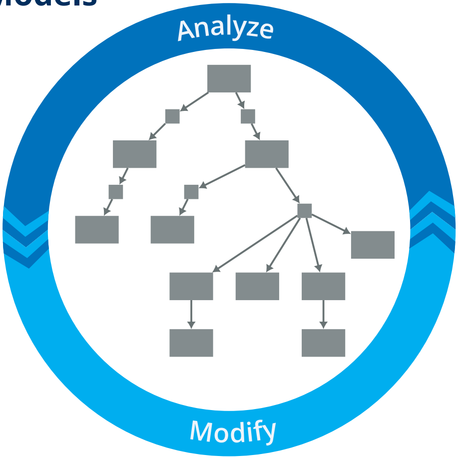
- Analyze **incrementally**
- Modify **continuously**



Reference Attribute Grammars as Models

Our approach:
Reference Attribute Grammars (RAGs)

- **Structure:** context-free grammar
- **Analysis:** attributes
- **Refactoring:** tree edits
- We use: **JastAdd**



RAGs for modelling offer:

- Shorthands for navigation and computation on trees
- Efficiency through memoization
- Incremental evaluation

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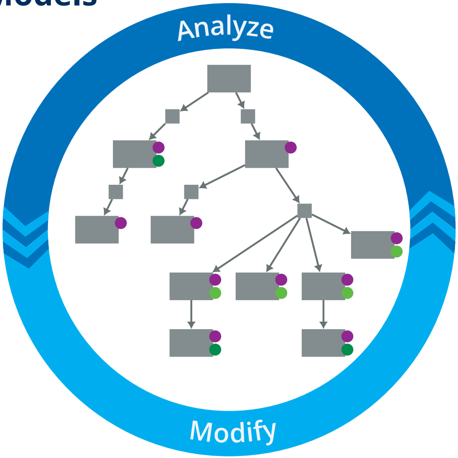

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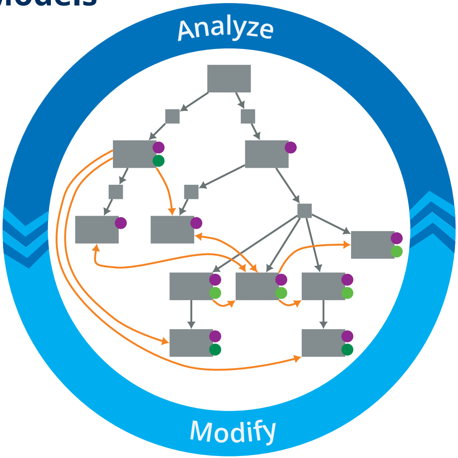

RAGs for modelling offer:

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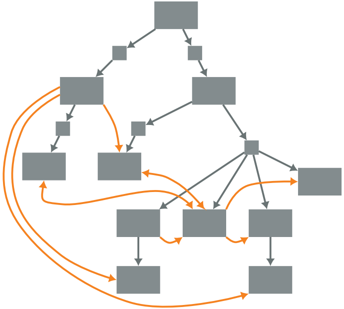
Model-Grammar Mismatch

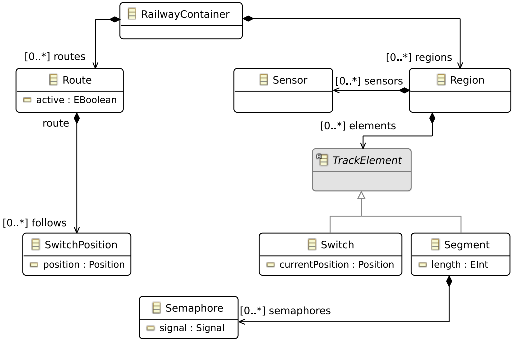
Relations are different:

- In **models**:
  - Containment relations form *overlay tree*
  - Non-containment relations
  - Bidirectional relations
- In **grammars**:
  - Containment references: **AST**
  - Non-containment references } **Relational RAGs**
  - Bidirectional references



Models vs Relational RAGs

Metamodels and Grammars



Abstract grammar (JastAdd syntax)

```
RailwayContainer ::= Route* Region*;
abstract RailwayElement ::= <Id:int>;
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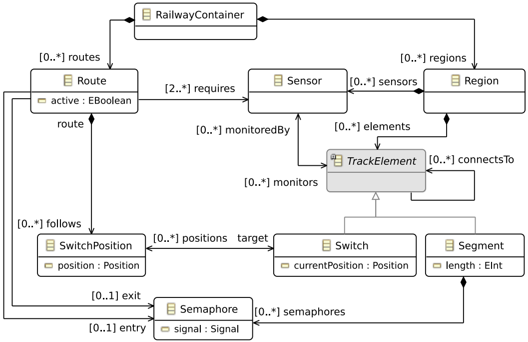
Metamodels and Grammars



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```

How to capture non-containment relations?

Handling Non-containment Relations in RAGs

Approach 1: Name analysis

- Unique identifier `Id` for each object
- Non-containment relations as `Id` uses
- Resolve with name analysis attributes

Approach 2: Explicit intrinsic reference attributes

- Store references as (Java) object references
- Resolve during model loading

Problem: Bidirectional relations:

- Either use *collection attributes* to reverse references (**slow!**)
- Or two unidirectional relations (**risk of inconsistency!**)

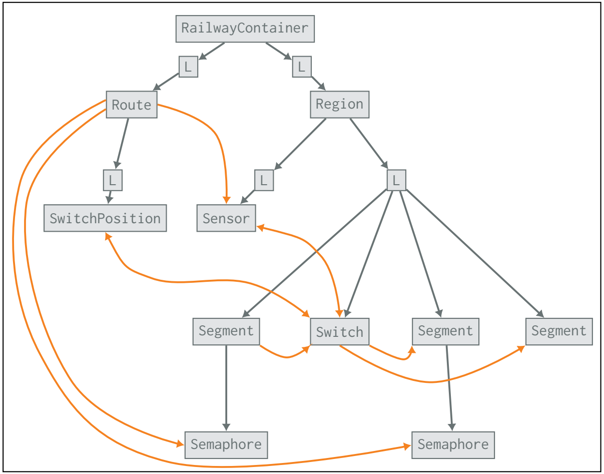
Non-Containment Relations in Detail

Non-Containment References

Cardinality

- 1 : 1
- 1 : {0..1}
- 1 : N

Bidirectional References



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Non-Containment References:

- **In RAGs:** typed reference nodes: R

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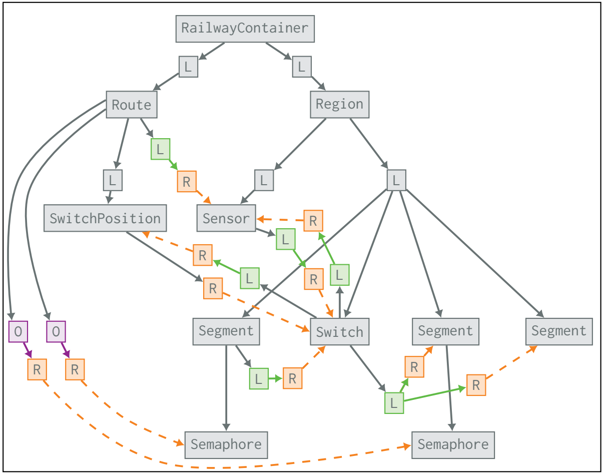
- **In RAGs:** *optional* O and *list nodes*: L

Bidirectional References



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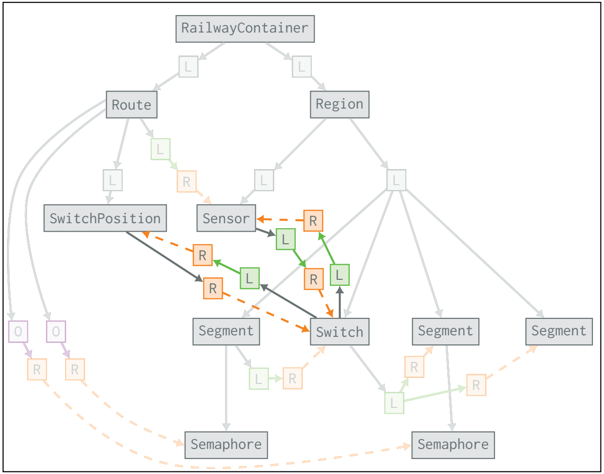
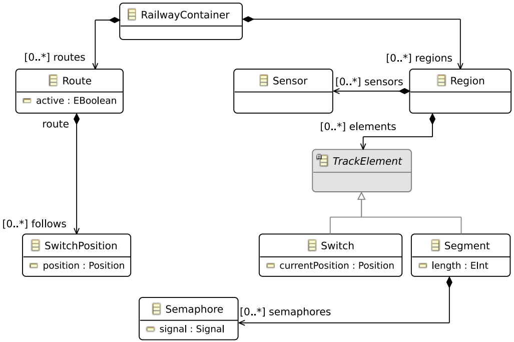
Bidirectional References:

- **In RAGs:**
  One direction in grammar,
  the other in grammar or attribute



Solution: Relational RAGs



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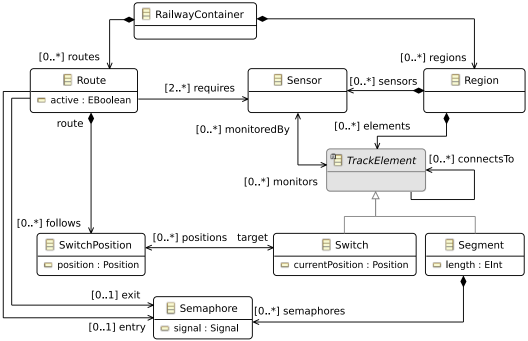

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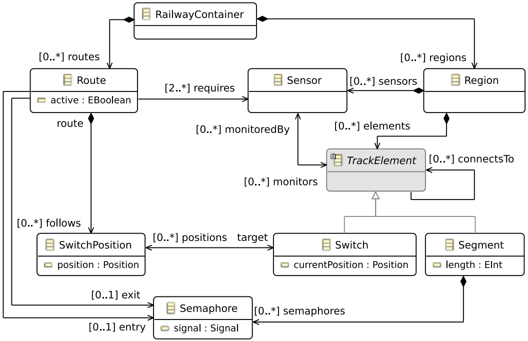
```

Extending RAGs with relations

```
rel Route.requires* -> Sensor;
rel Route.entry? -> Semaphore;
rel Route.exit? -> Semaphore;
rel SwitchPosition.target <-> Switch.positions*;
rel Sensor.monitors* <-> TrackElement.monitoredBy*;
rel TrackElement.connectsTo* -> TrackElement;
```

Solution: Relational RAGs



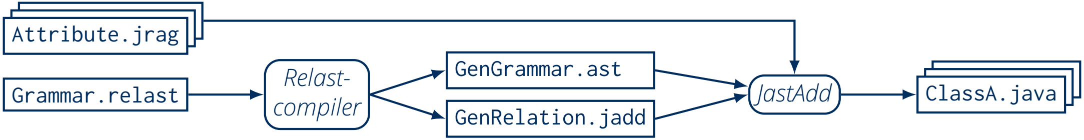
Modifying relations

```
public java.util.List<TrackElement> Sensor.getMonitors() {
  return Collections.unmodifiableList(get_impl_monitors());
}
public void Sensor.addMonitors(TrackElement o) {
  ArrayList<TrackElement> list = get_impl_monitors();
  ArrayList<Sensor> list2 = o.get_impl_monitoredBy();
  list.add(o);
  list2.add(this);
  set_impl_monitors(list);
  o.set_impl_monitoredBy(list2);
}
public void Sensor.removeMonitors(TrackElement o) {
  ArrayList<TrackElement> list = get_impl_monitors();
  if (list.remove(o)) {
    ArrayList<Sensor> list2 = o.get_impl_monitoredBy();
    list2.remove(this);
    set_impl_monitors(list);
    o.set_impl_monitoredBy(list2);
  }
}
```

Solution: The RelAST Preprocessor

Automatically generates

- Grammar with non-containment relations
- Accessor attributes
- Setter attributes
  - Ensuring consistency for bidirectional relations
- Optionally
  - Serialization and deserialization methods
  - Parsing support for non-containment relations



Extension: Serialization and Deserialization

Problem:

— Intrinsic relations must be resolved during parsing **before** the computed attributes are evaluated

Solution: (De-)Serialization Component

— Generate (de-)serialization components that handle this automatically

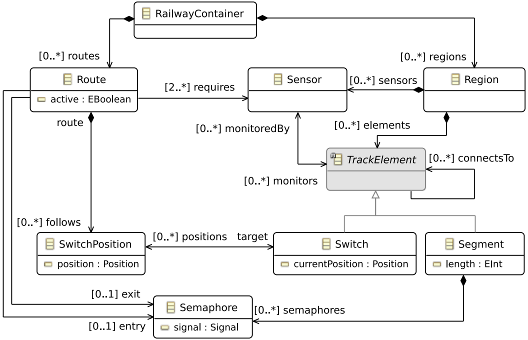
— Result: problem-specific JSON notation

Generated JSON

```
{
  "type": "Switch",
  "id": "15",
  "children": {
    "Id": 52,
    "CurrentPosition": "STRAIGHT"
  },
  "relations": {
    "connectsTo":  ["201" ],
    "monitoredBy": ["18", "19", "20", "21",
                   "22", "23", "24", "25"],
    "positions":   [ "14" ]
  }
}
```

Extension: Ecore to Relational RAGs

Automatically!



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```

Extension: Ecore to Relational RAGs

Relations in Ecore:

EClass

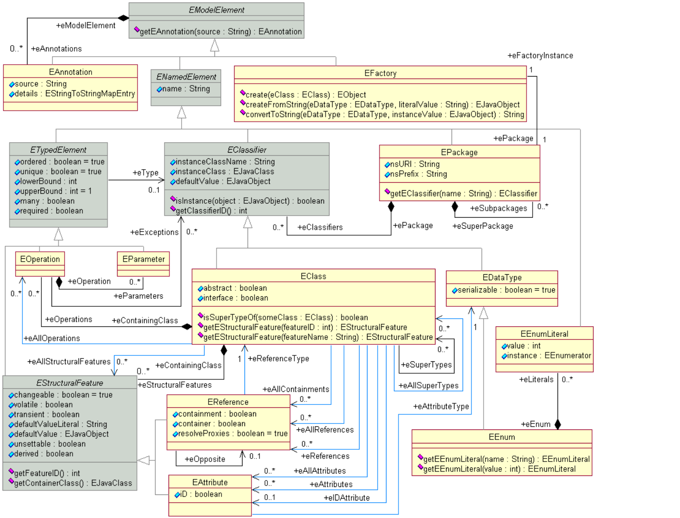
- becomes nonterminal
- ⚠ multiple inheritance

EAttribute

- become terminal

EReference

- becomes child
  - **if containment is true**
- becomes relation
  - **if containment is true**
- ⚠ various properties



https://download.eclipse.org/modeling/emf/emf/javadoc/2.9.0/org/eclipse/emf/ecore/package-summary.html

Refactoring with Relational RAGs

- results based on paper for *Software Language Engineering 2018* 👉 [Mey et al., 2018]
- extended journal version under review
- ⚠️ not about refactoring, but very related

Continuous Model Validation using Reference Attribute Grammars

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Abstract

Just like current software systems, models are characterised by increasing complexity and rate of change. Yet, these models only become useful if they can be continuously evaluated and validated. To achieve sufficiently low response times for large models, incremental analysis is required. Reference Attribute Grammars (RAGs) offer mechanisms to perform an incremental analysis efficiently using dynamic dependency tracking. However, not all features used in conceptual modelling are directly available in RAGs. In particular, support for non-containment model relations is only available through manual implementation. We present an approach to directly model uni- and bidirectional non-containment relations in RAGs and provide efficient means for navigating and editing them. This approach is evaluated using a scalable benchmark for incremental model editing and the *JastAdd* RAG system. Our work demonstrates the suitability of RAGs for validating complex and continuously changing models of current software systems.

CCS Concepts • **Theory of computation → Grammars and context-free languages**; • **Software and its engineering** → *System description languages*; • **Computing methodologies** → *Model verification and validation*;

SLE '18, November 5–6, 2018, Boston, MA, USA

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https://doi.org/10.1145/3276604.3276616

Keywords Incremental model evaluation, bidirectional relations, References Attribute Grammars

ACM Reference Format:
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1 Introduction

More and more software systems rely on models to easily reference, refine, and validate aspects of a business domain in a cost-effective way [32]. With current software systems increasing in complexity and rate of change [28], these models become more complex and change continuously, too. While maintaining and refining complex models is possible with state-of-the-art tools [22], their continuous evaluation and validation still poses problems for large complex models.

To approach continuous evaluation, researchers recently applied *Reference Attribute Grammars* (RAGs) [14] to encode and validate models, e.g., [6–8], because RAG systems offer mechanisms to perform an incremental analysis efficiently using dynamic dependency tracking [35]. Although RAG systems can efficiently rewrite and re-evaluate complex, large tree structures with derived information, including references, there exists a fundamental *semantic mismatch* between models, generally represented as graphs, and RAG trees.[1] While conceptual models comprise classes with attributes linked by inheritance, containment, and non-containment

[1] There is a striking similarity to the object-relational impedance mismatch [18].

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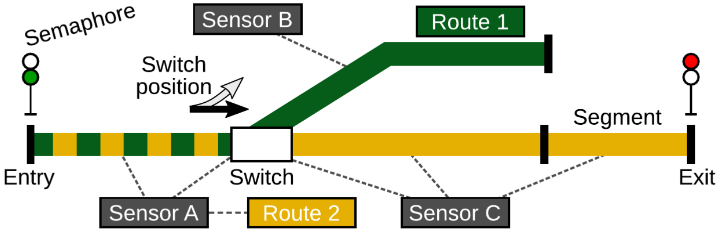
Relational RAGs for (Runtime) Models: An Example Use Case

Running example: Modeling train tracks and routes. 🚂



Example model, from [Szárnyas et al., 2017]

Use Case:

- Modeling editor for rail networks
- Continuously *find* and *repair* faults

[Szárnyas et al., 2017] Szárnyas, G., Izsó, B., Ráth, I., and Varró, D. (2017). The Train Benchmark: cross-technology performance evaluation of continuous model queries. Software & Systems Modeling, pages 1–29.

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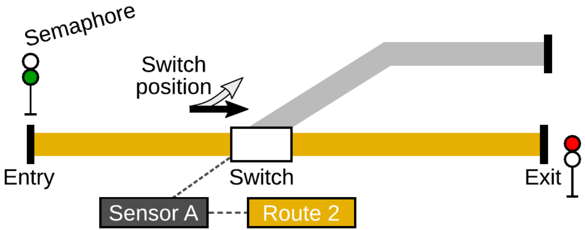

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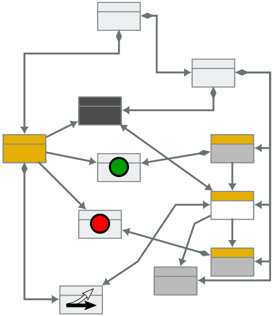

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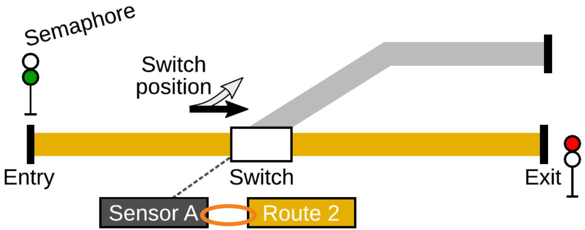

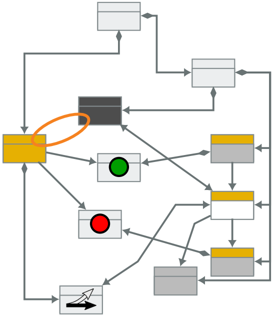

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Relational RAGs: An Evaluation

We investigated:

1. **Usability and Conciseness**
   - Measure complexity reduction
2. **Performance**
   - Compare the three approaches with model- and graph-based solutions

Use Case:

— Iterative model analysis and transformation with *Train Benchmark* [Szárnyas et al., 2017]

— Six model queries

— Fault injection and repair transformations for each

[Szárnyas et al., 2017] Szárnyas, G., Izsó, B., Ráth, I., and Varró, D. (2017).
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Questions?

References I

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