Contribution to the Analysis of the Design-Space of a Distributed Transformation Engine

Jolan PHILIPPE

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Bretagne-Pays de la Loire
École Mines-Télécom

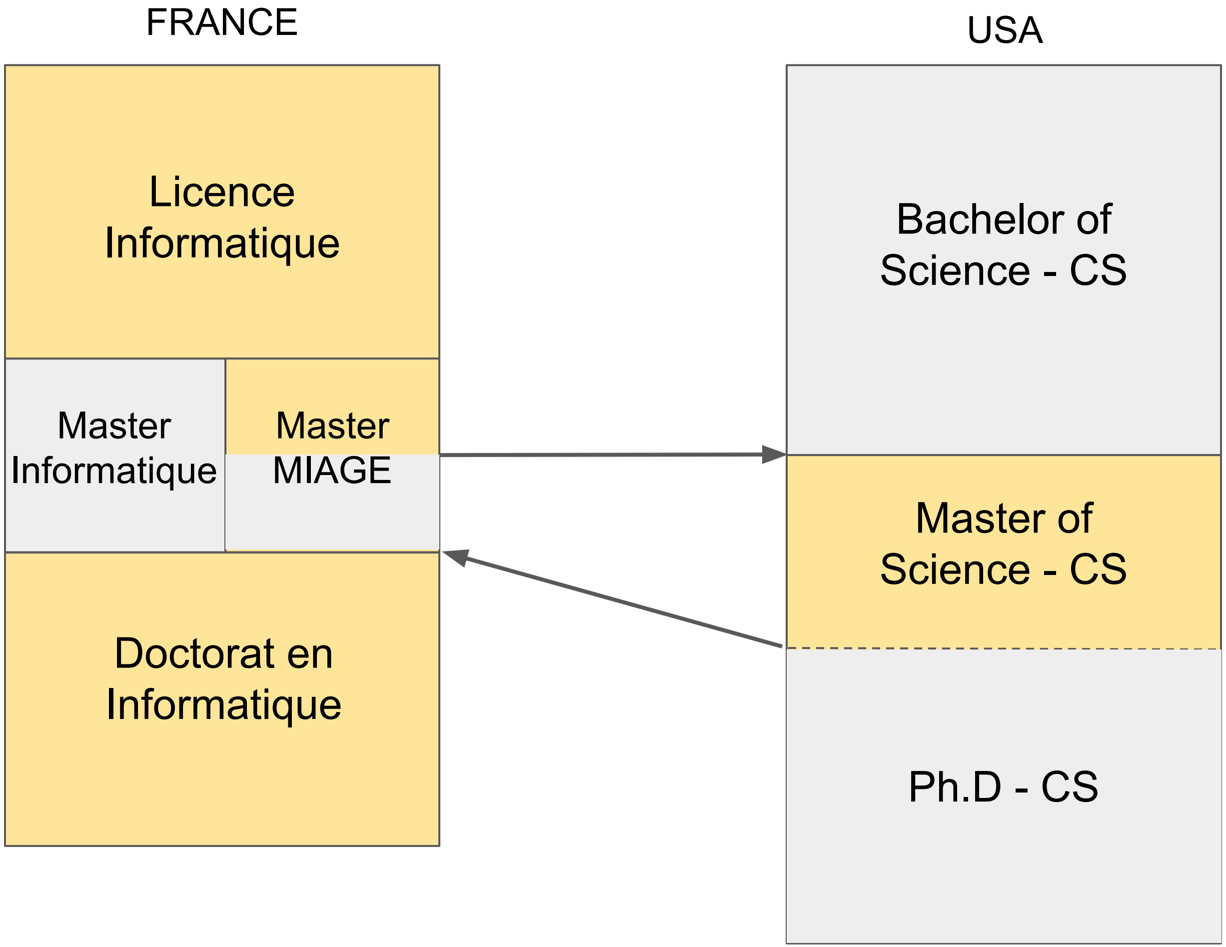
STACK

naomod

lowcomote

LS2N

Education


FRANCE
USA
Licence Informatique
Master Informatique
Master MIAGE
Doctorat en Informatique
Bachelor of Science - CS
Master of Science - CS
Ph.D - CS

Context of the thesis

lowcomote

Lowcomote is a H2020-ITN project aiming at training 15 PhD students, and build a low-code development platforms based on

- **Model-Driven Engineering**
- **Cloud Computing**
- **Machine Learning**

Marie Skłodowska--Curie Actions

WP5: Scalable Low-Code Artefact Management

Thesis supervision

Gerson SUNYE

Ph.D director

- Model Driven Engineering
- Software Testing
- Distributed Systems

Massimo TISI

Ph.D supervisor

- Model Transformation
- Deductive Verification in Model-Driven Engineering
- Domain-Specific Language

Hélène COULLON

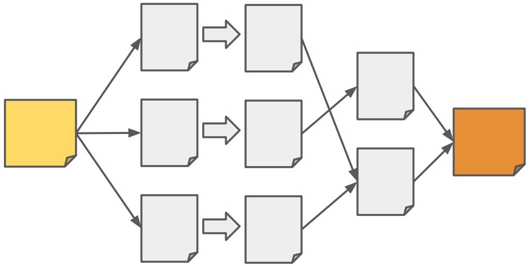
Ph.D supervisor

- Deployment of distributed systems and applications
- Reconfiguration of distributed systems and applications
- Autonomic computing and (self-)adaptation

Research area

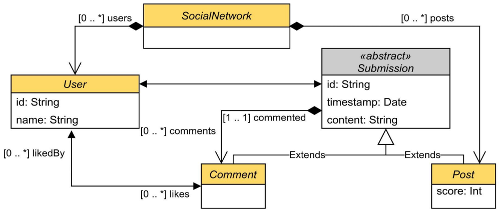
Master’s degree

- Parallel programming and skeletons
- Correctness of programs
- Distributed computing (MPI)



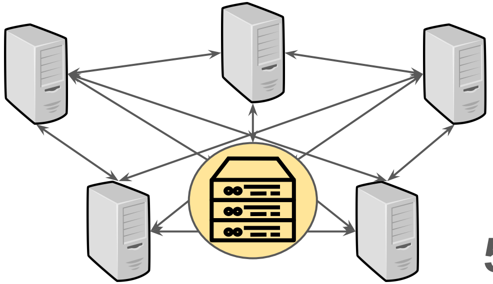
Ph.D

- Model-Driven Engineering and Model Transformation
- Distributed computing
- Feature analysis



Postdoc

- Distributed architecture
- (Re)configuration of systems
- Constraint programming



Outline

DOCTORAT BRETAGNE LOIRE / MATHSTIC

IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

THÈSE DE DOCTORAT DE

L'ÉCOLE NATIONALE SUPÉRIEURE
MINES-TÉLÉCOM ATLANTIQUE BRETAGNE
PAYS-DE-LA-LOIRE - IMT ATLANTIQUE

ÉCOLE DOCTORALE N° 601
Mathématiques et Sciences et Technologies
de l'Information et de la Communication
Spécialité : *Informatique*

Par
Jolan PHILIPPE

Contribution to the Analysis of the Design-Space of a Distributed Transformation Engine

Thèse présentée et soutenue à Nantes, le tbd
Unité de recherche : Laboratoire des Sciences du Numérique de Nantes
Thèse N° : tbd

Rapporteurs avant soutenance :

Jesus SANCHEZ CUADRADO	Associate professos, Universidad de Murcia, Spain
Matthias TICHY	Professor, Brandenburg University of Technology, Germany

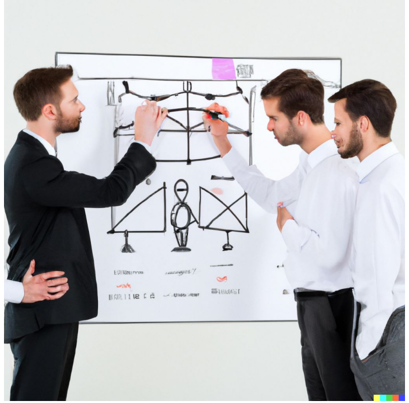
Composition du Jury :

Président :	Thomas LEDOUX	Professor, IMT Atlantique, France
Examinateurs :	Leen LAMBERS	Professor, University of Ulm, Germany
	Antonio VALLECILLO	Professor, University of Málaga, Spain
Dir. de thèse :	Gerson SUNYE	Associate professor, University of Nantes (France)
Co-dir. de thèse :	Massimo TISI	Associate Professor, Institut Mines-Telecom Atlantique (France)
	Hélène COULLON	Associate Professor, Institut Mines-Telecom Atlantique (France)

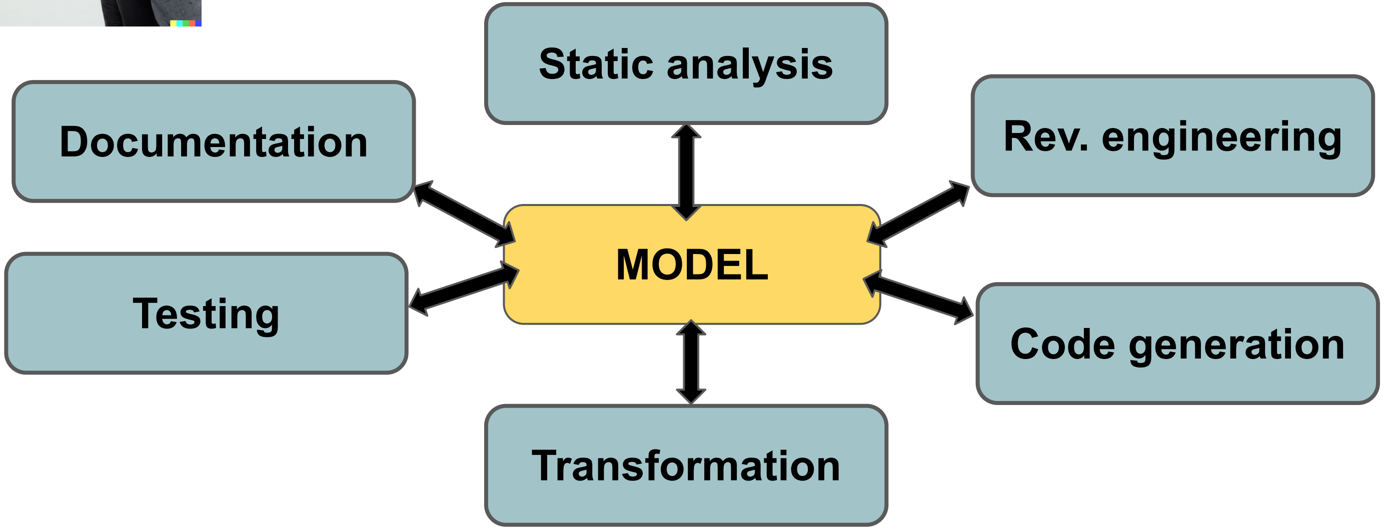
1. CONTEXT & MOTIVATION
2. CONTRIBUTIONS
   - 2.1 SPARKTE: A DISTRIBUTED TRANSFORMATION ENGINE
   - 2.2 DISTRIBUTED QUERY EVALUATION STRATEGIES
   - 2.3 FEATURE ANALYSIS
3. CONCLUSION

1 CONTEXT & PROBLEMATIC

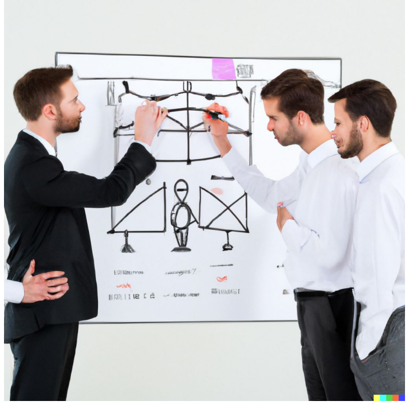
Model-Driven Engineering



- **Software engineering** approach
- Models as the **central artifact** to represent systems



Model-Driven Engineering



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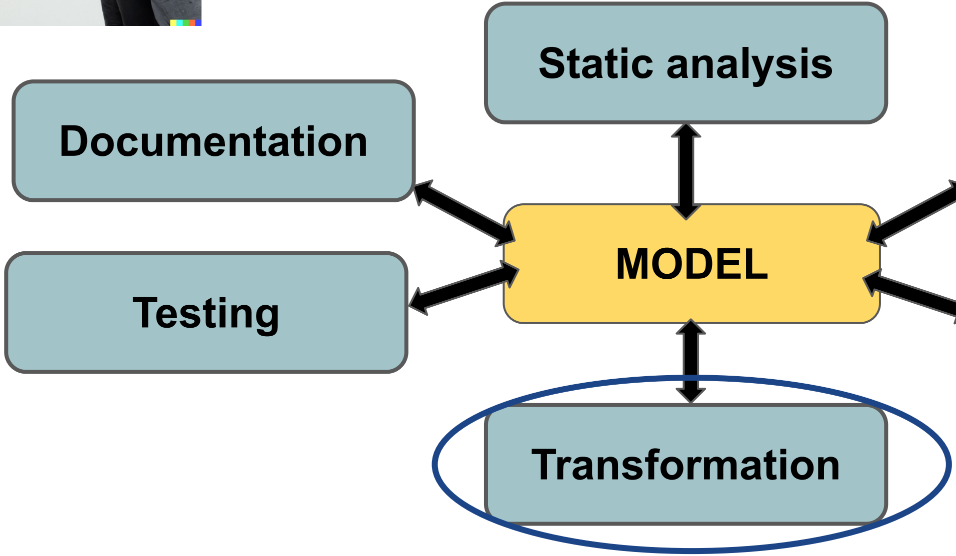
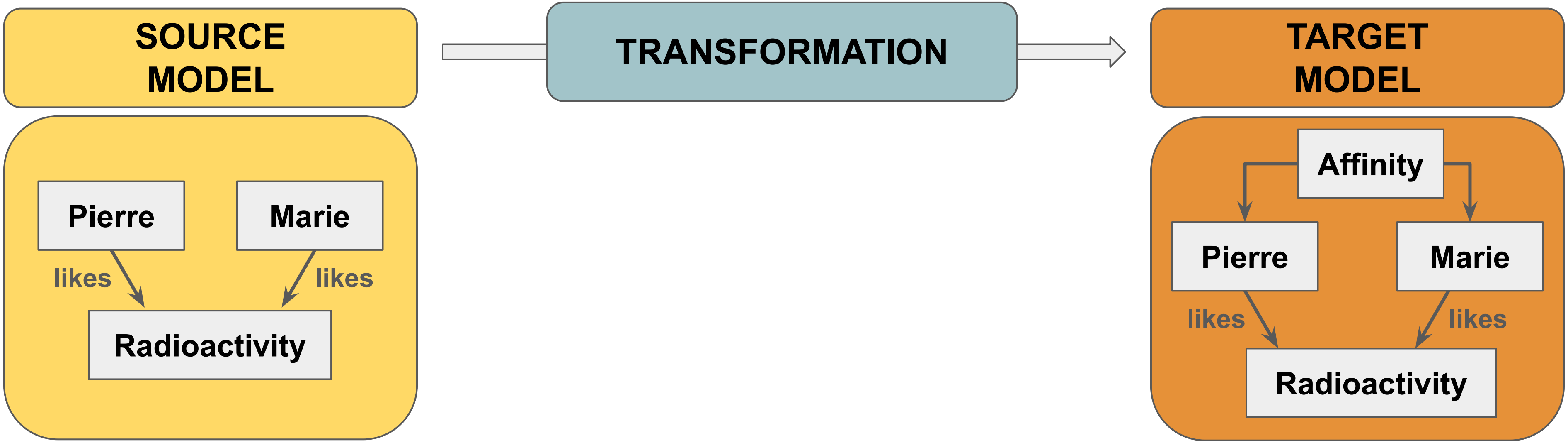


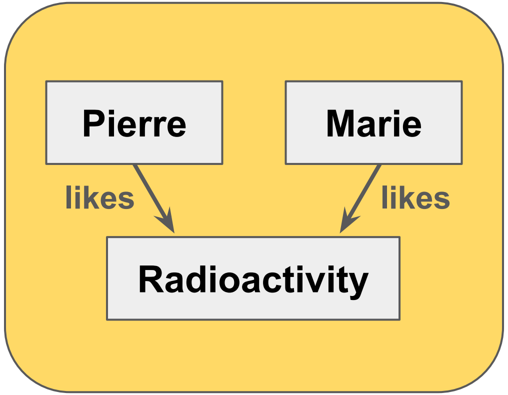
Model Transformation

Model Transformation



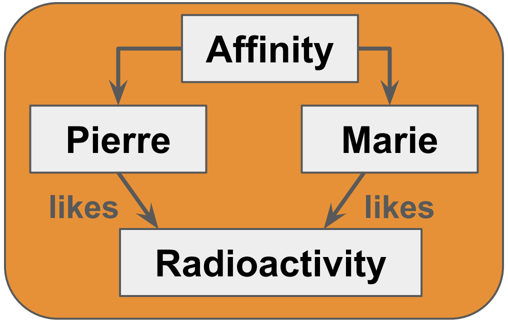
Model Transformation

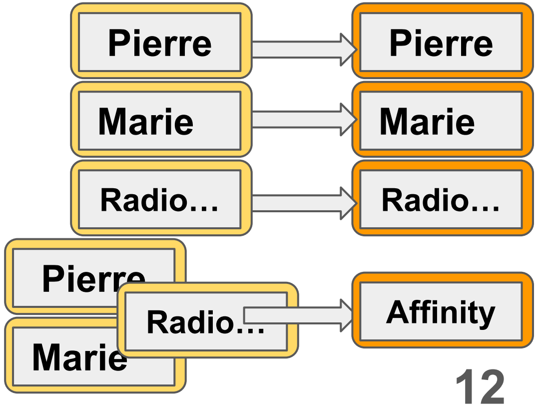
SOURCE MODEL → **TRANSFORMATION** → **TARGET MODEL**




```
rule copy (e: Element)
output:
  new Element (content ← e.content)

rule affinity (e1: Element,
               e2: Element)
matching:
  (e1.likes) ∩ (e2.likes) ≠ ø
output:
  new Affinity (from ←e1, to ← e2)
```





Many transformation languages: ATL, ETL, QVT, Henshin, Viatra, …

Model Transformation

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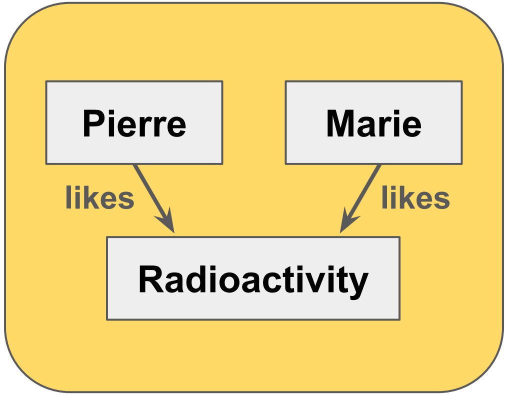


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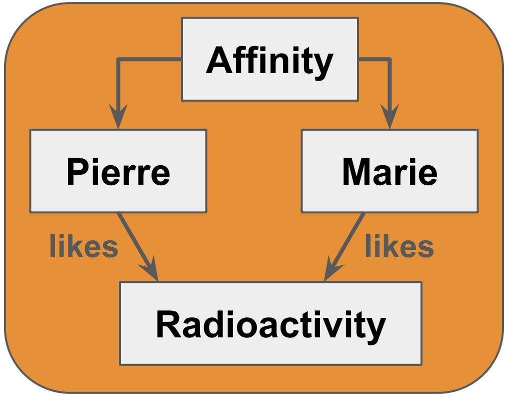
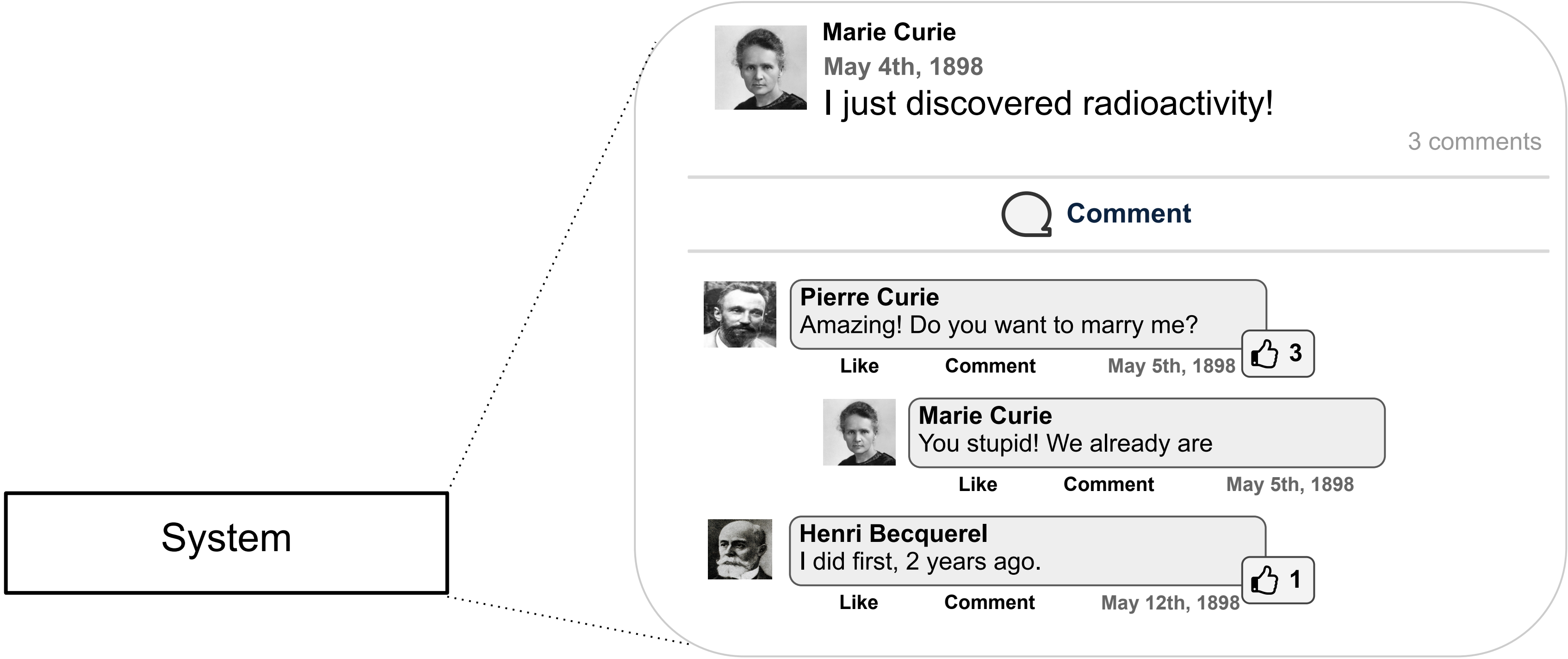


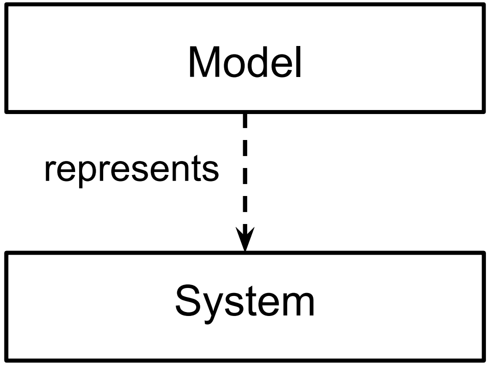
The **expression** e_i.likes can be expressed as a **query**

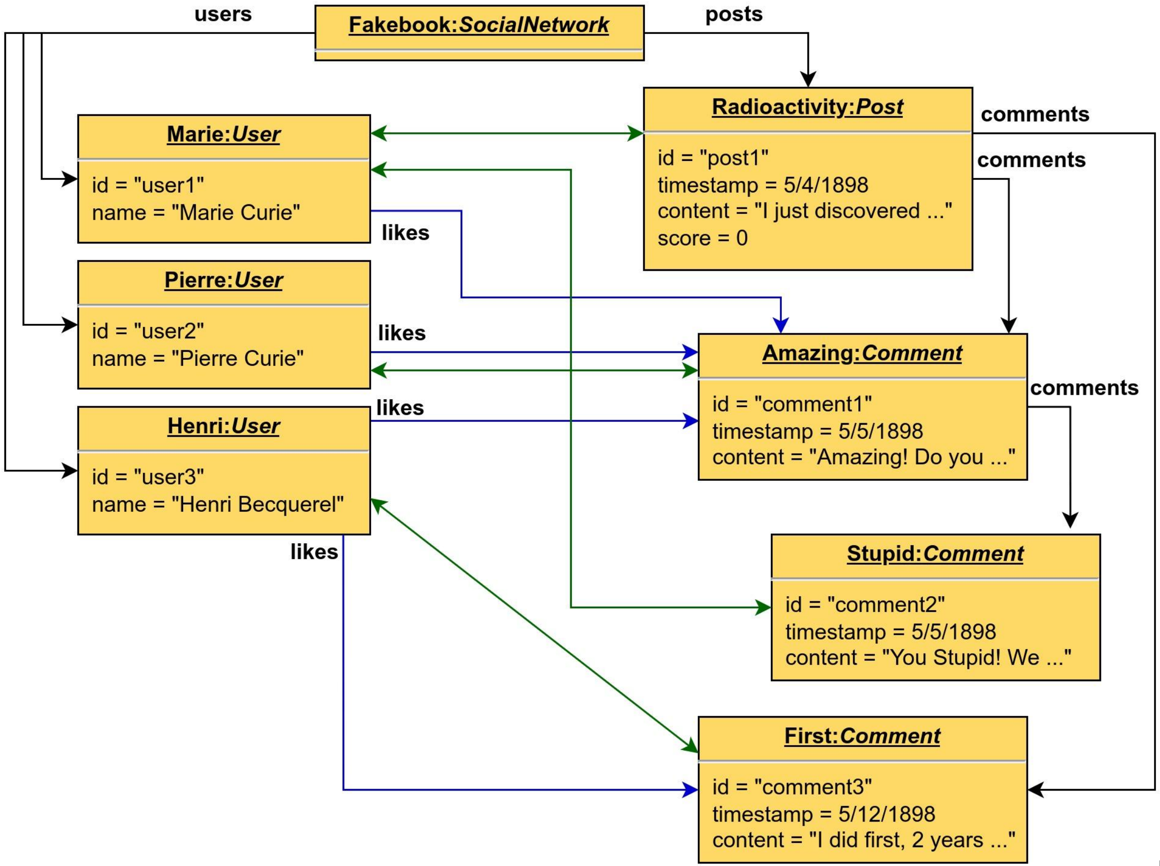
Many transformation languages: ATL, ETL, QVT, Henshin, Viatra, …

Use case: A platform for analysing a social network

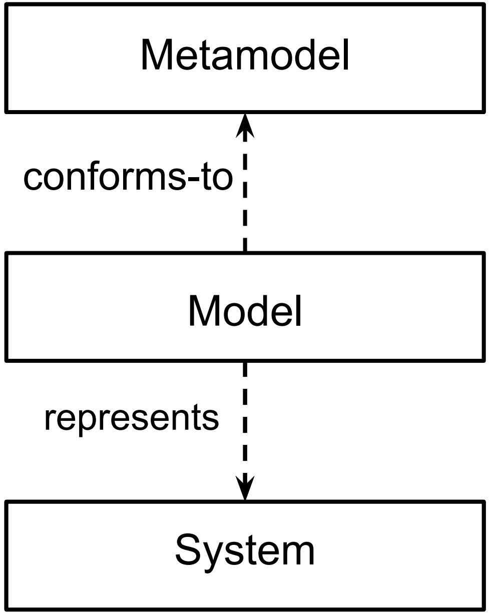


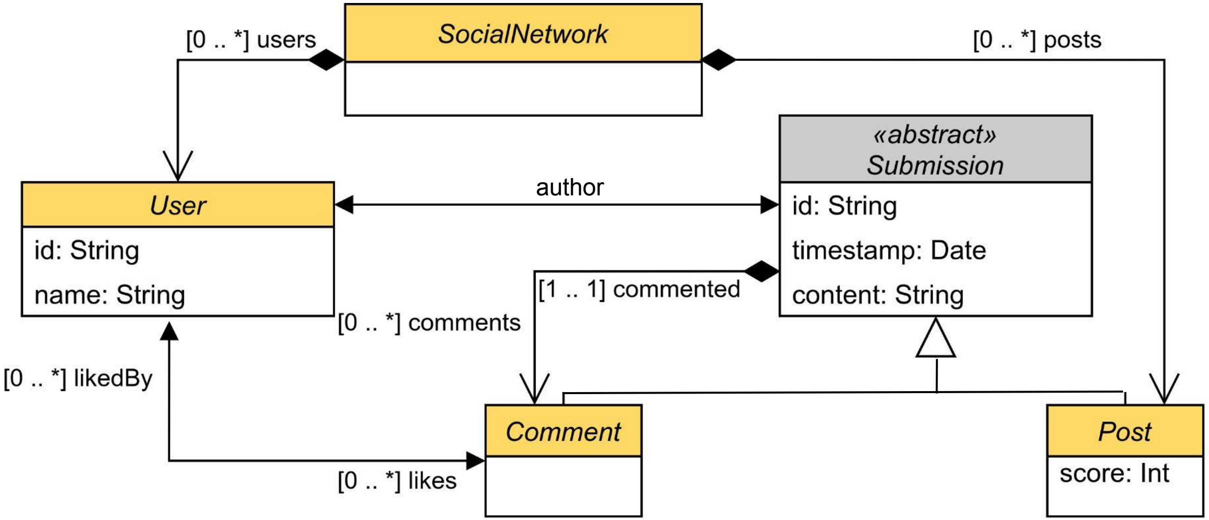
Use case: A platform for analysing a social network



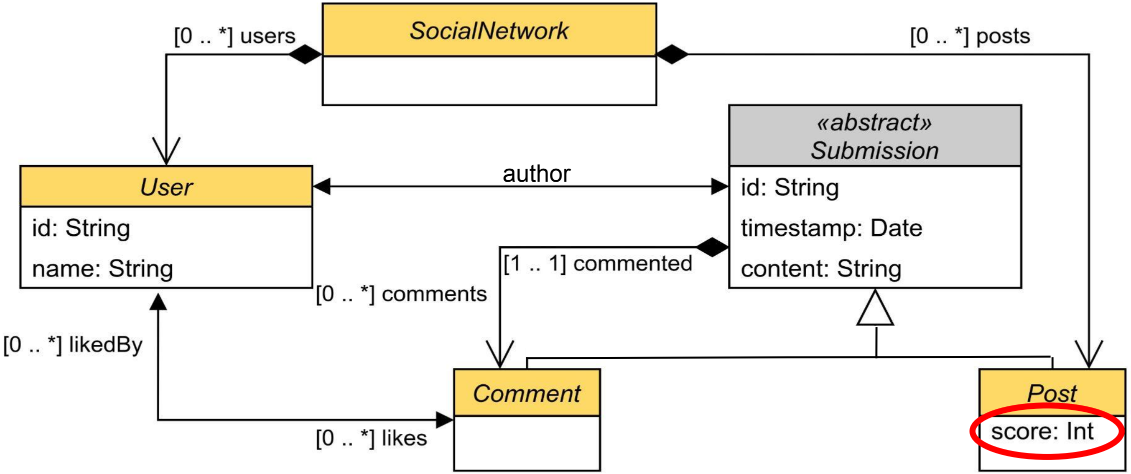


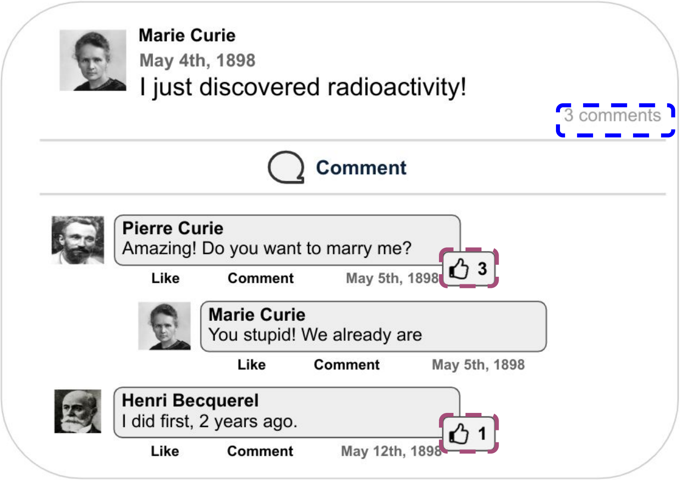
Use case: A platform for analysing a social network





Example 1: Give an activity score for posts in a social network

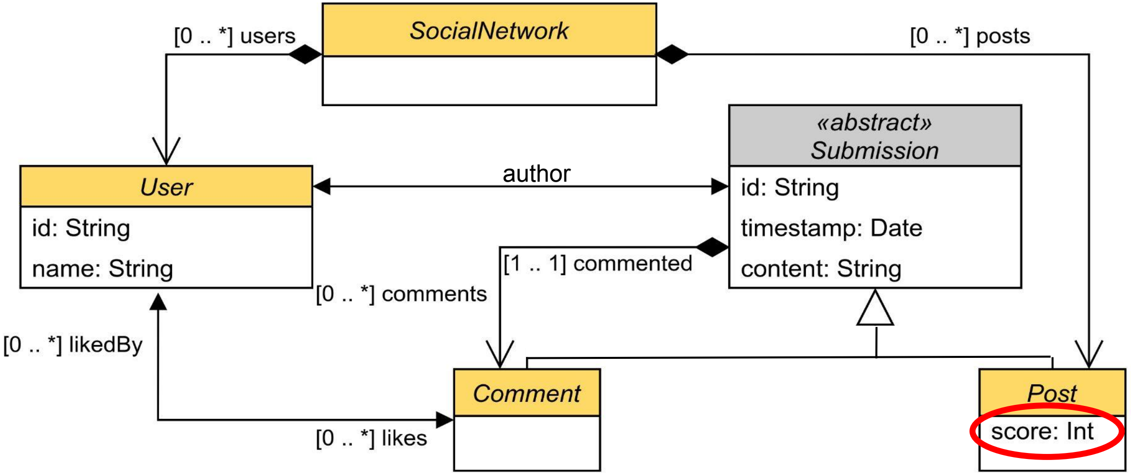


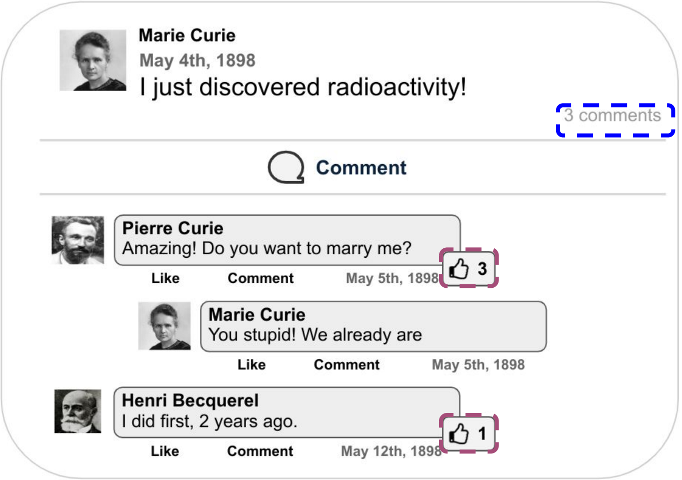


Example: score(p: *Post*) ≔ # comments × 10 + # likes

score(*Radioactivity*) = 3 × 10 + 4 = 34

Example 1: Give an activity score for posts in a social network



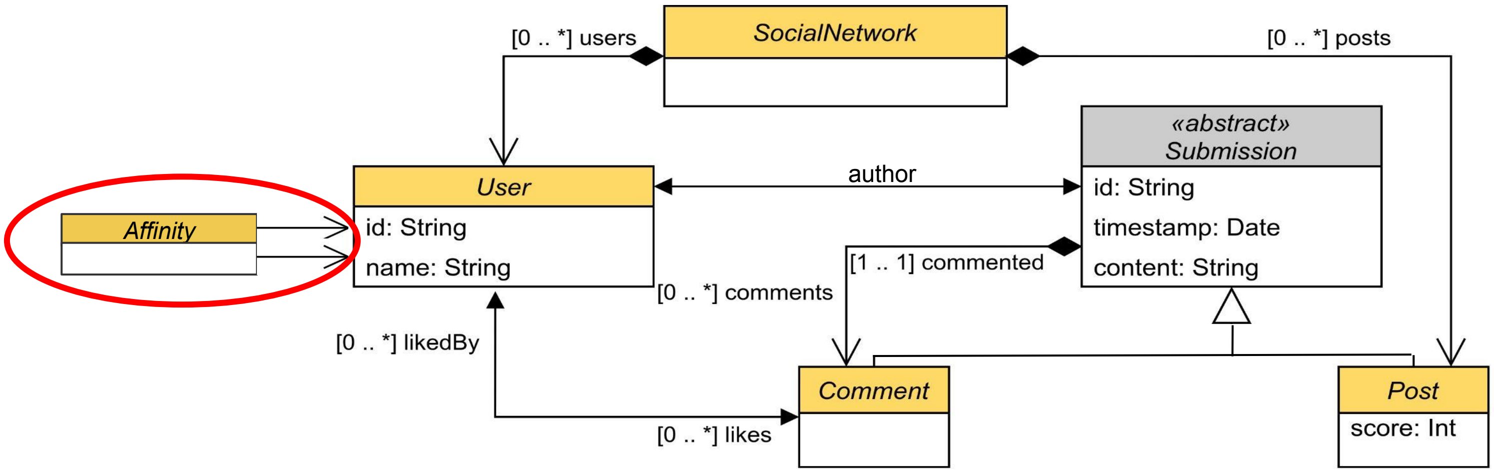


Example: score(p: *Post*) ≔ # comments × 10 + # likes

```
rule Post2ScoredPost (p:Post)
output:
  new Post (id ← p.id,
            timestamp ← p.timestamp
            content ← p.content,
            score ← score(p))
```

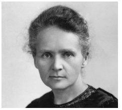
score as a **query**

Example 2: Look for user affinities in a social network



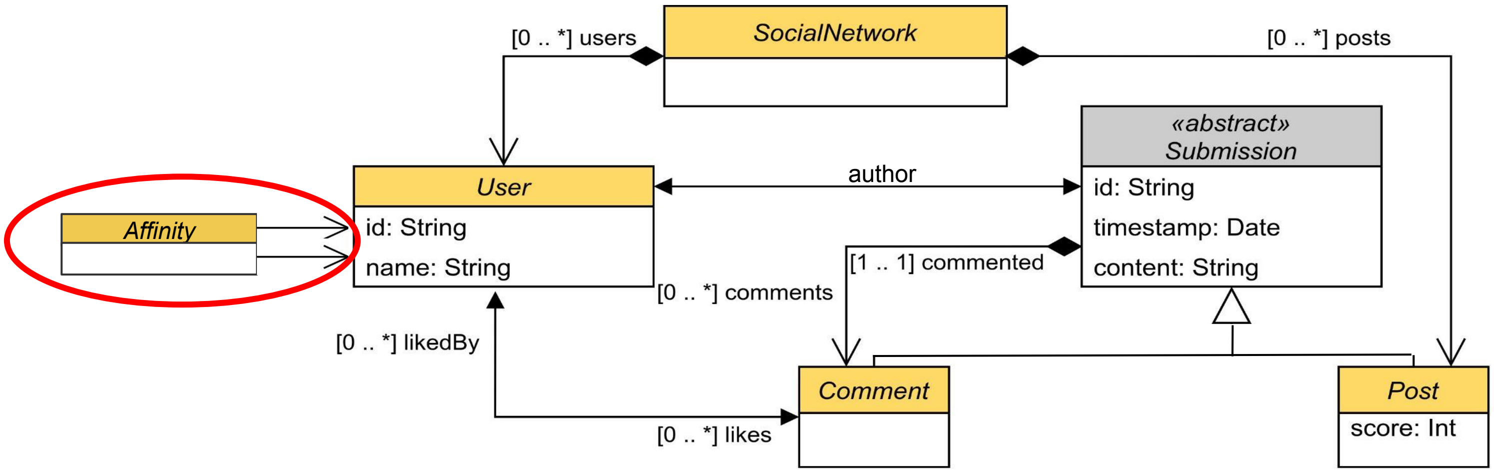
Example: Comment at least 3 same posts

Pierre Curie



Marie Curie

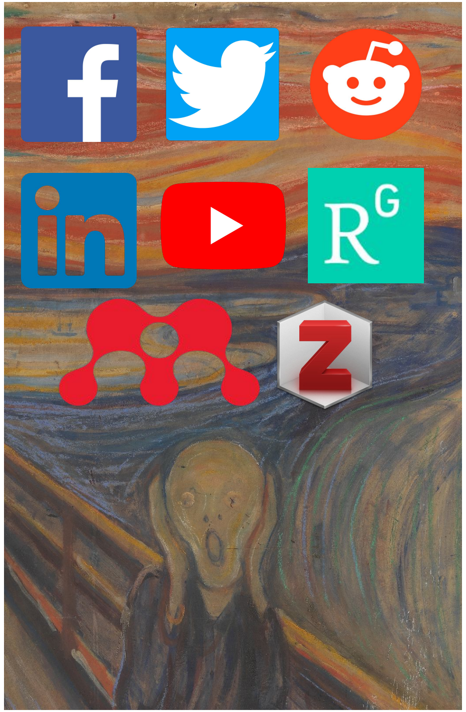
Example 2: Look for user affinities in a social network



Example: Comment at least 3 same posts

rule FindAffinity (u_1:User, u_2:User)
matching:
  $\text{commentedPosts}(u_1) \cap \text{commentedPosts}(u_2) \geqslant 3$
output:
  new Affinity($\text{user}_1 \leftarrow u_1, \text{user}_2 \leftarrow u_2$)

Model management for Very Large Models (VMLs)[1]

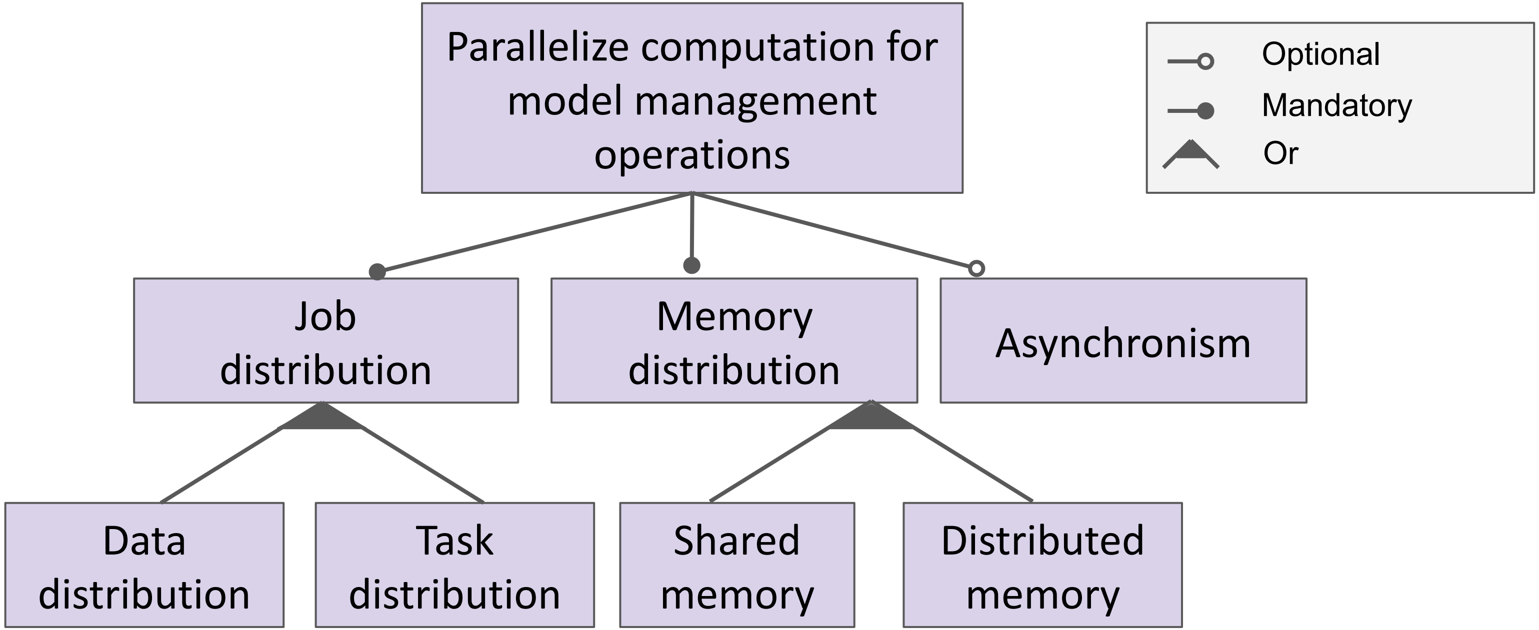


- Computational complexity
  - Size of the model
  - Storage and memory constraints
- Scalability with increasing resources
- Implicit optimization

➢ Two main approaches
  - Avoid computation
  - Parallelize computation

[1] Dimitrios S. Kolovos, Louis M. Rose, Nicholas Drivalos Matragkas, Richard F. Paige, Esther Guerra, Jesús Sánchez Cuadrado, Juan de Lara, István Ráth, Dániel Varró, Massimo Tisi, Jordi Cabot. **A research roadmap towards achieving scalability in model driven engineering.** *BigMDE@STAF 2013*

Scalability of model management for VLMs



Parallelization in model transformation

	Model query	Model transfo.	Pattern match.	Optimization	Shared mem.	Distrib. mem.	Task-parallel	Data-parallel	Asynchronism
Amine Benelallam et al. «**Efficient model partitioning for distributed model** …» SLE 2016		X		X		X		X	
Amine Benelallam et al. «**ATL-MR: model transformation on MapReduce**» SPLASH 2015		X				X		X	
Loli Burgueño et al. «**A Linda-Based platform for the parallel execution** …» IST 2016		X			X			X	X
Loli Burgueño et al. «**Towards distributed model transformations with LinTra**» JISBD 2016		X		X		X		X	X
Loli Burgueño et al. «**Parallel in-place model transformations with LinTra**» CEUR-WS 2015		X			X		X		X
Jesús S. Cuadrado et al. «**Efficient execution of ATL model transformations** …» TSE 2020		X			X			X	
Gábor Imre et al. «**Parallel graph transformations on multicore systems**» MSEPT 2012		X			X		X		
Christian Krause et al. «**Implementing graph transformations in the BSP model**» FASE 2014			X			X		X	
Sina Madani et al. «**Distributed model validation with Epsilon**» SSM 2021	X				X	X		X	
Sina Madani et al. «**Towards optimisation of model queries: a parallel** …» ECMFA 2019	X			X	X		X		
Gergely Mezei et al. «**Towards truly parallel model transformations: a** …» EURCON 2019			X			X	X		
Massimo Tisi et al. «**Parallel execution of ATL transformation rules**» MODELS 2013		X			X		X		
Le-Duc Tung et al. «**Towards systematic parallelization of graph transfo.** …» IJPP 2017		X				X		X	
Tamás Vajk et al. «**Runtime model validation with parallel object** …» MoDeVVa 2011	X				X		X		

Parallelization in model transformation

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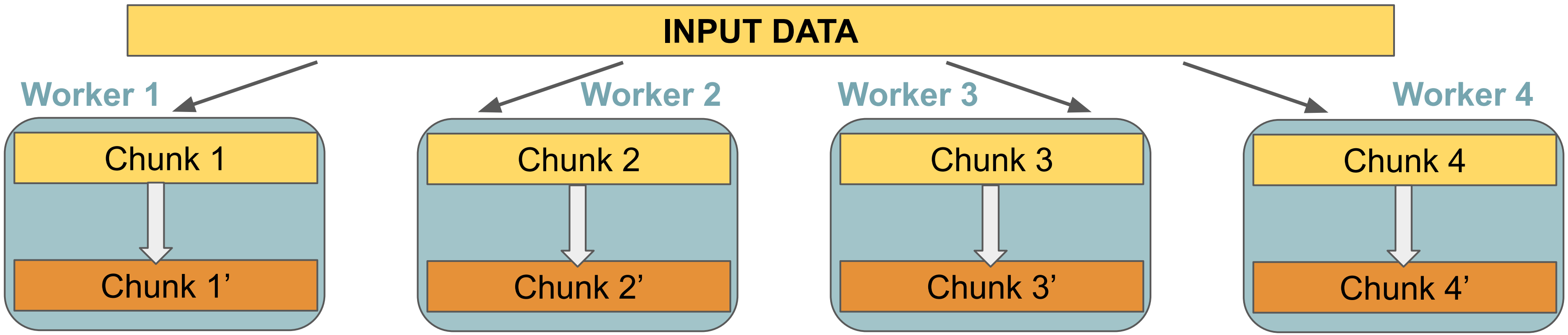
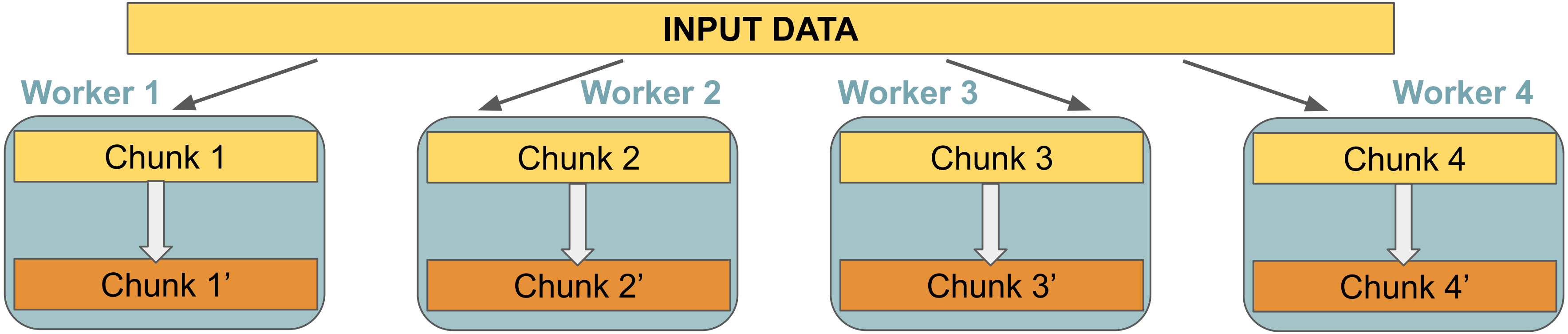
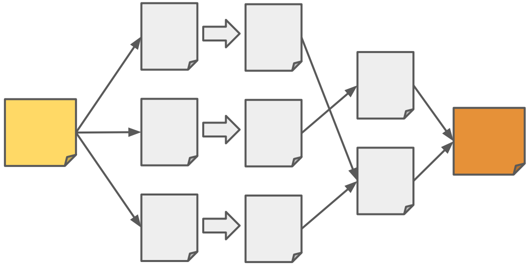
Data-parallelism as a strategy

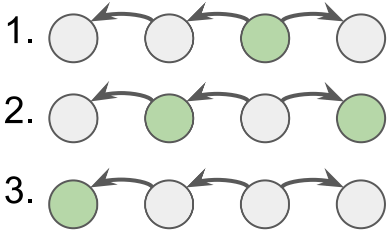


Data-parallelism as a strategy

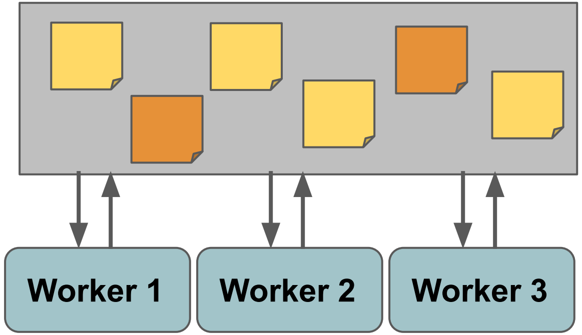




MapReduce



Pregel (vertex-centric)



Blackboard

Parallel / Distributed in model transformation

- Large number of distributed engines
  - Designed with ≠ **purposes**
  - Following ≠ **design choices**
  - Implemented on ≠ **languages** for ≠ **infrastructures**

⇒ What are the optimal design choices for a given case?

Related work

- Automatic adapted strategy
  - Pattern matching (**Bergman et al.**)

- Classification of features of MDE solution
  - For languages (**Tamura et al., M Rose et al.**)
  - Transformation approaches (**Czarnecki et al., Kahani et al.**)
  - Performance oriented (**Groner et al.**)
  - Specific topic: bi-directionality (**Hidaka et al.**)

Optimization in model transformation

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Massimo Tisi et al. «**Parallel execution of ATL transformation rules**» MODELS 2013		X			X		X		
Le-Duc Tung et al. «**Towards systematic parallelization of graph transfo.** …» IJPP 2017		X				X		X	
Tamás Vajk et al. «**Runtime model validation with parallel object** …» MoDeVVa 2011	X				X		X		

Problem: A configuration issue

- What solution to use?
- How to optimally configure a solution?

Problem 1:
Many solutions for executing rules distributively

Problem 2:
Many solutions for executing queries distributively

Problem 3:
Lack of unified proposition for comparing design choices

➢ **Goal:** Getting an insight of how design choices impact scalability of a distributed transformation

Problem 1:
Many solutions for executing rules distributively

Evaluation of distributed design choices for **rule execution**

- Building a new distributed transformation engine: SparkTE

Contribution of the thesis

Problem 1:
Many solutions for executing rules distributively

Evaluation of distributed design choices for **rule execution**

- Building a new distributed transformation engine: SparkTE

Problem 2:
Many solutions for executing queries distributively

Evaluation of distributed design choices for **query execution**

- Analysing different distributed execution strategies for a query

Contribution of the thesis

Problem 1:
Many solutions for executing rules distributively

Evaluation of distributed design choices for **rule execution**

- Building a new distributed transformation engine: SparkTE

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Many solutions for executing queries distributively

Evaluation of distributed design choices for **query execution**

- Analysing different distributed execution strategies for a query

Problem 3:
Lack of unified proposition for comparing design choices

Make possible configurable distributed transformation

- Modeling the design space
- Making the configurable engine: Configurable SparkTE

1st Contribution

2.1 SPARKTE, A DISTRIBUTED MODEL TRANSFORMATION ENGINE

Problematic and proposal

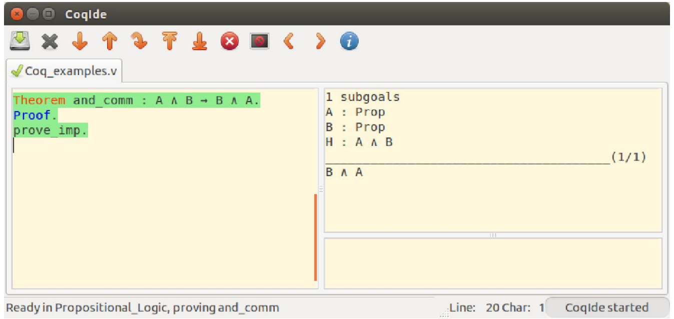
Many solutions for executing rules distributively

➢ Evaluation of distributed design choices for **rule execution**

- An engine with design choices for rule execution: SparkTE
- Prove design choices have no impact on the result
- Evaluate the scalability of a such engine

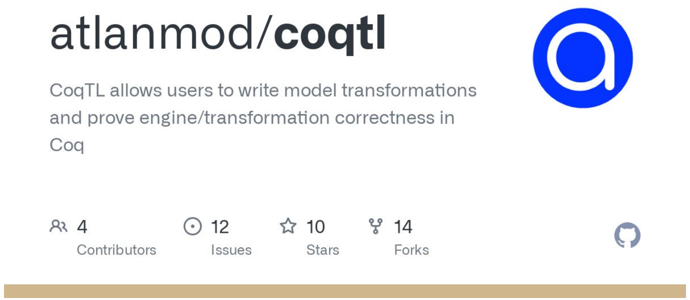
CoqTL for reasoning

Coq



- Designed for specifying semantics
- A proof assistant based on **Hoare logic**
- Extraction mechanism (to ML lang)

- **DSL** for rule-based model transformation
- Made for **reasoning on transformations**
- Can **reason on the semantic** of the transformation



Model formal definition


```
(* Model definition *)
Inductive Model (ModelElement: Type) (ModelLink: Type): Type :=
    BuildModel: list ModelElement →
                list ModelLink →
                Model ModelElement ModelLink.
```

Model formal definition


```
(* Model definition *)
Inductive Model (ModelElement: Type) (ModelLink: Type): Type :=
    BuildModel: list ModelElement →
                list ModelLink →
                Model ModelElement ModelLink.

(* SocialNetwork model definition *)
Inductive User: := BuildUser: (* id *) string → (* name *) string → User
…
Inductive SocialNetworkElement: Set := (* sum type for elements *)
        | SocialNetworkUser: User → SocialNetworkElement
        | …
Inductive SocialNetworkLink: Set := … (* sum type for links *)
```

Model formal definition

```
(* Model definition *)
Inductive Model (ModelElement: Type) (ModelLink: Type): Type :=
    BuildModel: list ModelElement →
                list ModelLink →
                Model ModelElement ModelLink.

(* SocialNetwork model definition *)
Inductive User: := BuildUser: (* id *) string → (* name *) string → User
…
Inductive SocialNetworkElement: Set := (* sum type for elements *)
        | SocialNetworkUser: User → SocialNetworkElement
        | …
Inductive SocialNetworkLink: Set := … (* sum type for links *)

Definition SocialNetworkModel := Model SocialNetworkElement
                                       SocialNetworkLink.
```

Transformation formal definition

⟨*transformation*⟩ ::= ⟨*header*⟩ ‘`:=`’ ‘`[`’ ⟨*rule-list*⟩ ‘`]`’

⟨*header*⟩ ::= ‘`transformation`’ ‘`from`’ ⟨*id*⟩ ‘`to`’ ⟨*id*⟩ ‘`with`’ ⟨*id*⟩ ‘`as`’ ⟨*id*⟩

⟨*rule-list*⟩ ::= ⟨*rule*⟩ ‘`;`’ ⟨*rule-list*⟩ | ⟨*rule*⟩

⟨*rule*⟩ ::= ‘`rule`’ ⟨*id*⟩ ‘`from`’ ⟨*input-pattern*⟩ ‘`for`’ ⟨*iteration*⟩ ‘`to`’ ⟨*output-pattern*⟩
| ‘`rule`’ ⟨*id*⟩ ‘`from`’ ⟨*input-pattern*⟩ ‘`to`’ ⟨*output-pattern*⟩

⟨*input-pattern*⟩ ::= ⟨*elem-decl-list*⟩ ‘`when`’ ⟨*gallina-expr*⟩ | ⟨*elem-decl-list*⟩

⟨*elem-decl-list*⟩ ::= ⟨*elem-decl*⟩ ‘`,`’ ⟨*elem-decl-list*⟩ | ⟨*elem-decl*⟩

⟨*elem-decl*⟩ ::= ⟨*id*⟩ ‘`class`’ ⟨*id*⟩

Transformation formal definition

$$\langle \textit{iteration} \rangle ::= \langle \textit{id} \rangle \text{ `}\texttt{in}\text{' } \langle \textit{gallina-expr} \rangle$$

$$\langle \textit{output-pattern} \rangle ::= \text{`}\texttt{[}\text{' } \langle \textit{output-list} \rangle \text{ `}\texttt{]}\text{'}$$

$$\langle \textit{output-list} \rangle ::= \langle \textit{output-elem} \rangle \text{ `}\texttt{;}\text{' } \langle \textit{output-list} \rangle \mid \langle \textit{output-elem} \rangle$$

$$\langle \textit{output-elem} \rangle ::= \langle \textit{string} \rangle \text{ `}\texttt{:}\text{' } \langle \textit{elem-def} \rangle \text{ `}\texttt{with}\text{' `}\texttt{[}\text{' } \langle \textit{link-def-list} \rangle \text{ `}\texttt{]}\text{'}$$

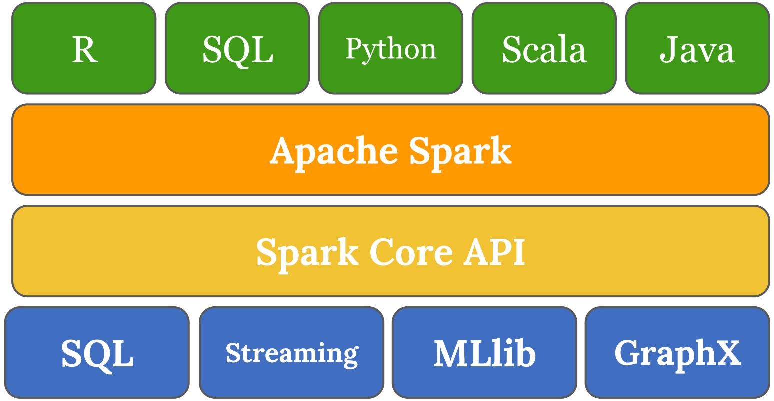
$$\langle \textit{elem-def} \rangle ::= \langle \textit{elem-decl} \rangle \text{ `}\texttt{:=}\text{' } \langle \textit{gallina-expr} \rangle$$

$$\langle \textit{link-def-list} \rangle ::= \langle \textit{link-def} \rangle \text{ `}\texttt{;}\text{' } \langle \textit{link-def-list} \rangle \mid \langle \textit{link-def} \rangle$$

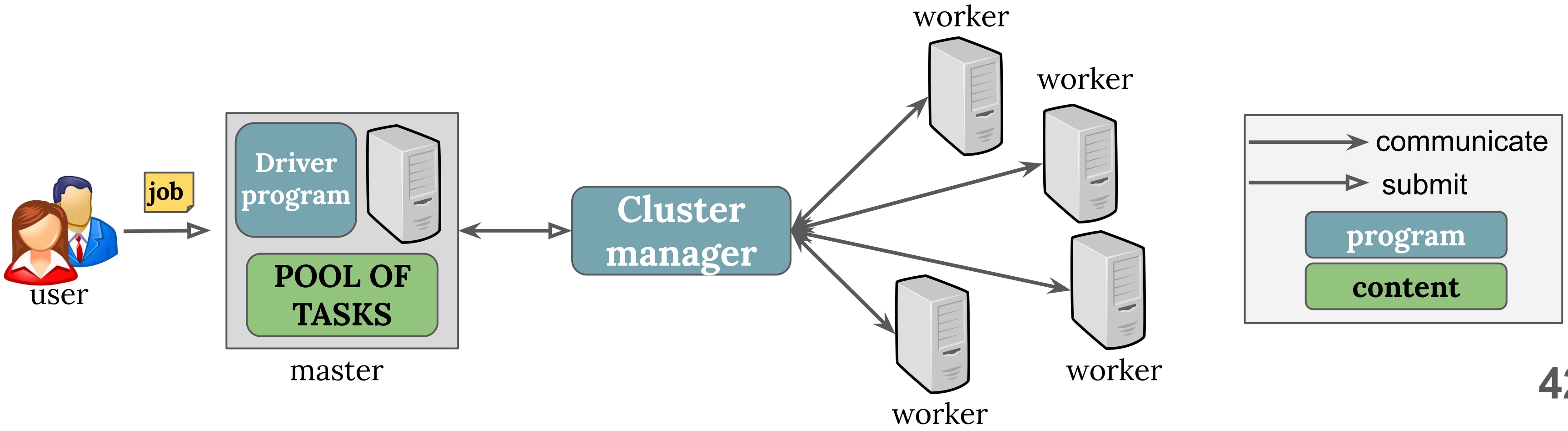
$$\langle \textit{link-def} \rangle ::= \langle \textit{link-decl} \rangle \text{ `}\texttt{:=}\text{' } \langle \textit{gallina-expr} \rangle$$

$$\langle \textit{link-decl} \rangle ::= \text{`}\texttt{ref}\text{' } \langle \textit{id} \rangle$$

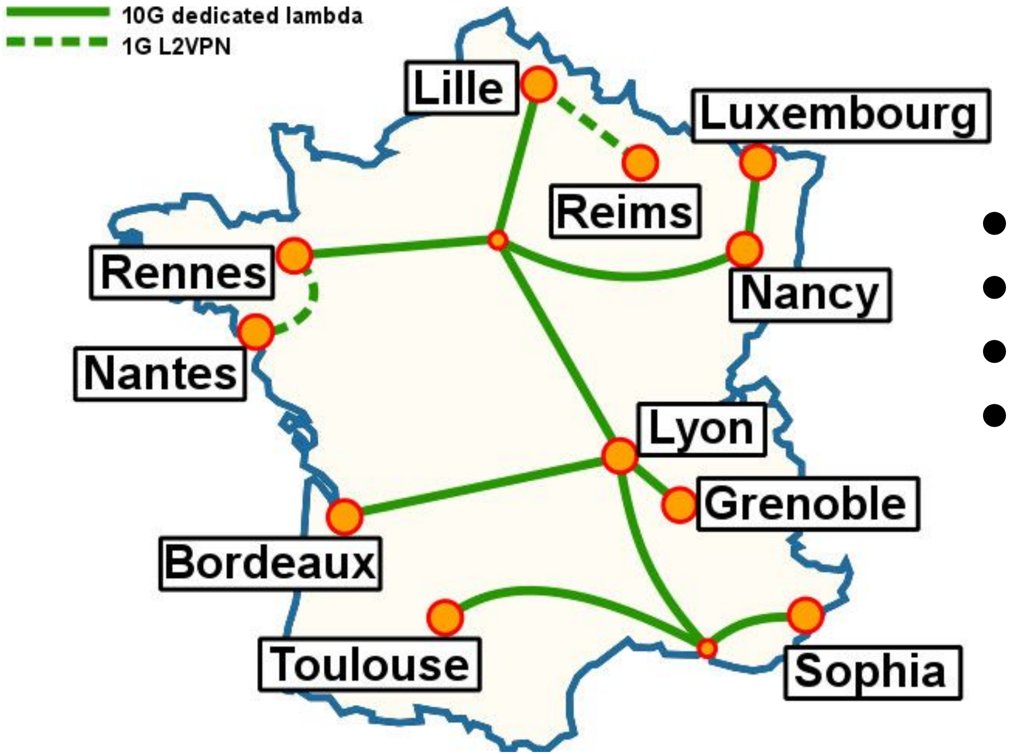
Spark as a target



- Popular distributed computing for **large-scale data** processing
- Support for **many paradigms**
  - MapReduce, vertex-based (Pregel), …
- **Open-source**



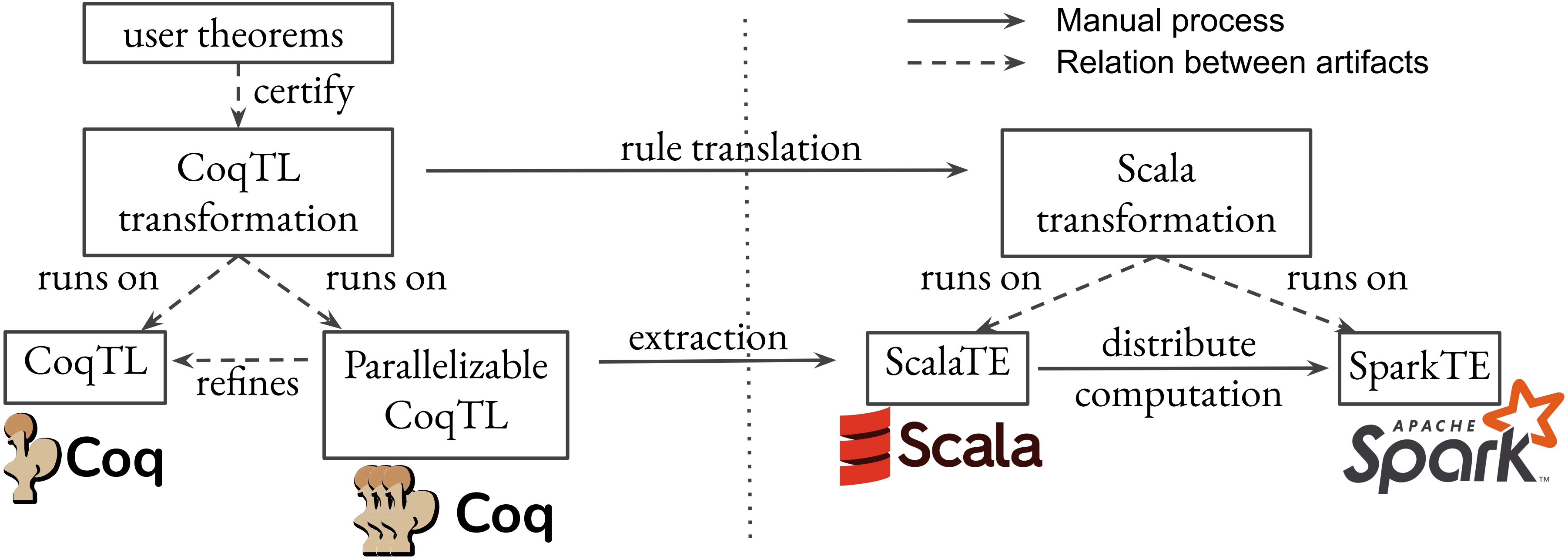
Spark on Grid’5000



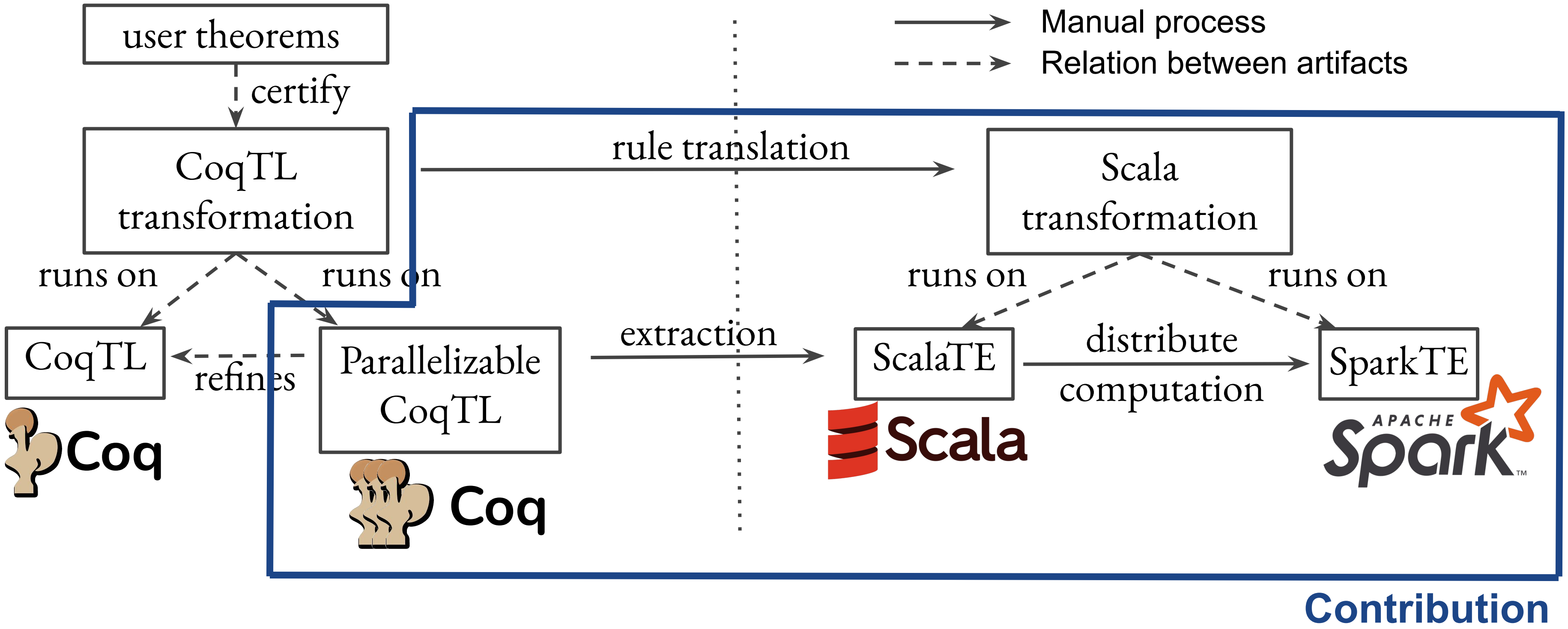
- French cluster for experimentation
- Library for benchmarking
- Support for distributed computing
- More than 15,000 cores; 800 nodes

Grid’5000

Engine based on a formal semantic: from CoqTL to SparkTE



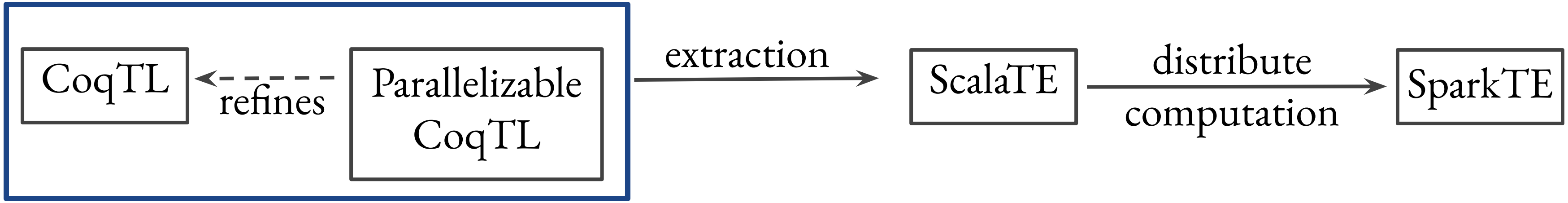
Engine based on a formal semantic: from CoqTL to SparkTE



Contribution: Parallelizable CoqTL as a CoqTL refinement

- **Increase parallelization**
  1. Two distinct phases: **instantiate** & **apply**
     - Define map-reduce phases
  2. Iterate on rules instead of src patterns
     - Avoid unnecessary computations
  3. Iterate on trace links instead of src patterns
     - Reuse of intermediate results

- **Formal proof** of equivalence with CoqTL



Proof of equivalence

Theorem equivalence:
∀ (SME: Type) (SML: Type) (TME: Type) (TML: Type)
(tr: Transformation) (sourceModel: Model SME SML)
(targetModel: Model TME TML) (new_targetModel: Model TME TML) :

Proof of equivalence

```
Theorem equivalence:
  ∀ (SME: Type) (SML: Type) (TME: Type) (TML: Type)
    (tr: Transformation) (sourceModel: Model SME SML)
    (targetModel: Model TME TML) (new_targetModel: Model TME TML) :
  (* if the two executions, with same input, produce 2 target models *)
    execute tr sourceModel = targetModel →
    new_execute tr sourceModel = new_targetModel
```

```
Theorem equivalence:
  ∀ (SME: Type) (SML: Type) (TME: Type) (TML: Type)
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  (* if the two executions, with same input, produce 2 target models *)
    execute tr sourceModel = targetModel →
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→ (* then the second output is included in the first *)
  (∀ e ∈ allModelElements targetModel → e ∈ allModelElements new_targetModel
 ∧ (∀ l ∈ allModelLinks targetModel → l ∈ allModelLinks new_targetModel)
```

Proof of equivalence

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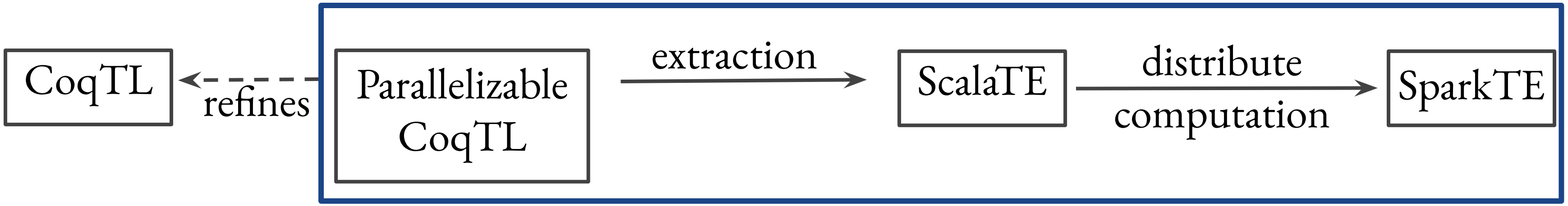
(∀ e ∈ allModelElements targetModel → e ∈ allModelElements new_targetModel
∧ (∀ l ∈ allModelLinks targetModel → l ∈ allModelLinks new_targetModel)

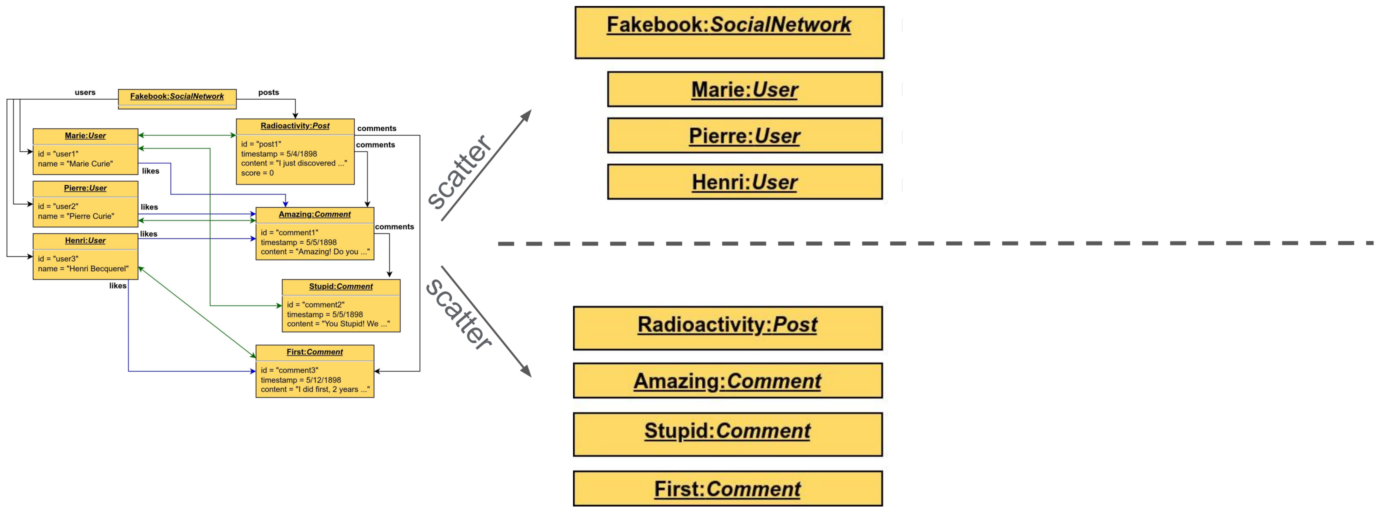
	Spec. size (LoC)	Cert. size (LoC)	Proof effort (man-days)
1.	69	484	10
2.	42	487	7
3.	69	520	4

Contribution: Build executable and distributed transformation engine

1. **Produce** executable and maintainable **code**
    - Object-oriented approach
    - Pure Scala functions (correctness)
2. **Distribute the computation**
    - Distribute data-structures
    - Explicit communication operations
        - Take advantage of scatter/gather operations
        - Broadcast global knowledge



Instantiate phase: Create output elements



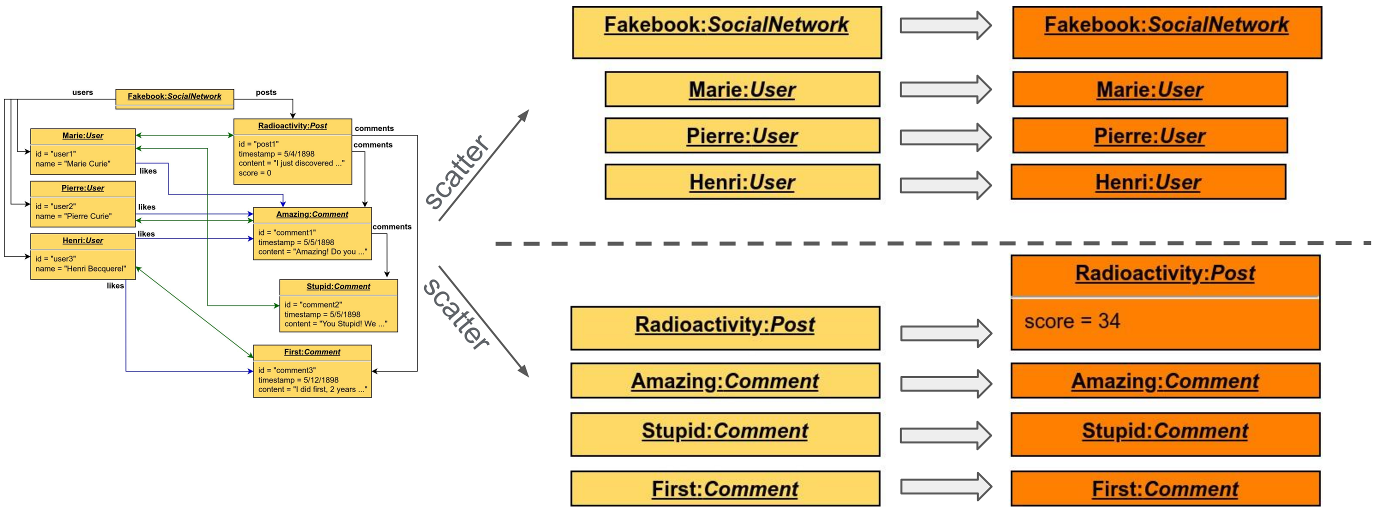
Data-distributed strategy: (*Map-Reduce* phase)

- Input **elements** are **distributed**
- Input **model** is **broadcasted**

As output:

- Instantiated **output model elements**
- **Trace-links** (mapping input-output)

Instantiate phase: Create output elements



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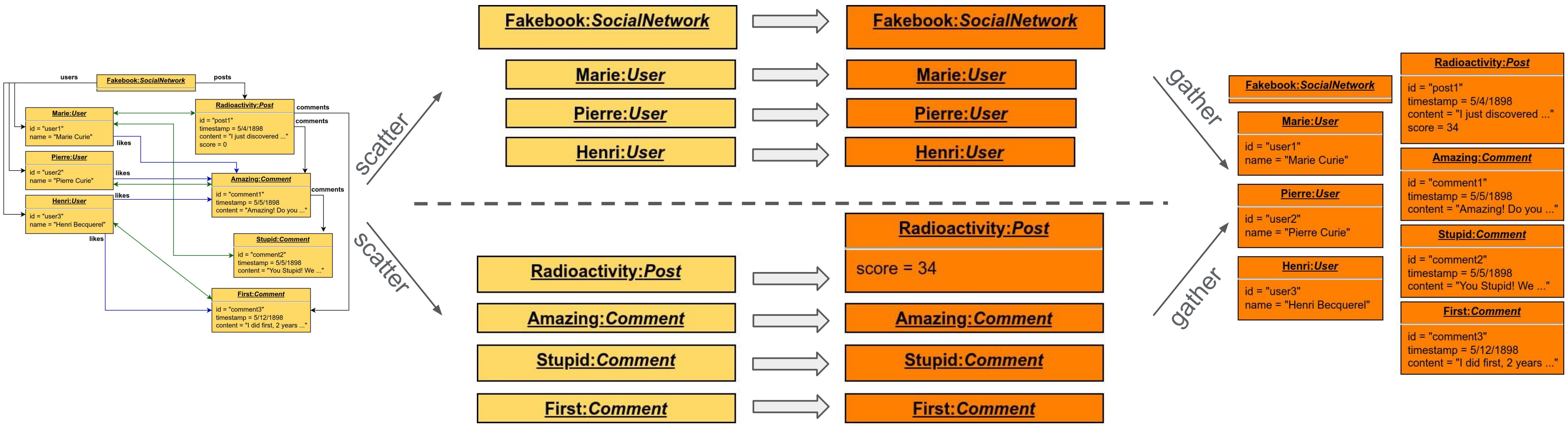

Data-distributed strategy: (*Map-Reduce* phase)

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As output:

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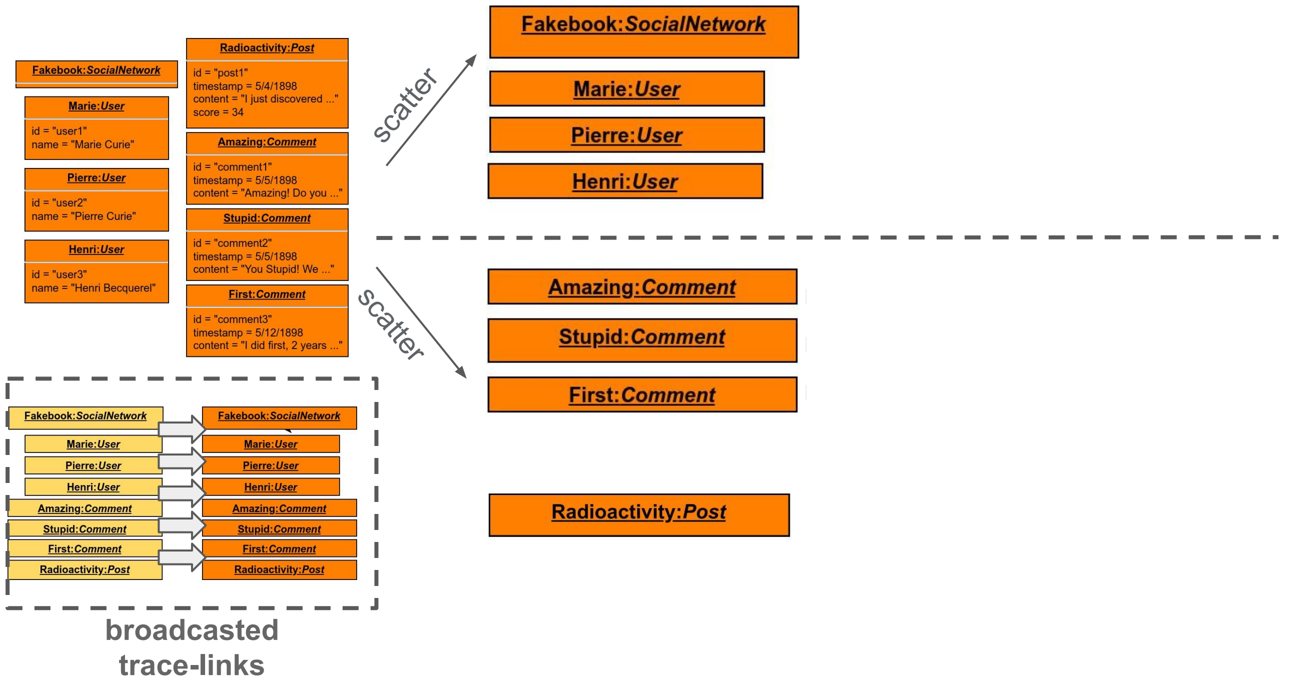
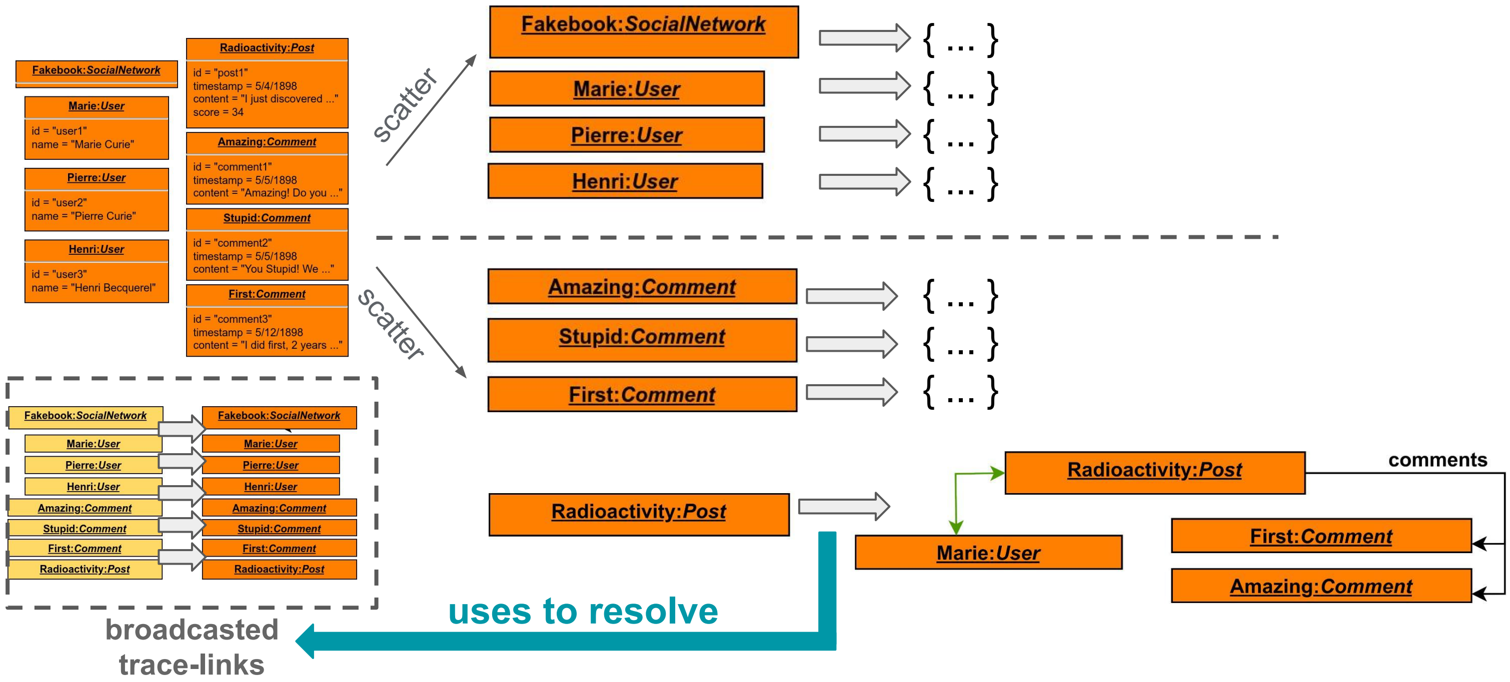
Apply phase: Create output links



Data-distributed strategy: (*Map-Reduce* phase)

- Output **elements** are **distributed**
- Trace-links are **broadcasted**

Apply phase: Create output links



Data-distributed strategy: (*Map-Reduce* phase)

- Output **elements** are **distributed**
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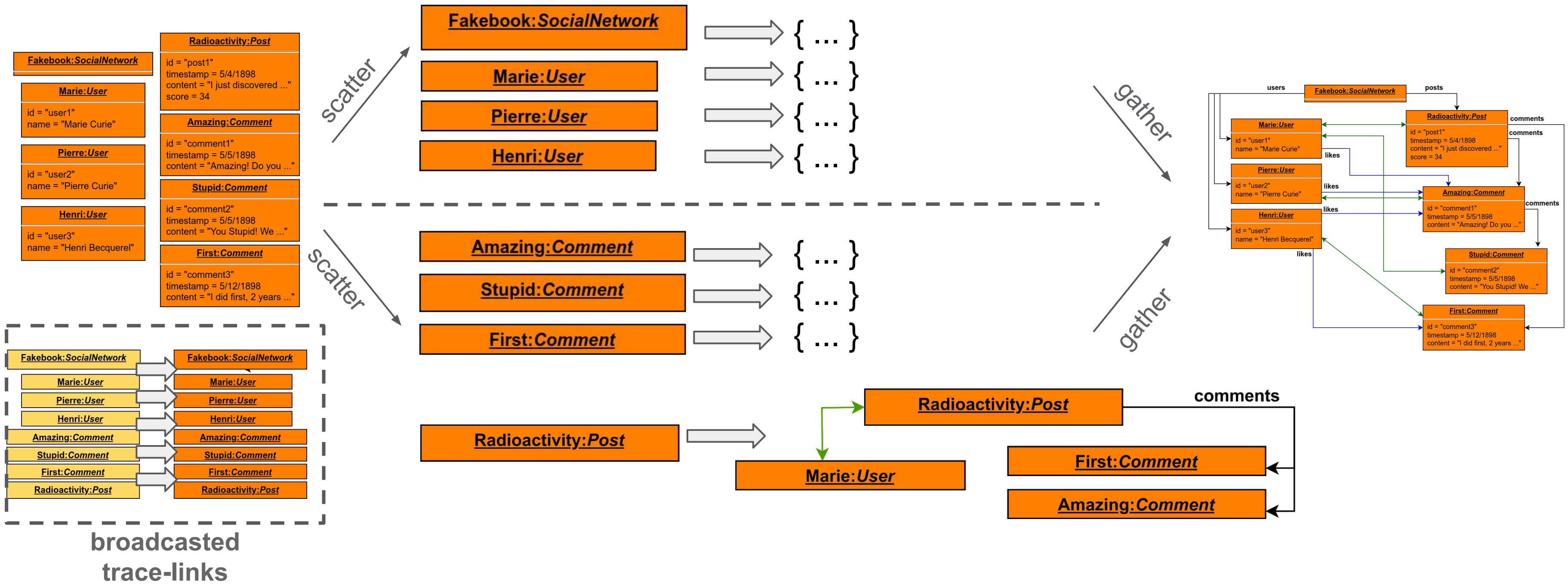
Apply phase: Create output links



Data-distributed strategy: (*Map-Reduce* phase)

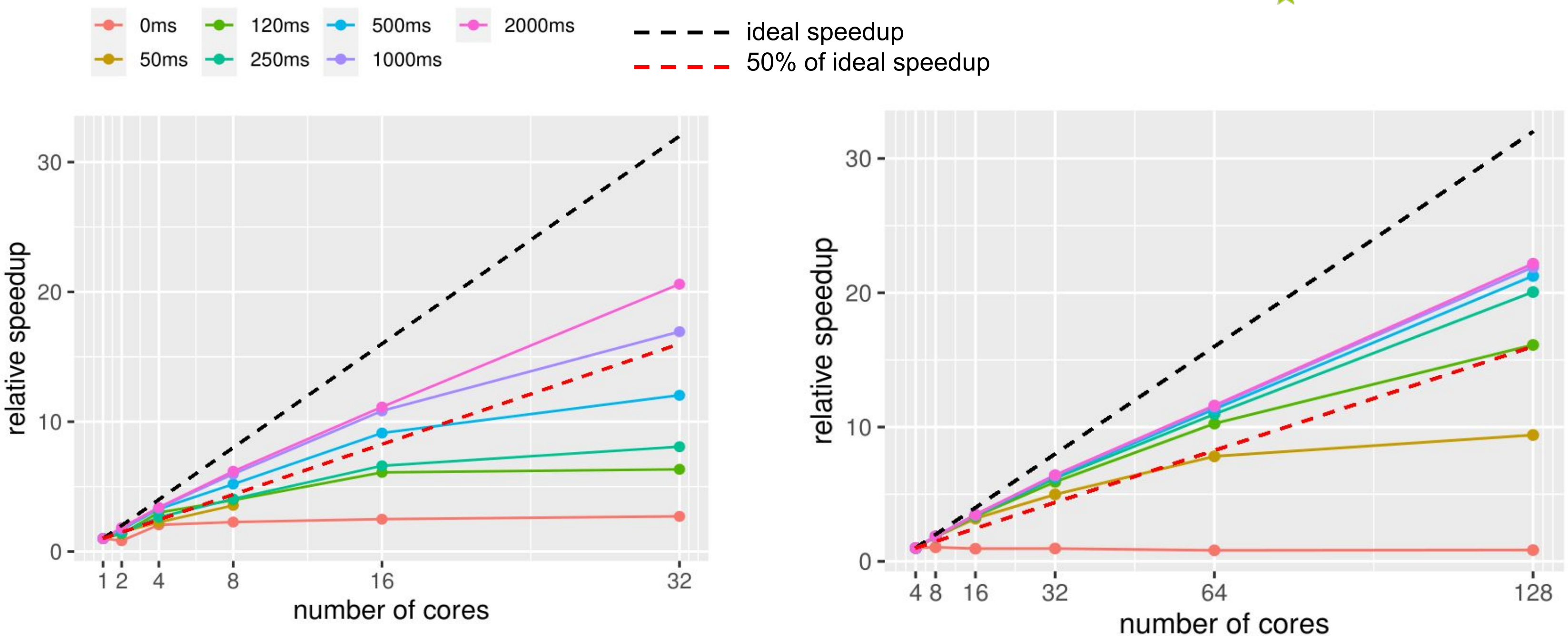
- Output **elements** are **distributed**
- Trace-links are **broadcasted**

Use cases

- Social network metamodels
  - Identity
  - Find affinity
- Class and relational metamodels
  - Class2Relational
  - Relational2Class
- IMDb metamodel
  - Identity
  - Find couples
- DBLP metamodels
  - Find ICMT authors
  - Find ICMT active authors
  - Find active authors, former ICMT
  - Find journals for IST active authors

Vertical scalability of model transformation on Spark

- Simulate a uniform amount of computation on nodes
  - fixed time for each task



Model of 150 elements and 290 links, on 4 machines

Model of 600 elements and 1060 links, 8 machines

2.2

2nd Contribution

DISTRIBUTED QUERY EVALUATION STRATEGIES

Problematic and proposal

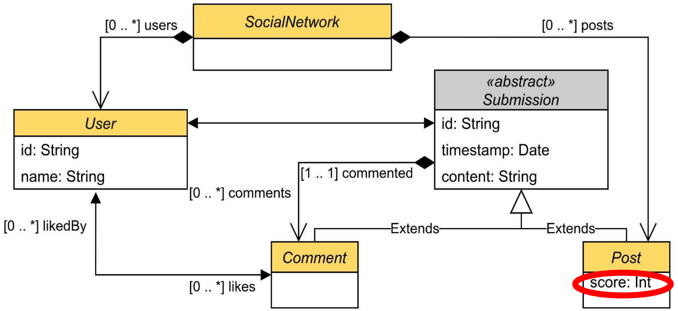
Many solutions for executing queries distributively

➢ Evaluation of distributed design choices for **query execution**

- Take a query whose evaluation is dependant from input model
- Implement with several design choices
- Evaluate them and try to correlate with input

Several design choices for running a query

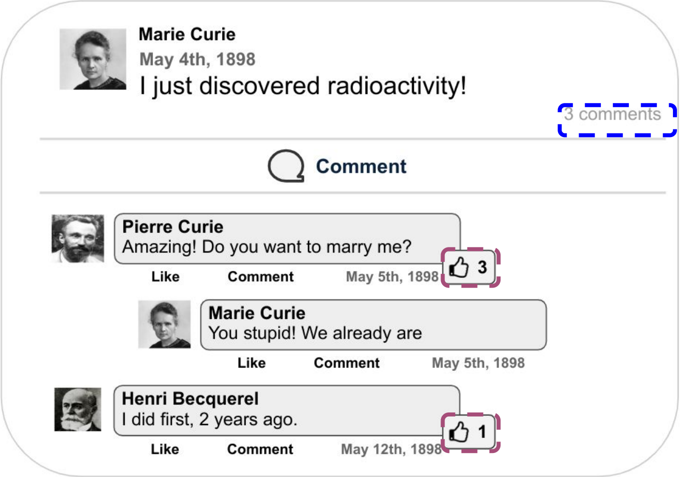
- Query:
  What is the score for a post in a social network?
- A score function
  score(p: *Post*) ≔ **# comments** × 10 + **# likes**




```
score(p: Post) :=   comments(p).size() * 10
                  + likes(p).size()

comments(s: Submission) :=  [s.comments].
        union(c: s.comments.flatMap(
                 λc.comments(c))

likes(p: Post) := comments(p).map(λc.likes)
```



Several design choices (implementation)


```
score(p: Post) :=
   comments(p).size() * 10
        + likes(p).size()

comments(s: Submission) :=
  [s.comments].union(
       c: s.comments.flatMap(
       λc.comments(c))

likes(p: Post) :=
  comments(p).map(λc.likes)
```

- Design-choices for running the query:
  1. **Scala-OCL**
     - No distribution (sequential)
  2. **Spark-OCL** (Spark core API)
     - Delegate distribution to Spark
  3. **MapReduce** (Spark core API)
     - More control of parallelism
  4. **Pregel** from (GraphX)
     - Iterative process
  5. Hybrid approaches
     - **Spark-OCL + Pregel**
     - **MapReduce + Pregel**

Experiments

- Proposed models from TTC
- Calculate score value
- Cannot really extract relevant metrics about topology

	Dataset				Speed-up (compared to Sequential Scala-OCL)					
#	# users	# posts	# comments	# likes	Scala-OCL	Spark-OCL	Pregel	MapReduce	Spark-OCL + Pregel	MapReduce + Pregel
1	889	1064	118	24	**1x**	0.39x	0.36x	0.46x	0.44x	0.46x
2	1845	2315	190	66	**1x**	0.51x	0.68x	**0.85x**	0.66x	0.71x
3	2270	5056	204	129	**1x**	0.27x	0.35x	2.34x	0.15x	**2.96x**
4	5518	9220	394	572	**1x**	4.25x	**5.21x**	4.17x	4.68x	4.03x
5	10929	18872	595	1598	**1x**	**4.68x**	2.83x	2.39x	1.97x	3.91x
6	18083	39212	781	4770	**1x**	4.07x	4.12x	4.58x	**5.17x**	3.27x

Experiments: Correlation input vs. results

Correlation matrix: *input model* vs. *speed-ups*					
Size	Spark- OCL	Pregel	MapReduce	Spark-OCL + Pregel	MapReduce + Pregel
# users	0.78	0.67	0.74	0.76	0.39
# posts	0.71	0.62	0.75	0.75	0.32
# comments	**0.86**	**0.74**	**0.78**	**0.79**	**0.51**
# likes	0.62	0.57	0.7	0.73	0.19

Experiments: Correlation input vs. results

Correlation matrix: *input model* vs. *speed-ups*

Size	Spark- OCL	Pregel	MapReduce	Spark-OCL + Pregel	MapReduce + Pregel
# users	0.78	0.67	0.74	0.76	0.39
# posts	0.71	0.62	0.75	0.75	0.32
# comments	**0.86**	**0.74**	**0.78**	**0.79**	**0.51**
# likes	0.62	0.57	0.7	0.73	0.19

Correlation matrix: *ratio in input model* vs *speed-ups*

	Spark-OCL	Pregel	MapReduce	Spark-OCL + Pregel	MapReduce + Pregel
ratio: #users / #likes	-0.85	-0.79	**-0.89**	-0.75	-0.82
ratio: #posts / #likes	**-0.96**	**-0.88**	-0.82	**-0.85**	-0.66
ratio: #comments / #likes	-0.8	-0.74	-0.86	-0.69	**-0.83**

2.3

3rd Contribution

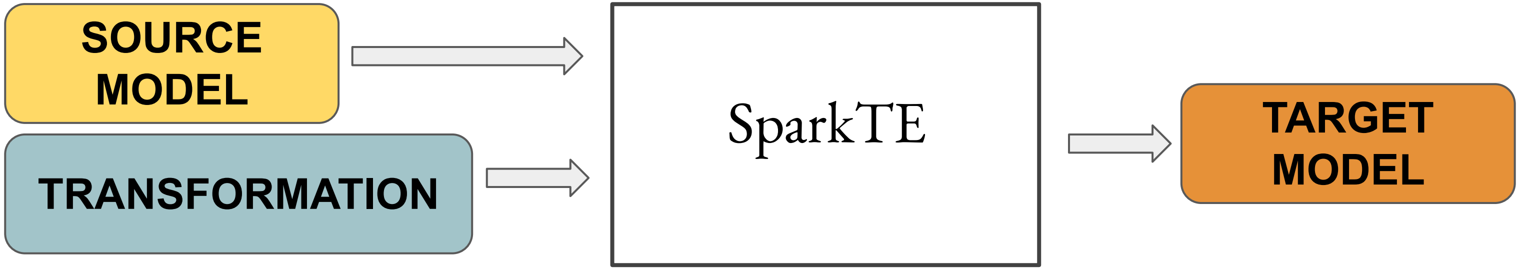
FEATURE ANALYSIS

Problematic and proposal

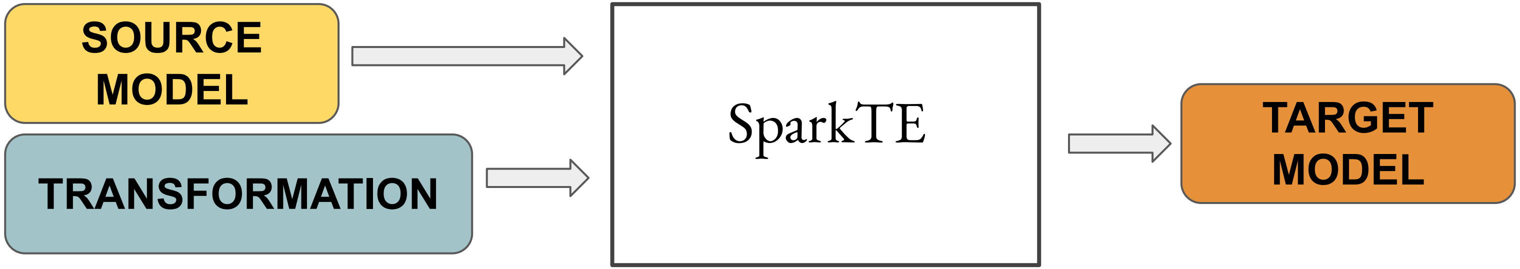
Lack of unified proposition for comparing design choices

- ➢ Make possible configurable distributed transformation
  - Formalized past contributions and additional design choices
  - Design a configurable engine
  - Evaluate them and analyse impact

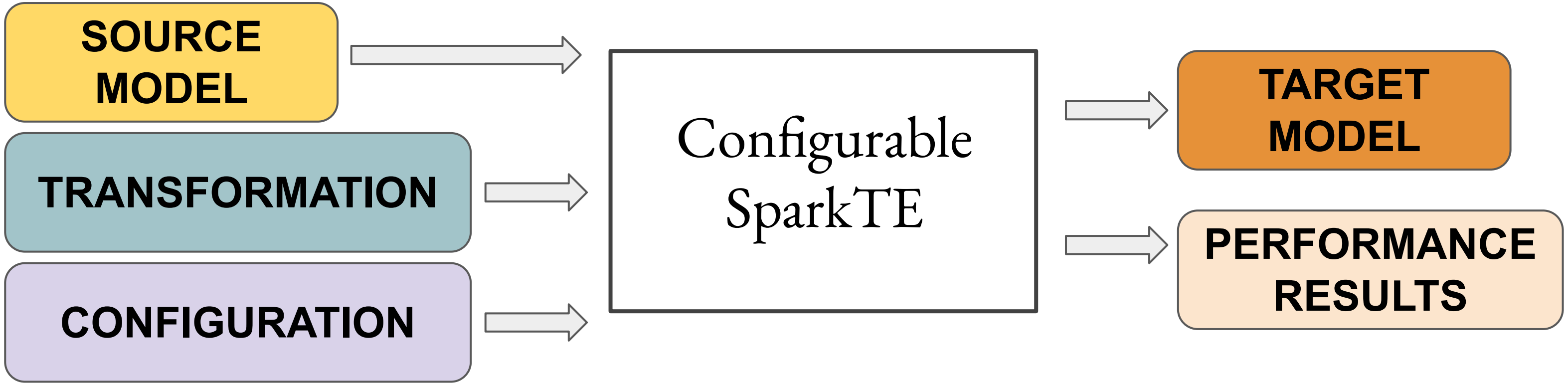
Configurable engine



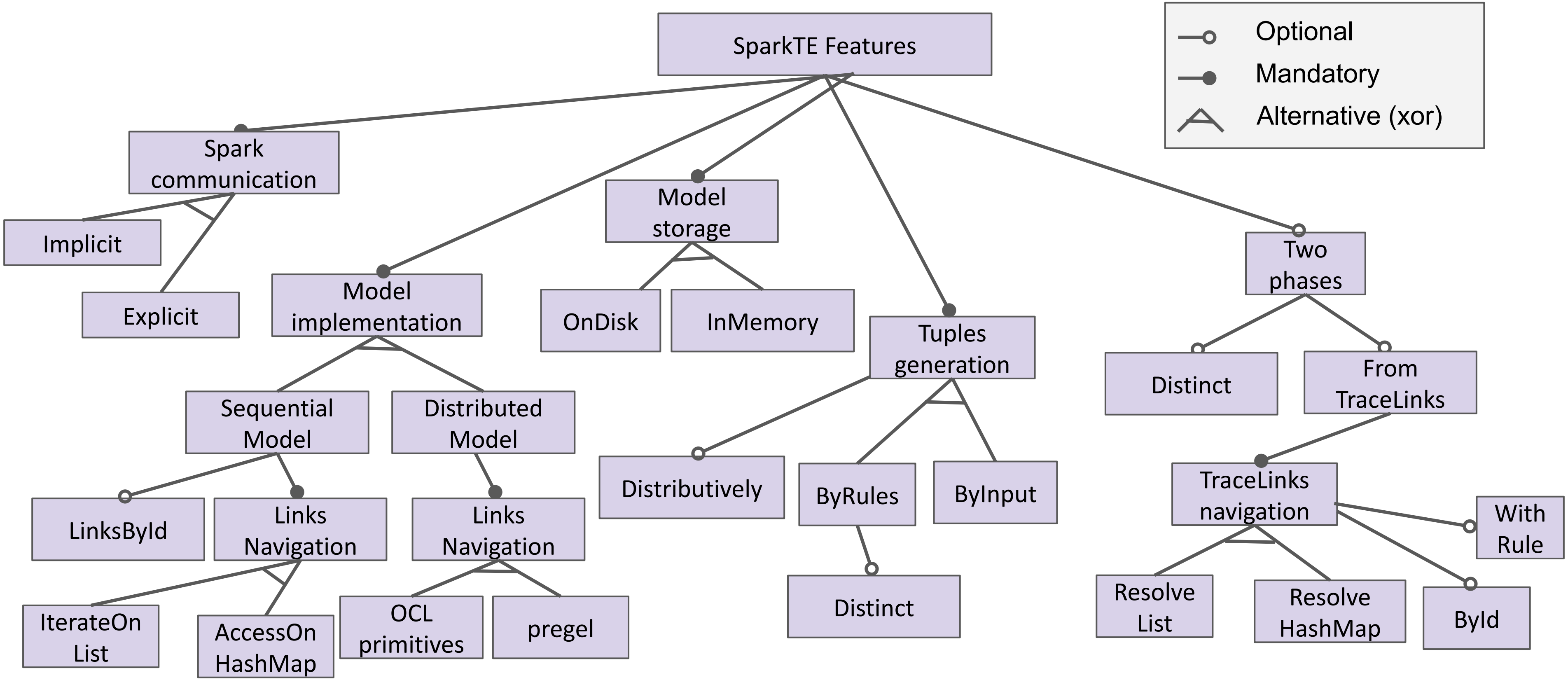
Configurable engine



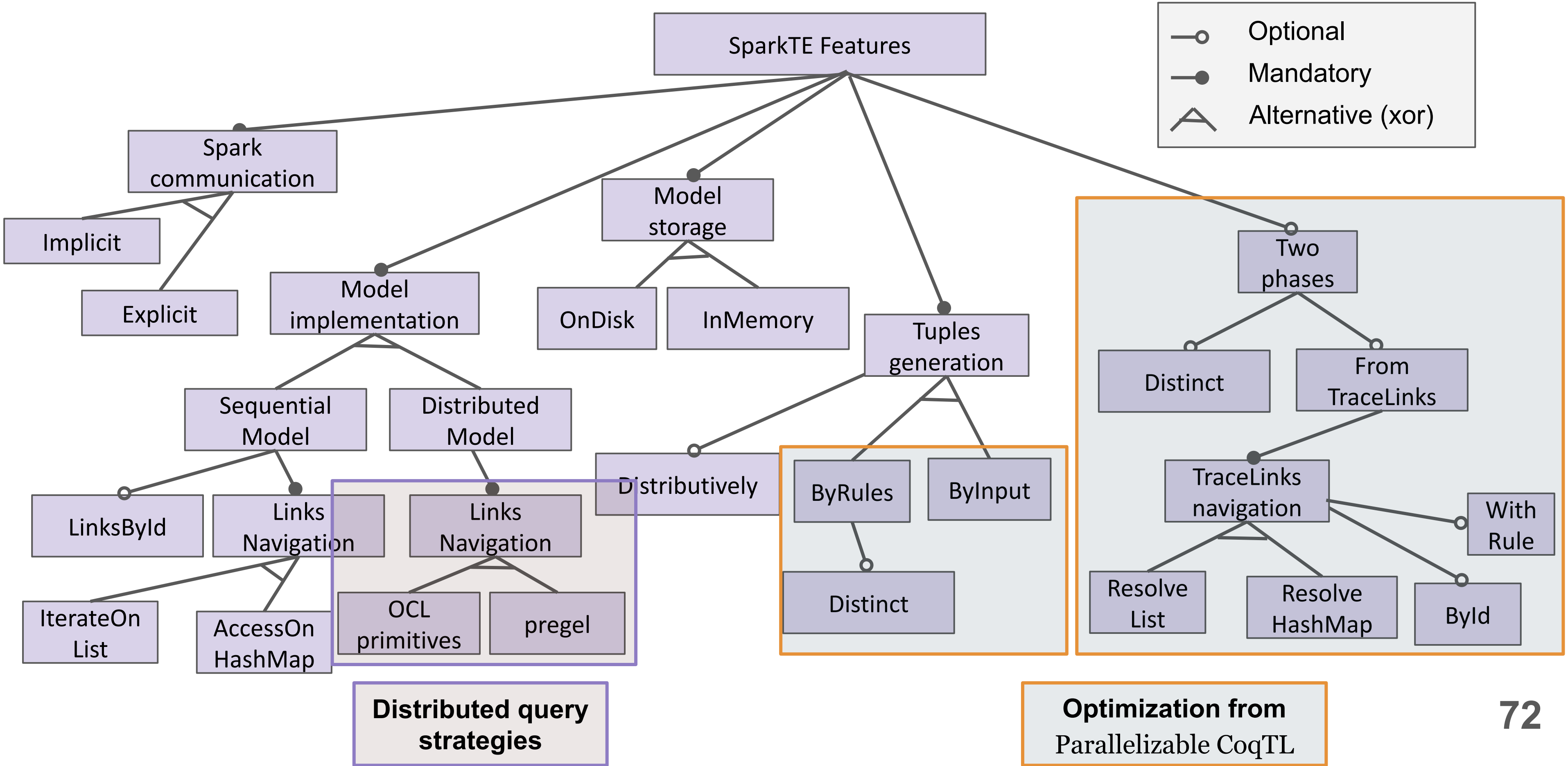
- Take **as input** a configuration conforms to the feature model
- Produce **as output** performance results (computation time)



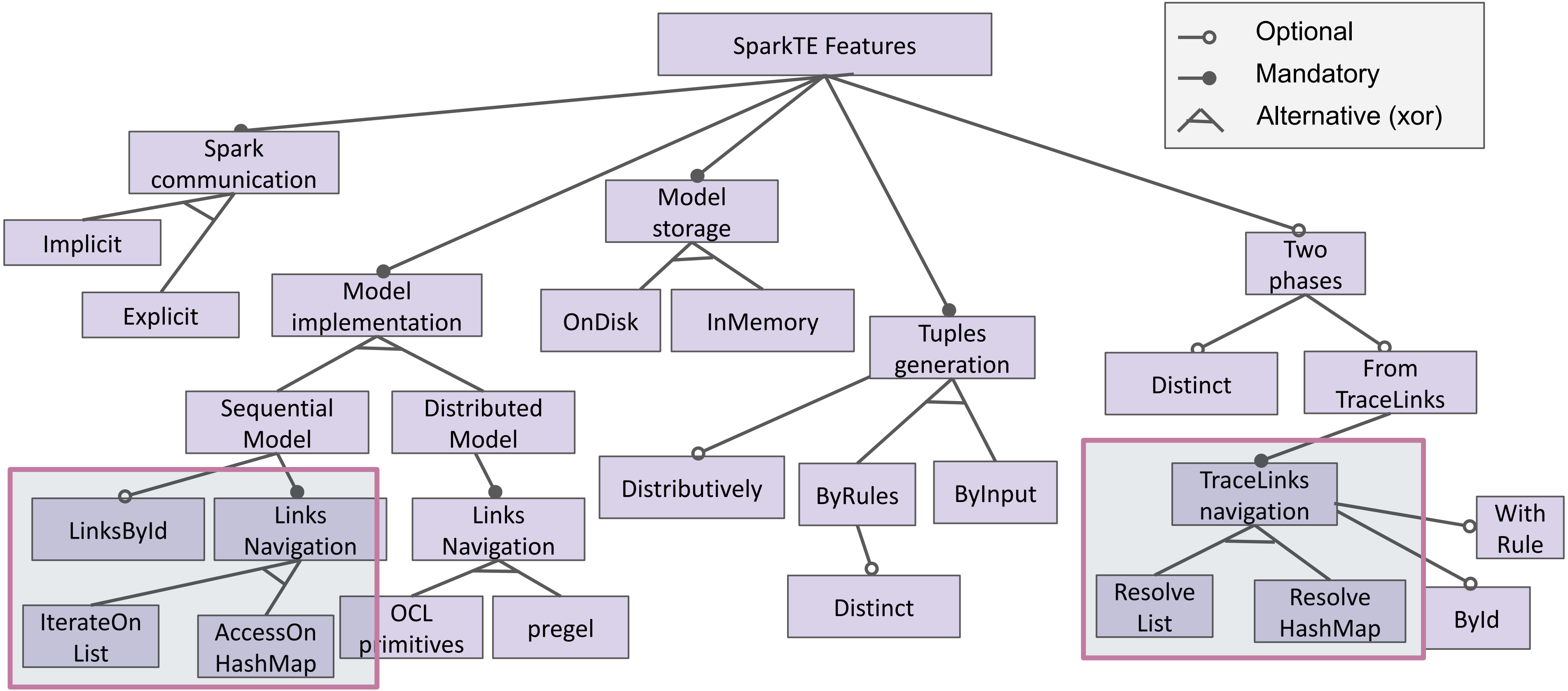
SparkTE feature diagram



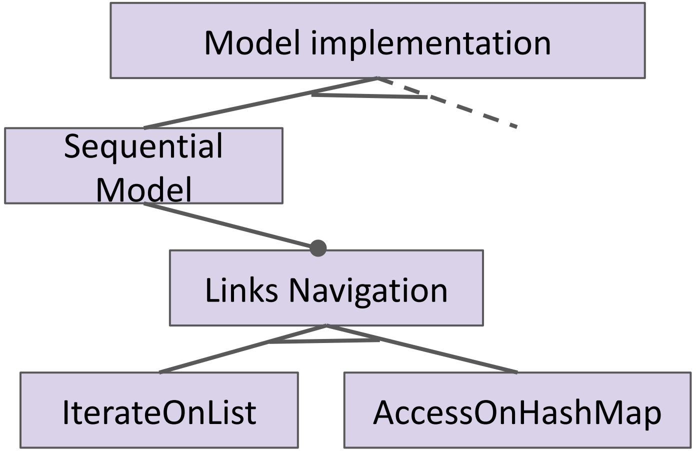
SparkTE feature diagram



SparkTE feature diagram

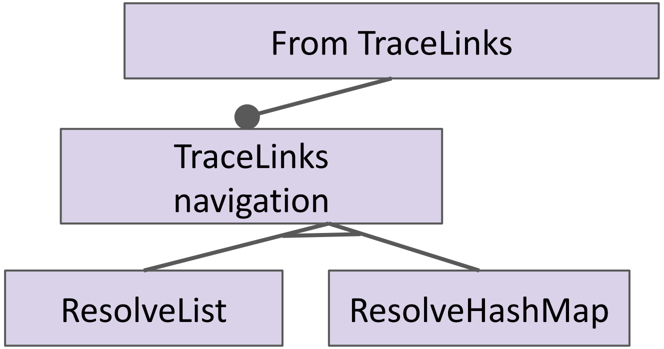


Feature 1: Link navigation strategy in sequential model



- IterateOnList :
  - Navigation by iteration
  - Simple to set-up
- AccessOnHashMap :
  - Additional computation in model loading
  - Increase memory usage
  - Direct access on links from elements

Feature 2: Trace-Links structure and resolution in apply phase



- ResolveList:
  - Resolution by iteration
  - Naturally gathered by master node
- ResolveHashMap:
  - Additional computation in instantiate phase
  - Increase memory usage
  - Fastest resolution

Using configurable engine to find features synergie

Execution of **Identity** transformation on a model of 100k elements and 250k links (4 cores)

Configuration 1: Links navigation	Configuration 2: TraceLinks navigation	Computation time (sec)	Instantiate phase (sec)	Apply phase (sec)
IterateOnList	ResolveList	1636 sec	3 sec	1633 sec
IterateOnList	ResolveHashMap	1584 sec	3 sec	1581 sec
AccessOnHashMap	ResolveList	233 sec	6 sec	227 sec
AccessOnHashMap	ResolveHashMap	12 sec	6 sec	6 sec

- **TraceLinks navigation**'s impact
  - on the **whole** computation is **negligible**
  - is **important** when **Links navigation** is processed by AccessOnHashMap
- **Links navigation**'s impact
  - decreases the **whole** computation time
  - increases the computation time of the instantiate phase

Design-space exploration for the Find affinity case

Feature label	Parallelizable CoqTL design choices (C1)	Optimal design choices (C2)
Model implementation	Sequential Model	Sequential Model
○ linksById	false	false
● **Link Navigation**	**IterateOnList**	**ResolveHashMap**
Model storage	InMemory	InMemory
Spark communication	**Implicit**	**Explicit**
Tuples generation	**ByRules**	**ByInput**
○ Distributively	false	false
○ **Distinct**	**false**	**true**
TraceLinks Navigation	ResolveList	ResolveList
○ byId	false	false
○ **withRule**	**false**	**true**
○ **Distinct**	**false**	**true**

Design-space exploration for the Find affinity case

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○ **Distinct**	**false**	**true**
TraceLinks Navigation	ResolveList	ResolveList
○ byId	false	false
○ **withRule**	**false**	**true**
○ **Distinct**	**false**	**true**

#elements	#links	C1 computation time	C2 computation time
1000	3000	9.799 sec	4.978 sec
2500	7300	81.047 sec	7.803 sec
5000	15000	882.708 sec	19.127 sec
7500	22000	> 2h	36.928 sec
10000	45000	Timeout error	65.198 sec

- ➢ The feature model is useful for comparing implementations
- ➢ Gives useful insights about the engine
- ➢ Highlighted correlation between features

CONCLUSION

Contribution of the thesis

Problem 1:
Many solutions for executing rules distributively

Built a **distributed solution** from a **specification**

- Re-designed specification to make it distributable
- Made a proof of equivalence for optimizations
- Shown our solution is scalable

Problem 2:
Many solutions for executing queries distributively

Evaluated distributed execution **strategies for a query**

- Implemented three design-choices
- Proposed hybrid solution
- Performance variation depending on the strategy

Problem 3:
Need an unified proposition for comparing design choices

Formalized features in our distributed solution

- Shown the synergies between them
- Shown the impact on performance

Publications

- Jolan Philippe, Hélène Coullon, Massimo Tisi, Gerson Sunyé. **Towards Transparent Combination of Model Management Execution Strategies for Low-Code Development Platforms.** *23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems (MODELS): Companion Proceedings*, Oct 2020, Montreal (Virtually), Canada. 10.1145/3417990.3420206. Hal-02952952

- Jolan Philippe, Massimo Tisi, Hélène Coullon, Gerson Sunyé. **Executing Certified Model Transformations on Apache Spark.** *14th ACM SIGPLAN International Conference on Software Language Engineering (SLE)*, Oct 2021, Chicago IL, United States. 10.1145/3486608.3486901. Hal-03343942

- *Several public Lowcomote deliverables*
  - **Concepts for Multi-paradigm distributed transformation**
  - **Scalable low-code artefact persistence and query**
  - **Multi-paradigm distributed transformation engine**

Future work

- **Automated design-space exploration for a given scenario**
  - A model of the input (e.g., topological metrics)
  - A model of the platform **(Spark and ≠)**
  - Constraints and requirements

- **Other parameters to optimize (≠ CPU time)**
  - Network bandwidth
  - Memory consumption
  - Energy consumption/production

\+ **Other execution strategies (≠ data-dist)**
  - Take advantage of Spark for task-distribution
  - Combine incrementality and laziness to distribution

Contribution to the Analysis of the Design-Space of a Distributed Transformation Engine

Jolan PHILIPPE
Seminaire LMV - LIFO

THANK YOU

QUESTIONS ?