REASONING WITH GRAPHS

Visual Analytics Supporting Rule Based Modeling

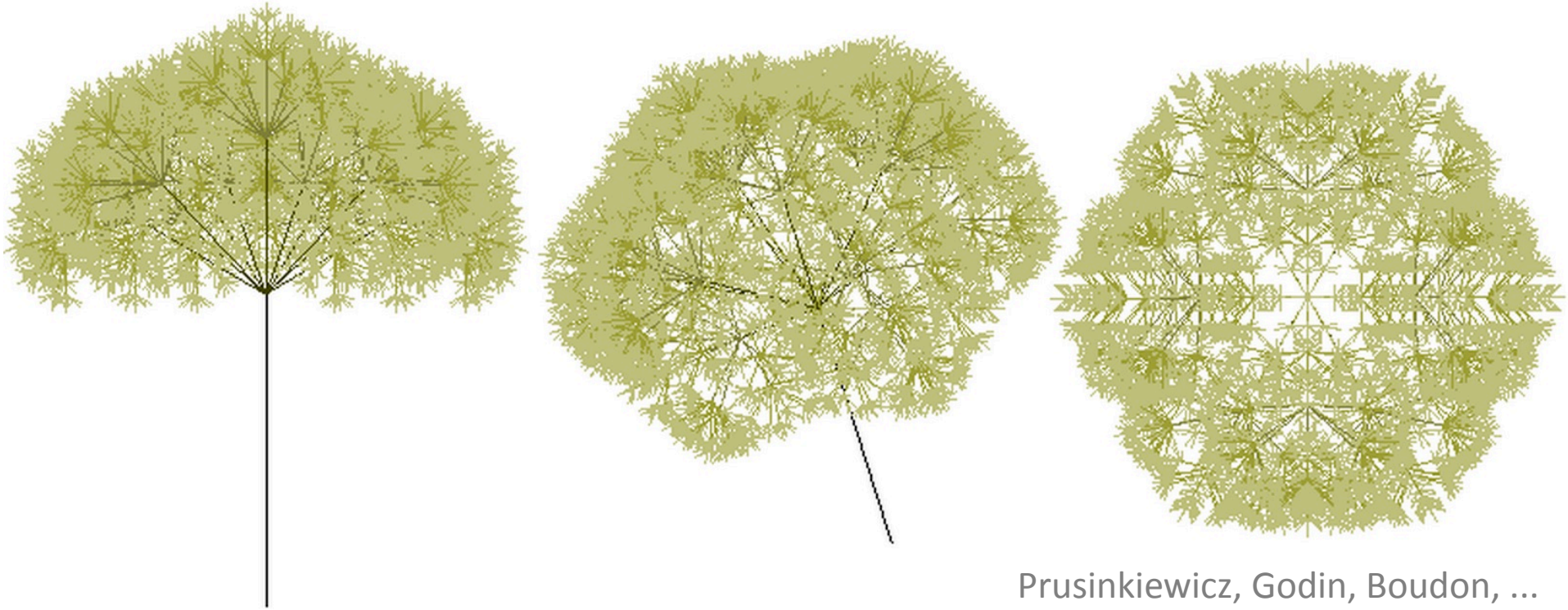
G. Melançon, B.Pinaud, H. Kirchner,
M. Fernandez, O. Namet, J. Dubois

THE DRIVING FORCE

EMERGENCE

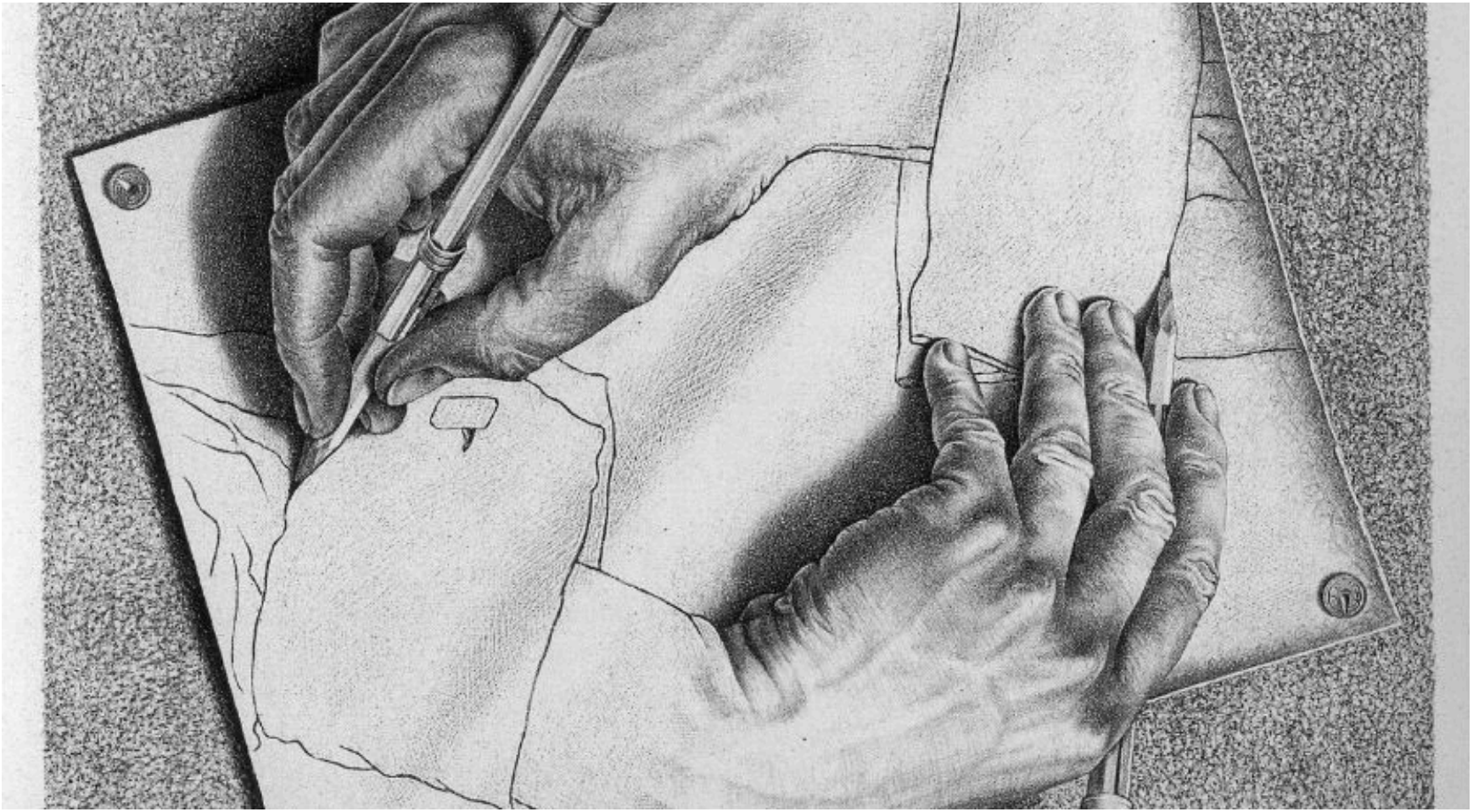
EMERGENCE

- The whole is greater than the sum of its parts
  - Structure emerges from the repeated application of lower scale local transforms



Prusinkiewicz, Godin, Boudon, ...

Designing Emergence



WWW.EMERGENCEBYDESIGN.ORG

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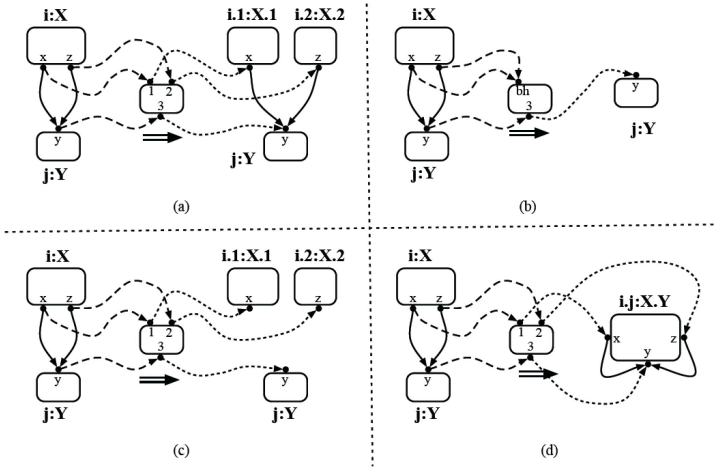
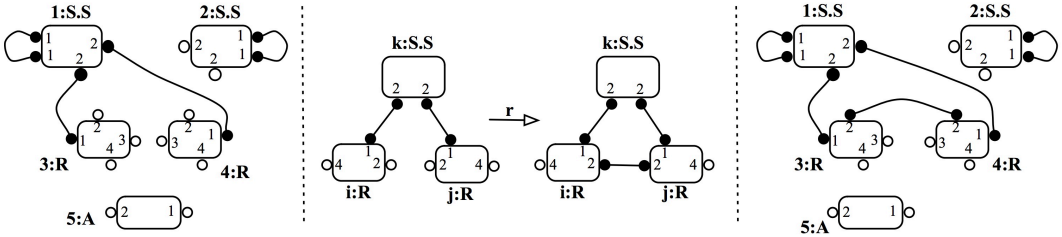
GRAPH REWRITING SYSTEMS

THE PARADIGM

RULE-BASED MODELING

- Graphical reasoning
  - Rooted in Graph Rewriting Systems theory
  - Rules are defined, communicated and specified by *drawing* them
  - Most of the time implemented GUI





RULE-BASED MODELING

- Basic entities are graphs
- We use port graphs
  - Edges connect to ports
  - Ports have states

Rule-Based Modeling

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  - Rules model interaction between nodes
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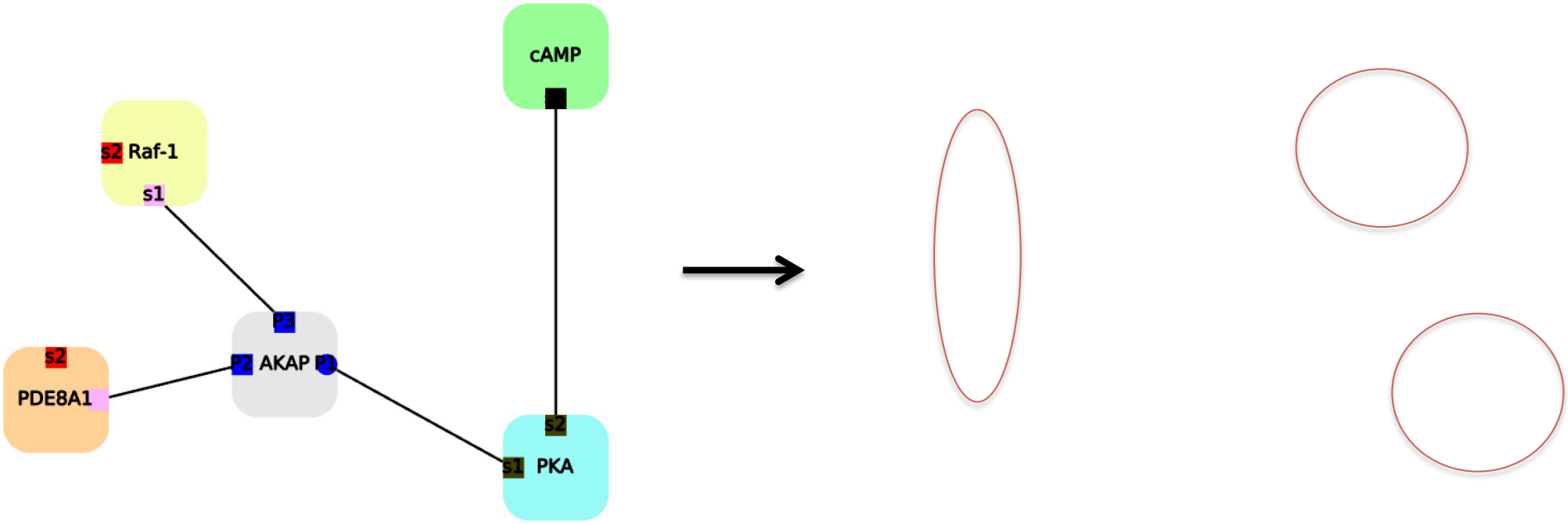

LHS *RHS*

Rule-Based Modeling

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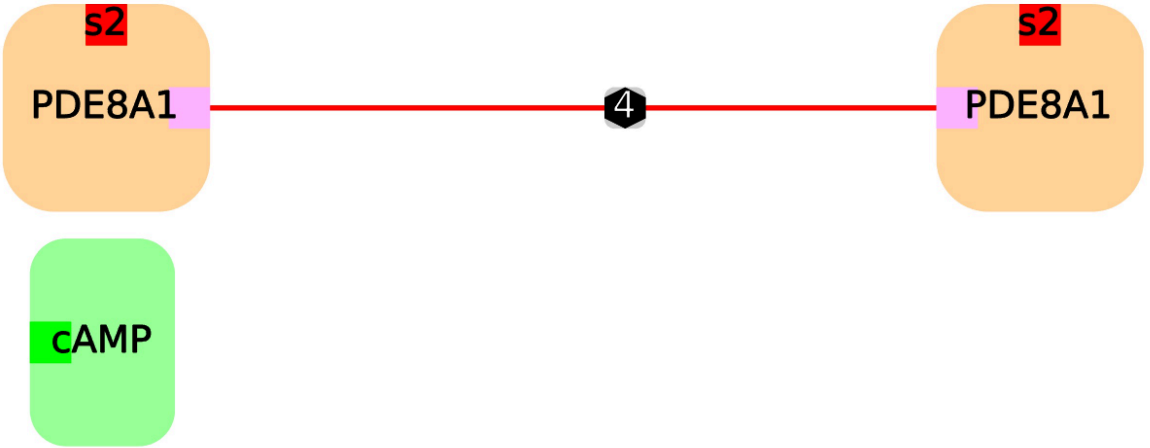
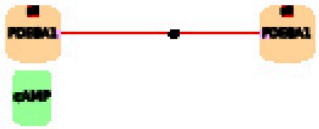


LHS *RHS*

VALIDATING RULE-BASED MODELS

THE CHALLENGE

THE HOLY GRAIL



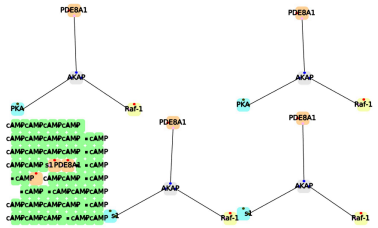
rule_4

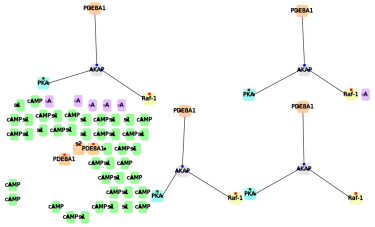
- You model a situation with a graph
  - Entities interact
  - Entities change states

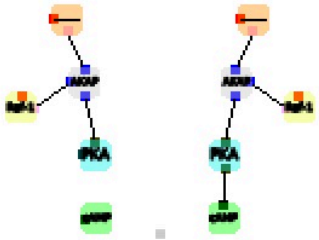
rule_3

- Define simple transformation rules that explain the dynamics driving this situation

rule_2





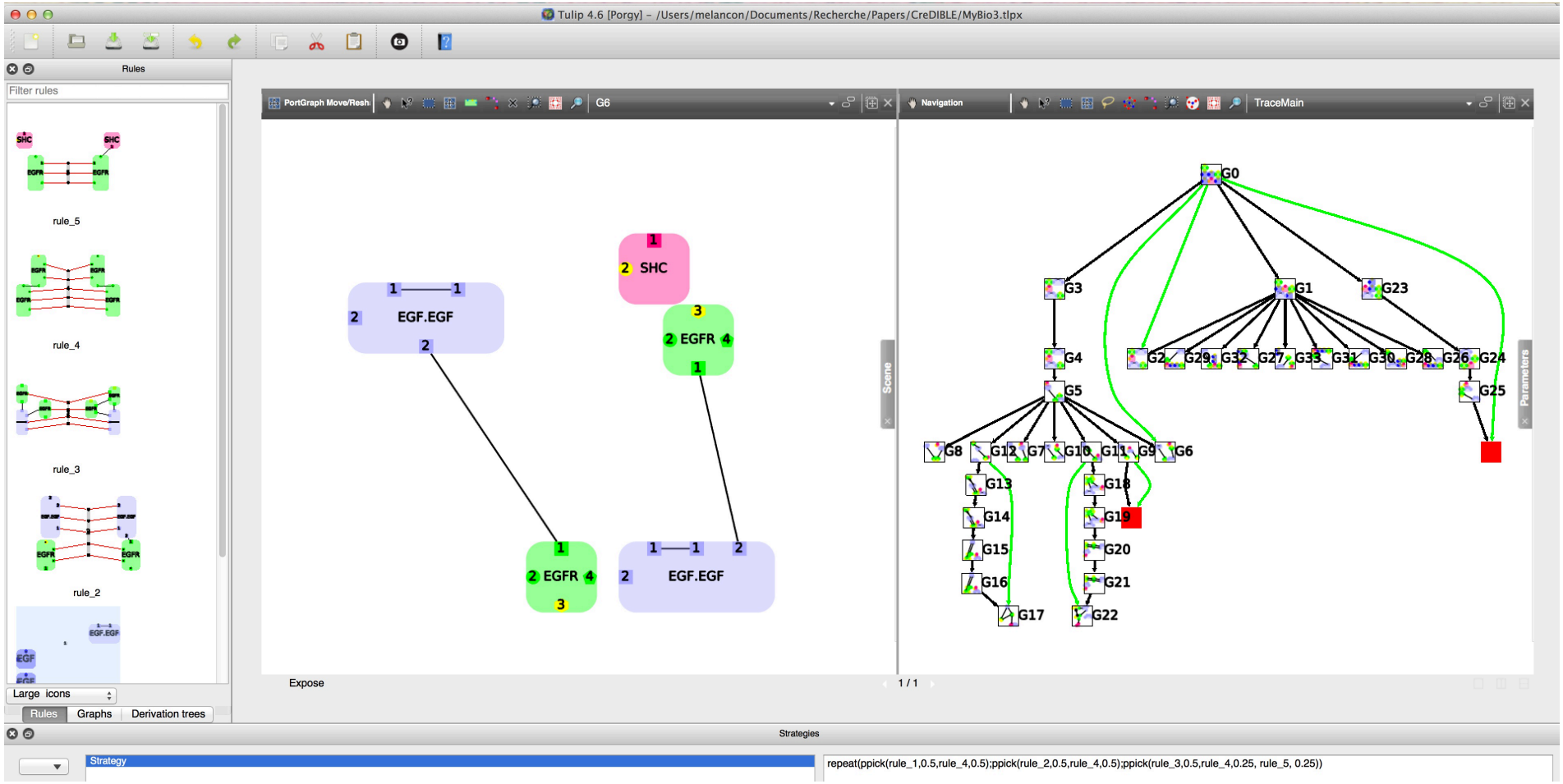


rule_1

VISUAL ANALYTICS DASHBOARD FOR PORT GRAPH REWRITING

THE FRAMEWORK

SUPPORTING RULE-BASED MODELING



PORGY

- Visual Analytics Dashboard for Port Graph Rewriting
  - Based on Tulip

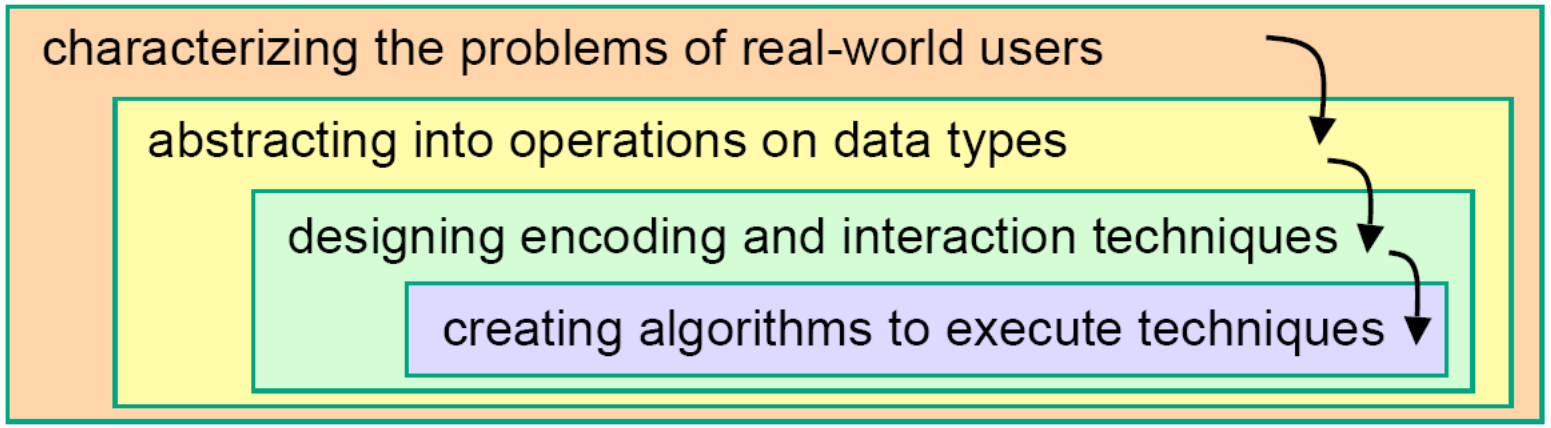
Pinaud, B., G. Melançon, J. Dubois (2012) Computer Graphics Forum

Fernandez, Kirchner, Pinaud (2014) Elec. Proc. TCS

http://tulip.labri.fr/

VISUALIZATION SYSTEM DESIGN

- Adopt a methodology according to Munzner



Munzner 2009, IEEE TVCG

- 3 year project
  - Biologists (O. Andrei), GRS experts (Fernandez, Kirchner)

VISUAL ENCODINGS

- Node-link diagrams an obvious choice due to strong graphical conventions (from both user communities)
  - For graphs
  - For rules
- The derivation tree is drawn using a classical top-down hierarchical layout

DESIGN: TASK REQUIREMENTS

SYSTEM MODELING	GRS QUESTIONS
Define elementary molecule interactions	Define *rhs/lhs* subgraphs
Define an evolution scenario	Define a *rewriting strategy* [Fernandez, Kirchner, Namet]

- System modeling tasks/questions correspond to ‘pure’ GRS questions
  - Therefore indicating that genericity is achievable

DESIGN: TASK REQUIREMENTS

SYSTEM MODELING
Heading towards model validation
Query for the presence of molecules
Study model parameters

GRS QUESTIONS
Iterate rule applications
Local inspection of graph items
Compute graph structural properties (metrics)

Design: task requirements

Task requirements
Build/Edit rules or graphs, rewriting strategy
Trigger computations
Show dead-end situations
Selection
View synchronization

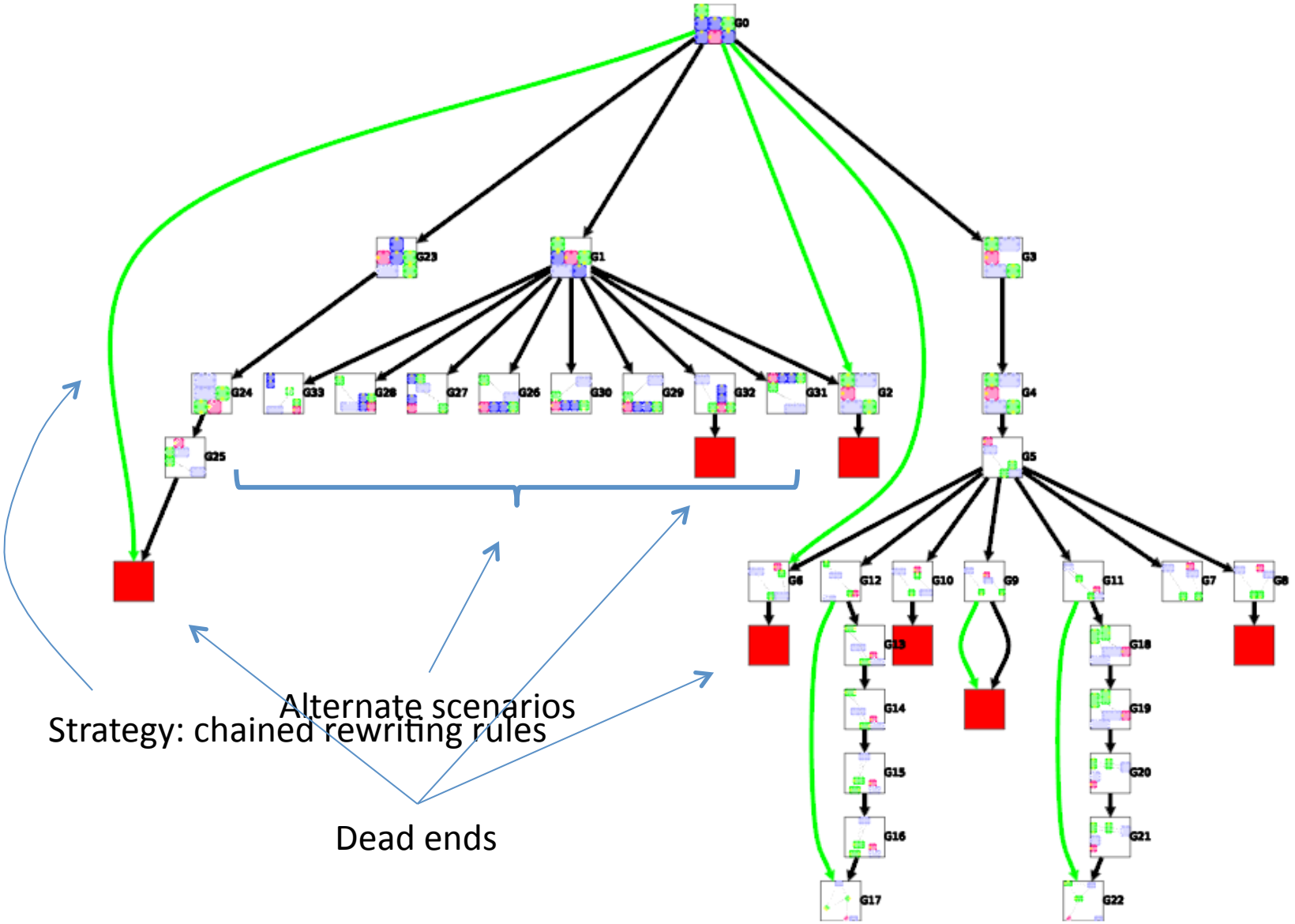
Visual / interaction / Algorithms
Graph editing
Show graph transformations
Drag & drop entites between views
Subgraph isomorphism heuristics

More involved tasks

System modeling
Keep track of computations Allow backtracking to check, adjust and/or modify model
Study model computational / structural properties

GRS questions
Check for convergence or termination / premature end of computation Eventually fix the ruleset
Check for confluence of Computation
Inquire about structure of underlying ruleset

KEEPING TRACK OF COMPUTATION



KEEPING TRACK OF COMPUTATION

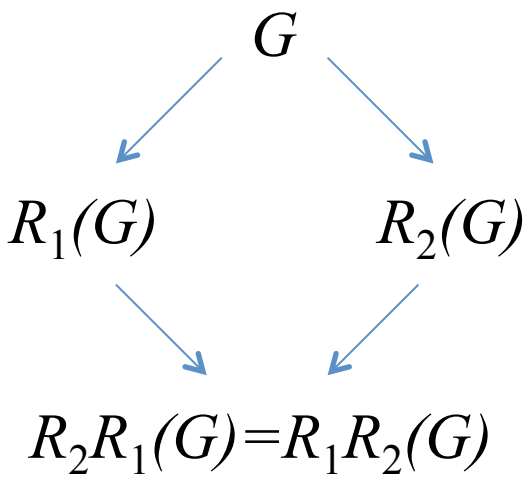
SYSTEM MODELING	GRS QUESTIONS
Keep track of computations Allow backtracking to check, adjust and/or modify model	Check for *convergence* or termination / premature end of computation Eventually fix the ruleset

- Derivation *tree* as a history mechanism and data structure
  - Rule application is *non-deterministic*

More involved tasks

System modeling
Study model computational / structural properties

Inquire about structure underlying ruleset
Check for *confluence* of Computation
Inquire about structure of underlying ruleset

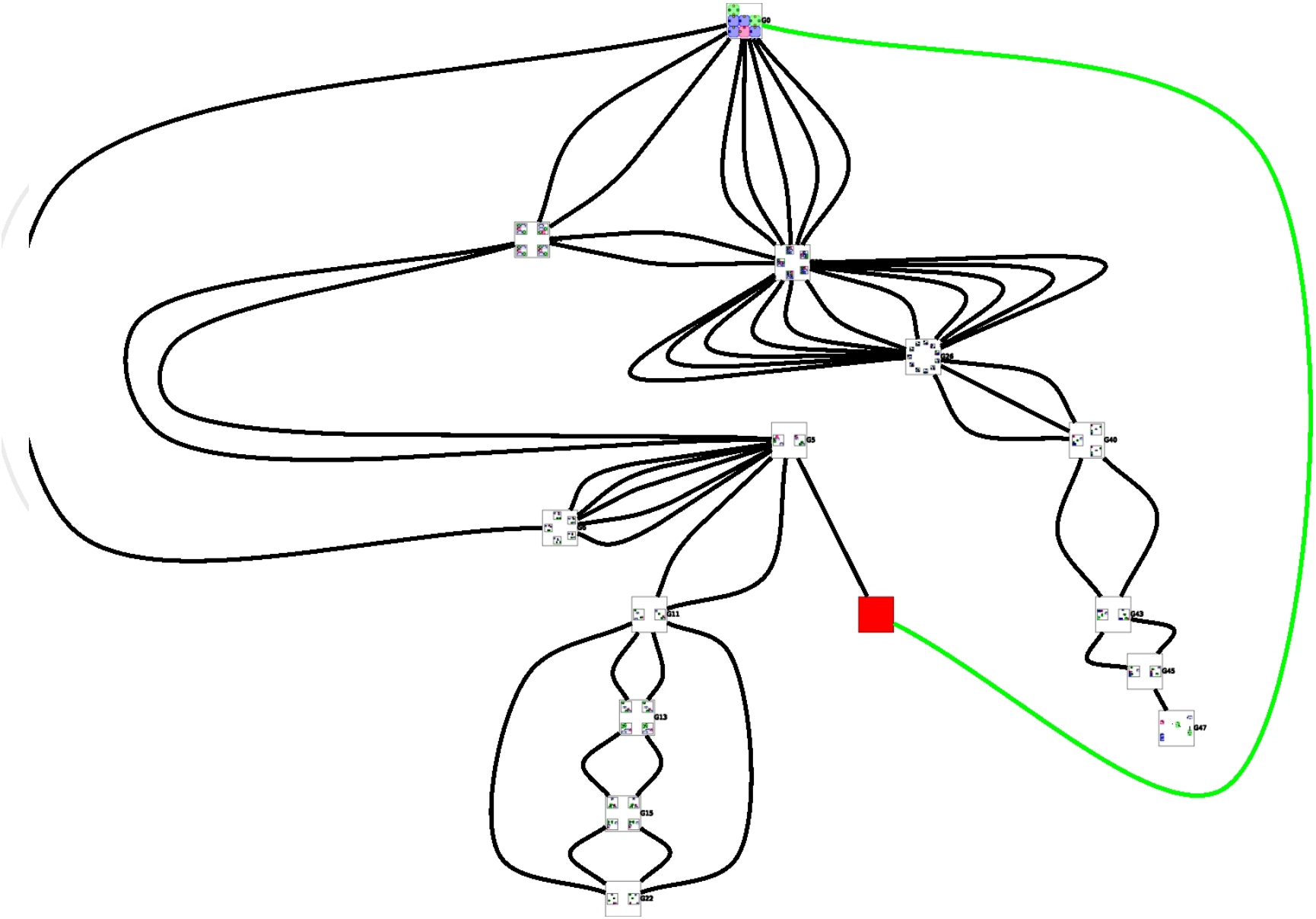


- *Confluence* means rules ‘commute’

CONFLUENCE: "ALL ROADS LEAD TO ROME"

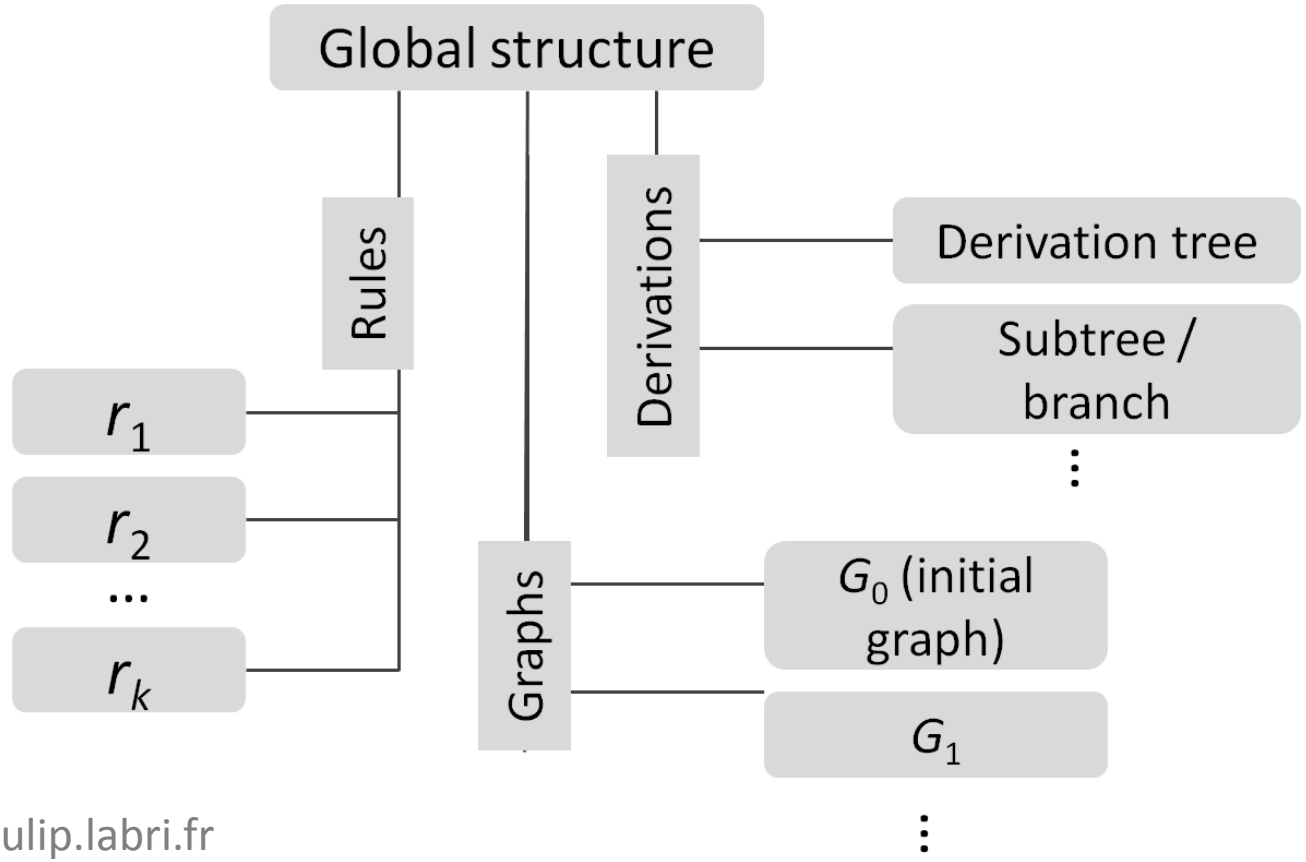
- *Confluence* is heavy duty stuff – both conceptually and computationally
  - Testing confluence requires identifying isomorphic copies of a graph
  - After identifying isomorphic copies, the derivation tree may be *folded* into a graph
  - Confluence is studied through pattern identification in the *folded* graph

CONFLUENCE



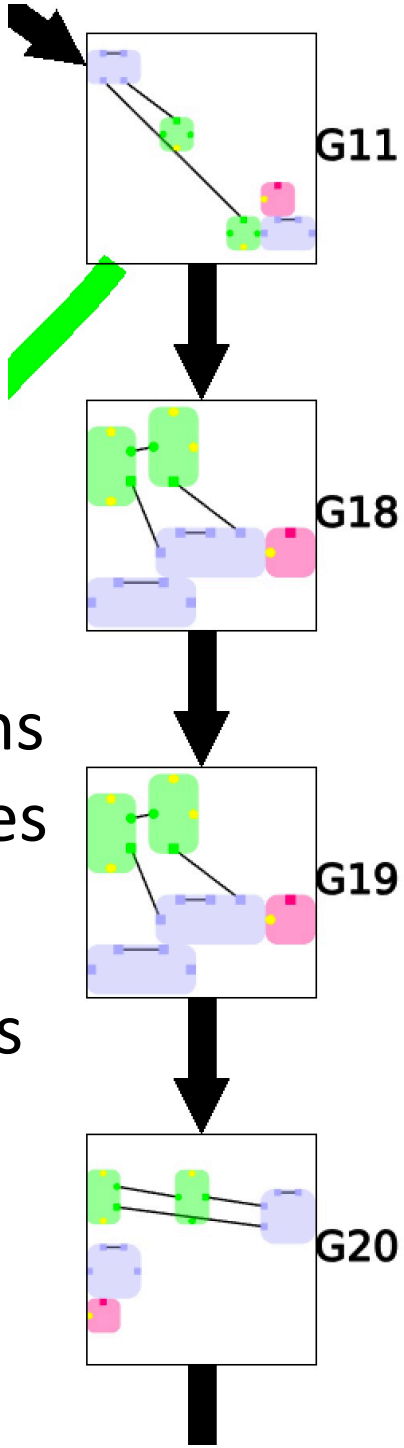
DATA STRUCTURE

- Implementing the necessary underlying data structures is far from obvious



DATA STRUCTURE

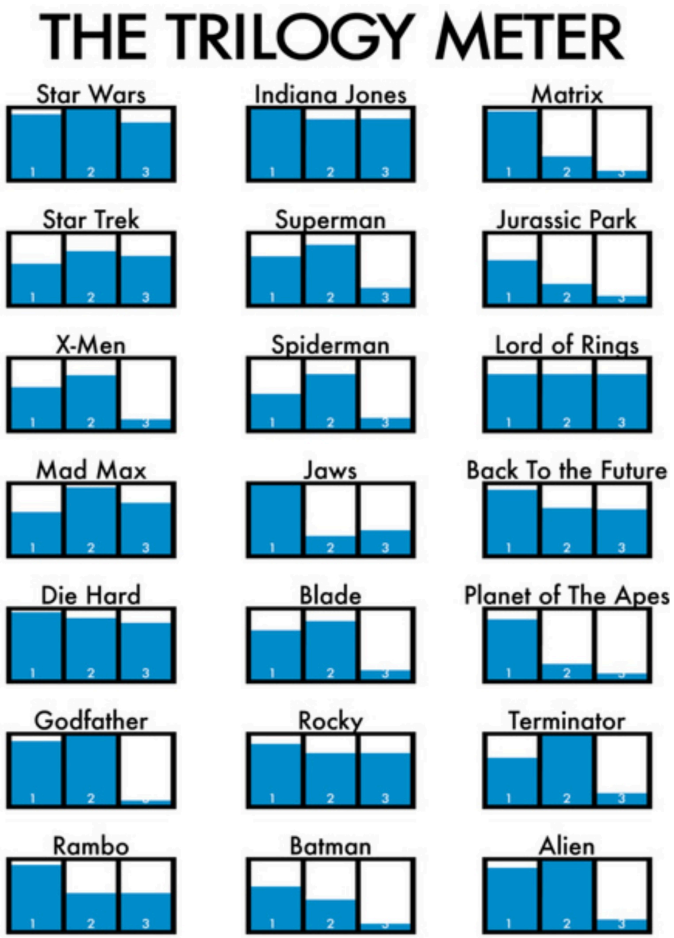
- Implementing the necessary underlying data structures is far from obvious
  - All graphs resulting from rule applications share a common pool of nodes and edges
  - Derivation tree: nodes contain graphs
  - Nodes in scatterplots *are* graphs – allows direct selection from/to derivation tree

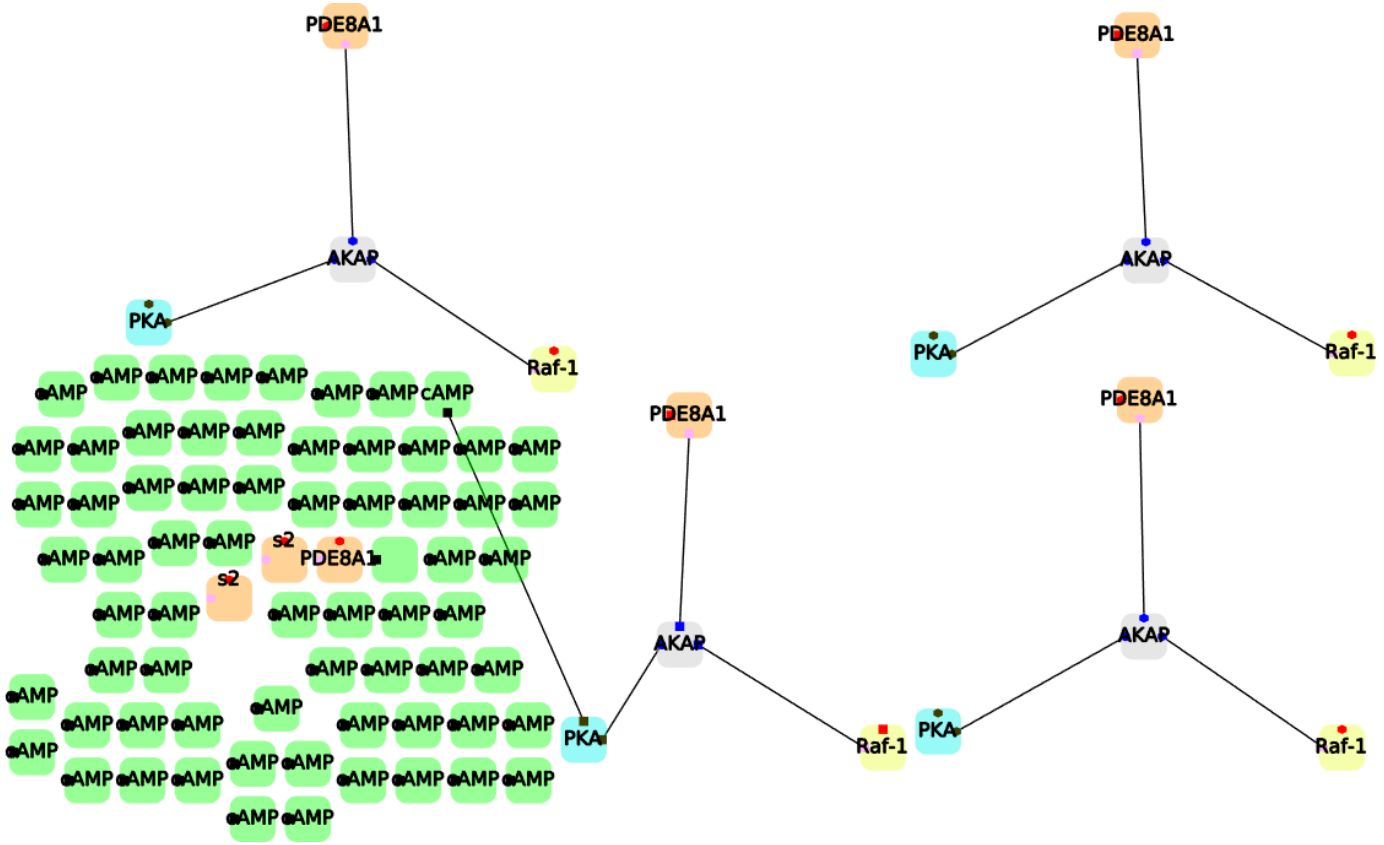


SUPPORTING TASK EXECUTION: INTERACTION

- Easy entity manipulation between views (drag & drop)
  - Rules / strategies dropped on graphs
- Tooltips to have a closer look at entities (rules, graphs) without having to instantiate views
  - For graphs
  - For rules
- Selection of entities *across* all views

Eager Eye: Spotting Changes in Small Multiples

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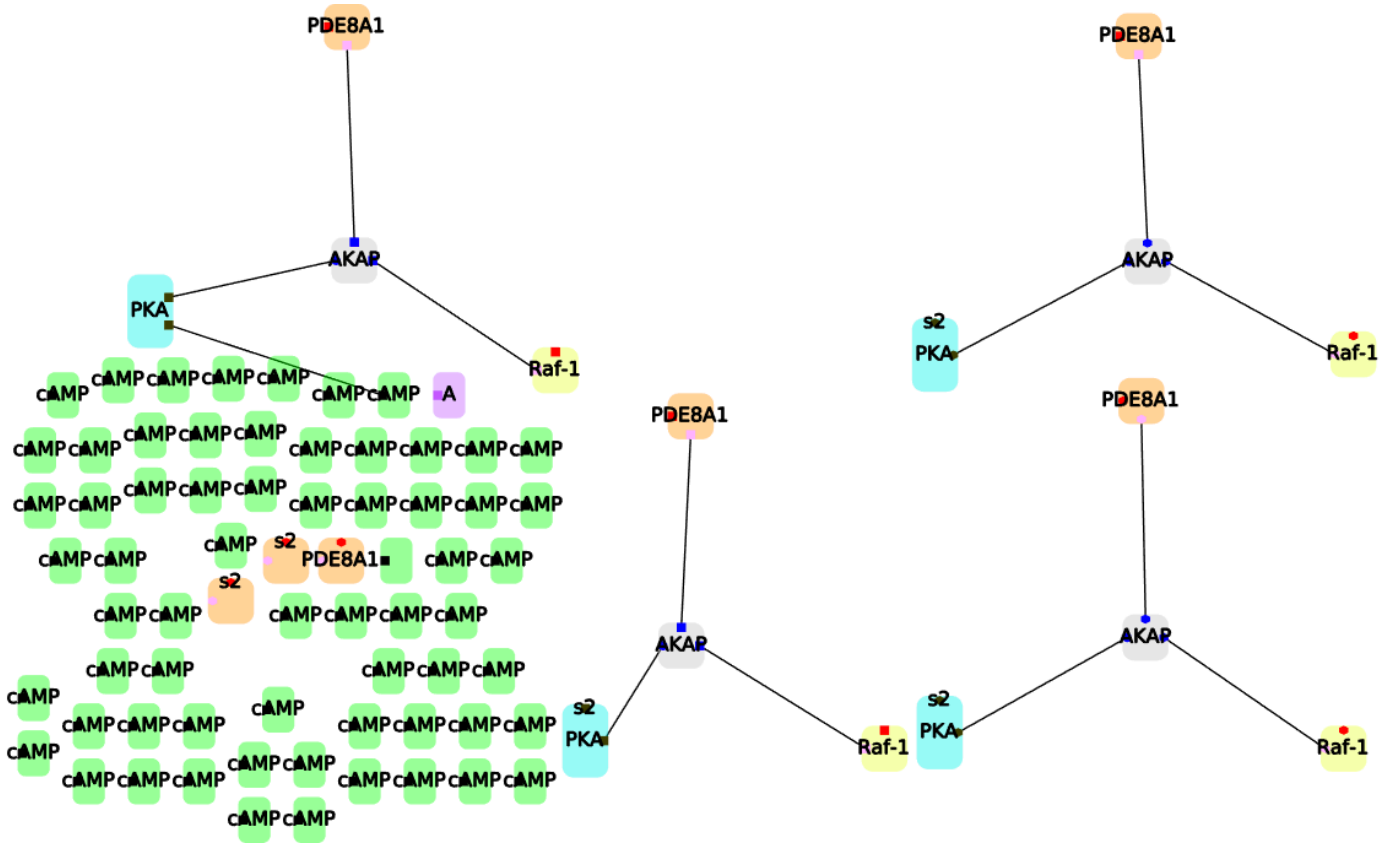
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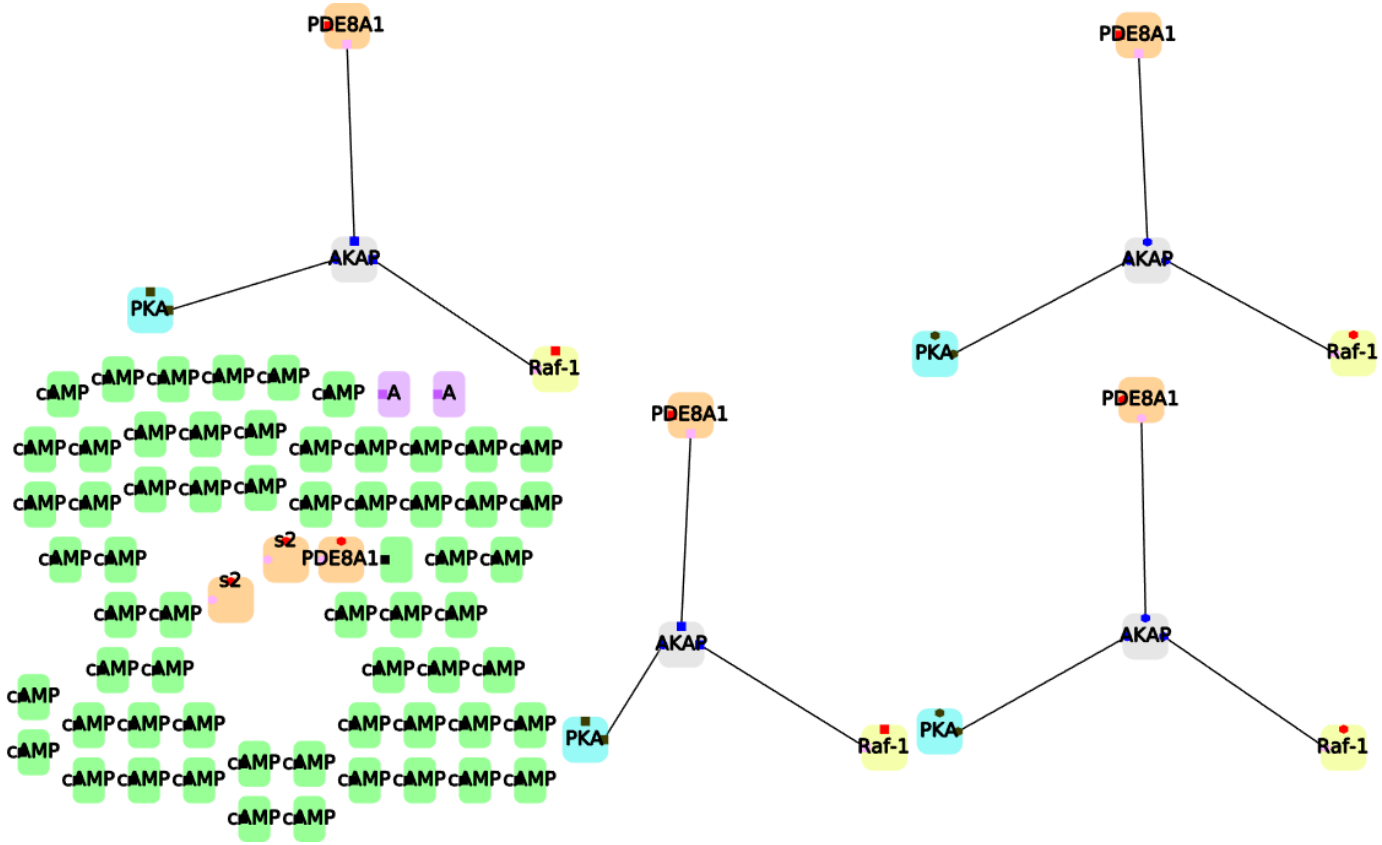
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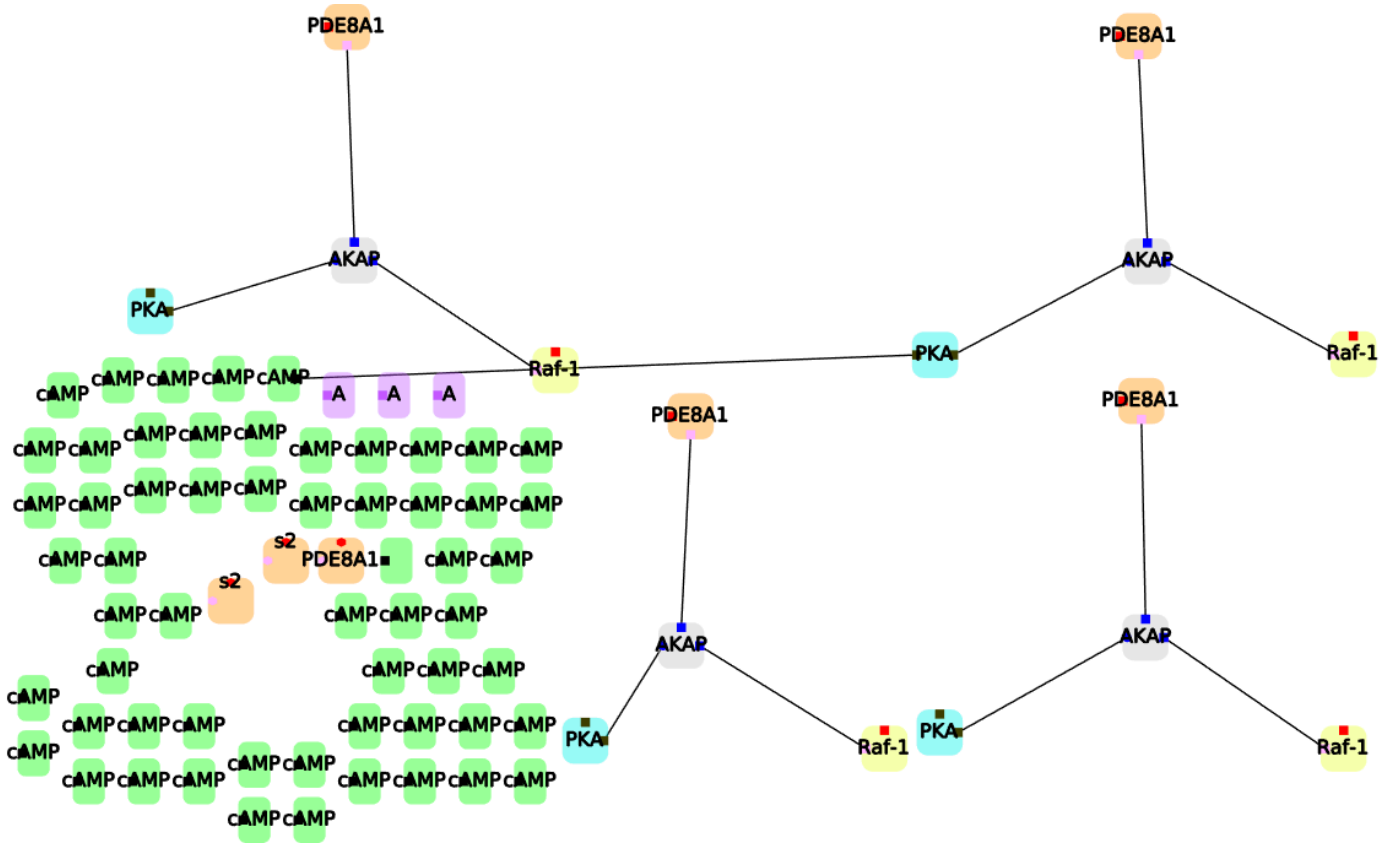
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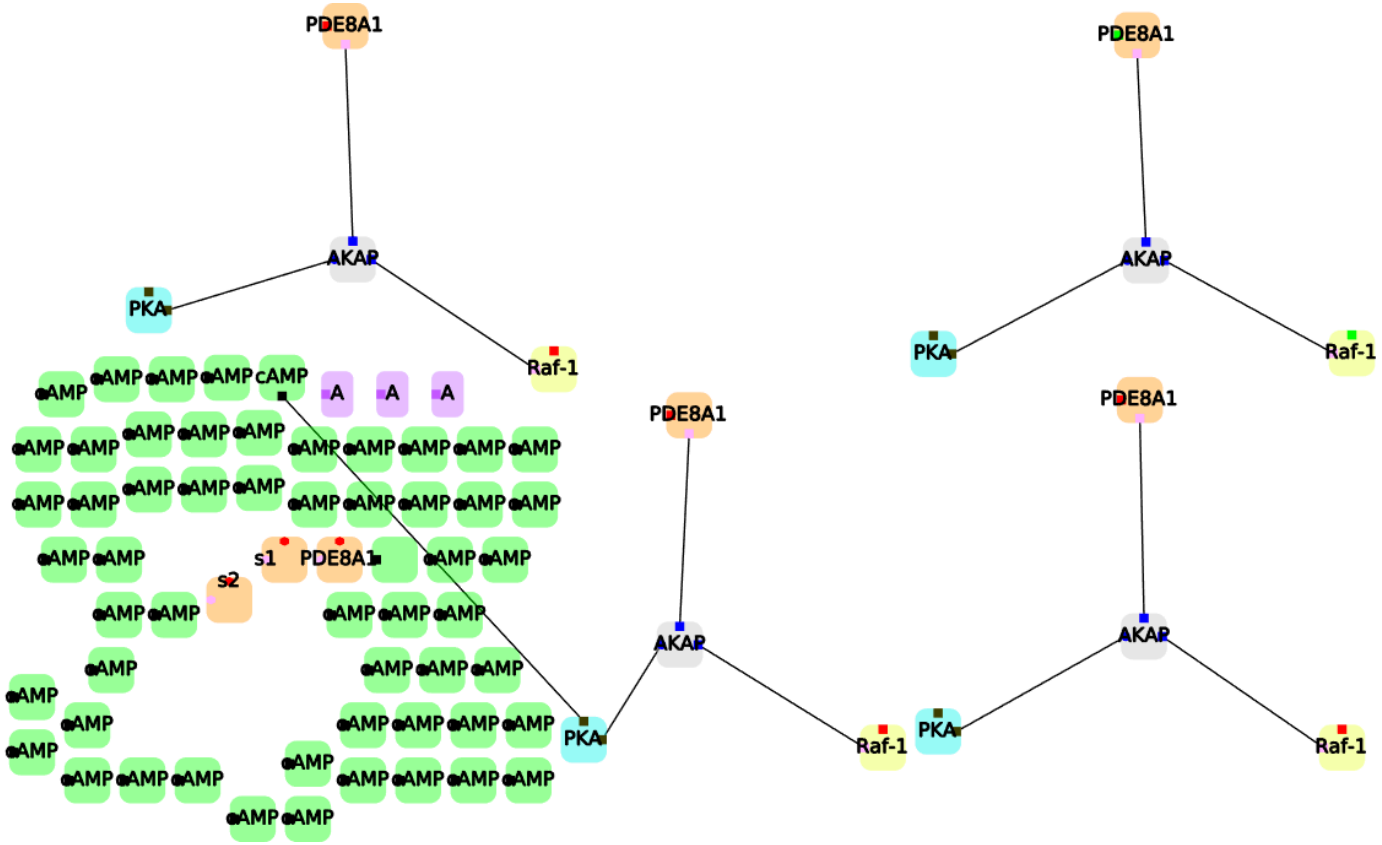
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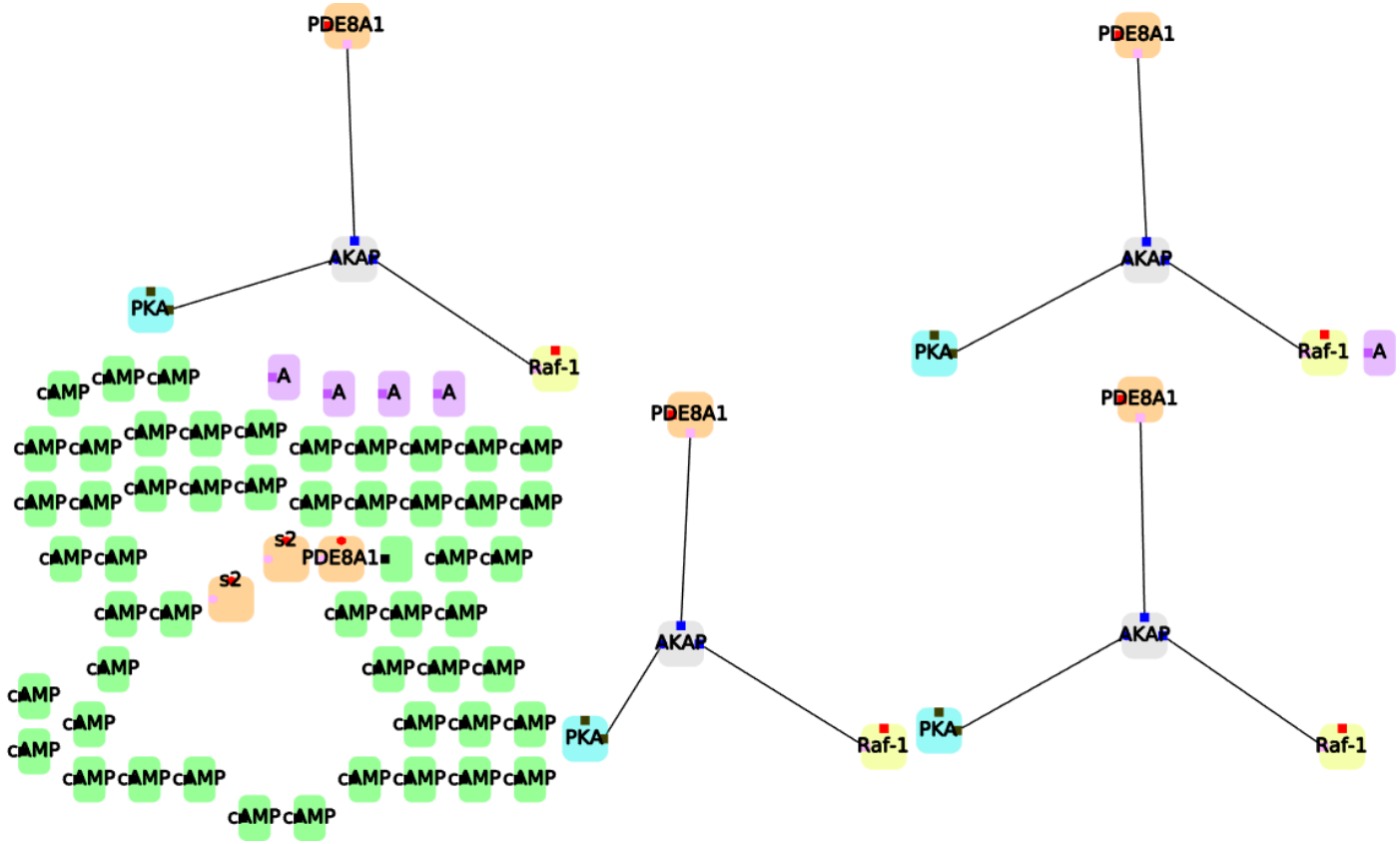
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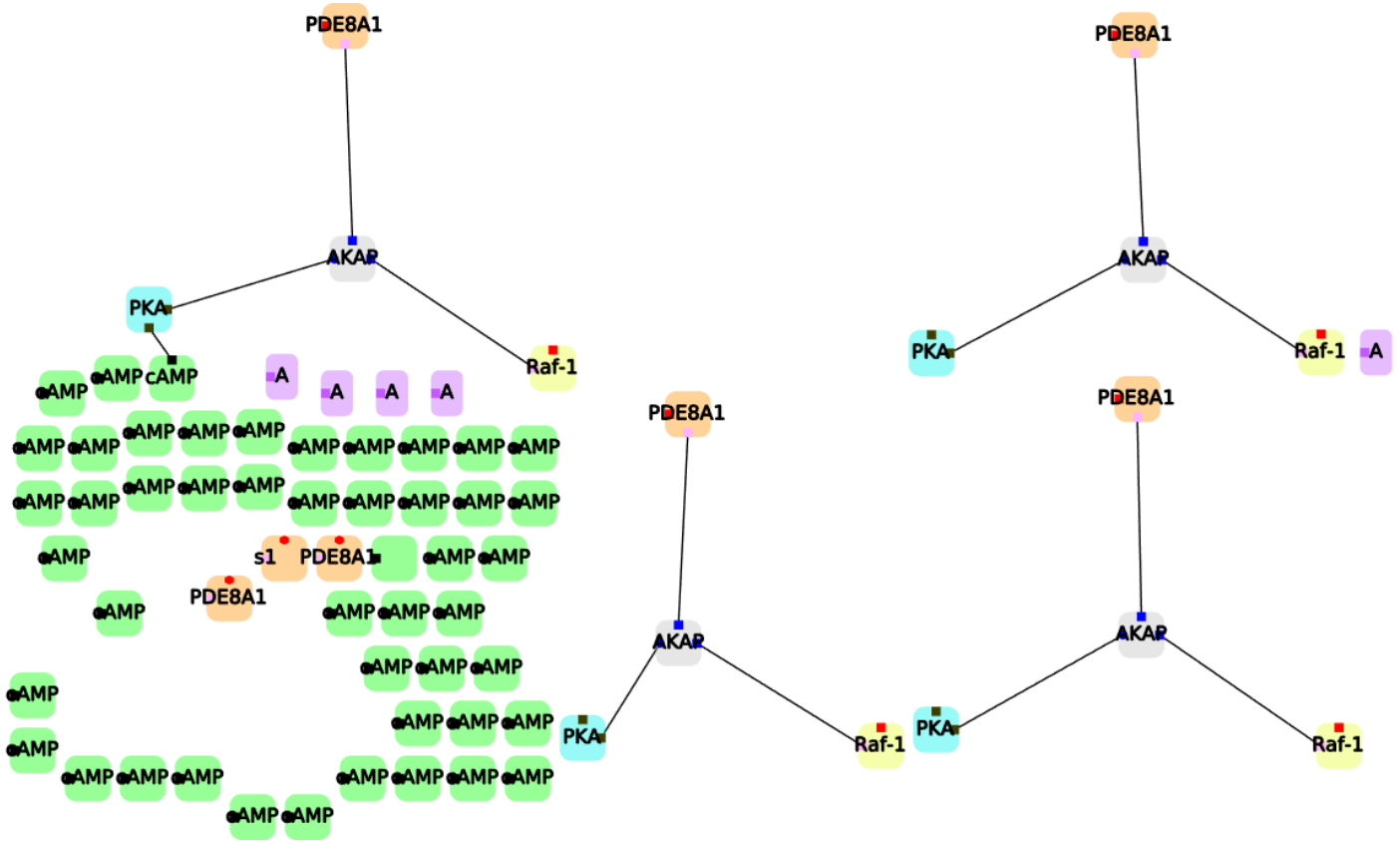
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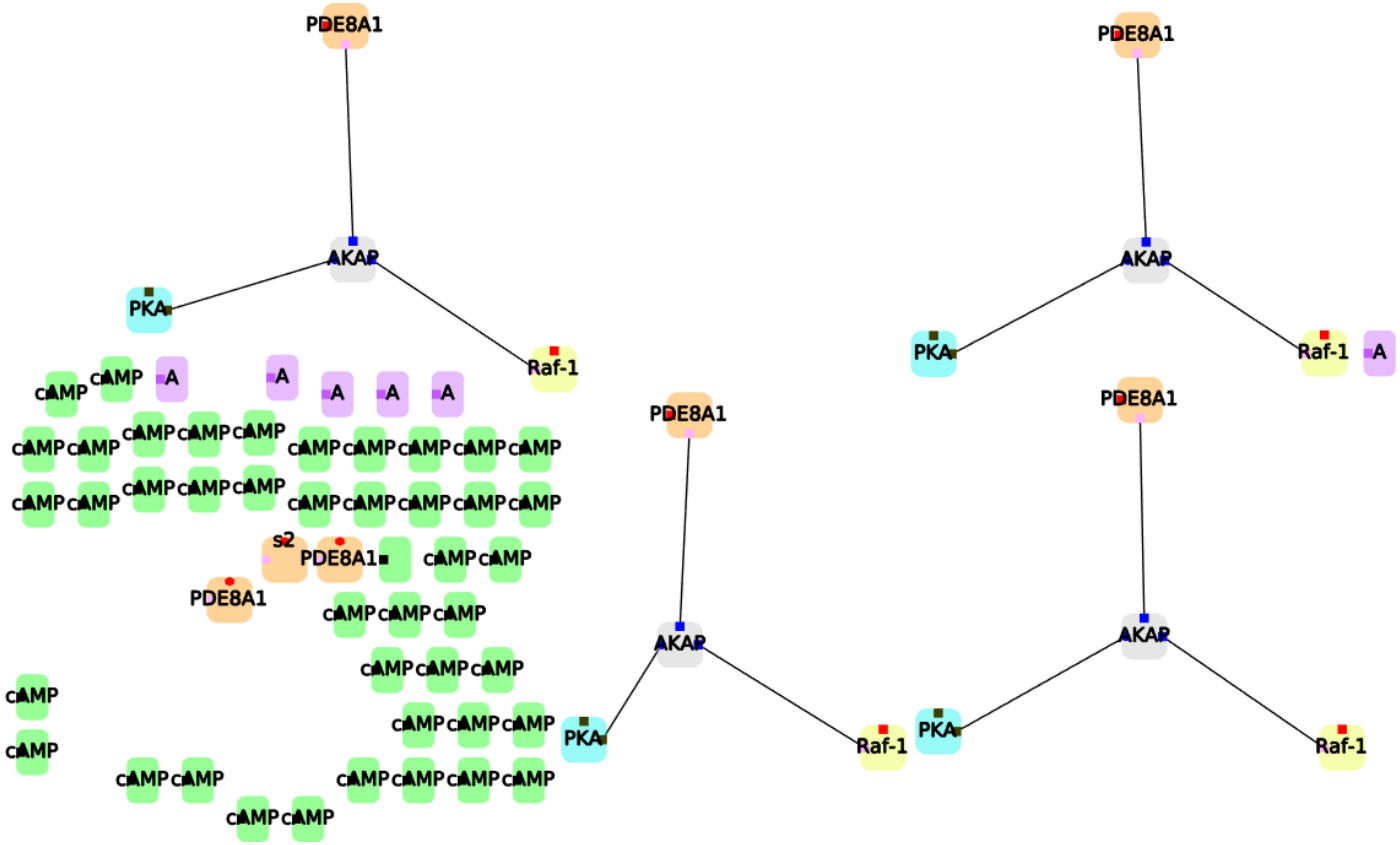
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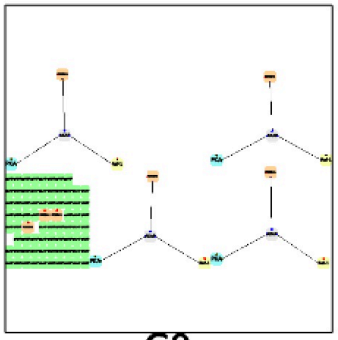
Animation, Small Multiples, and Mental Map Preservation

- Animation not always best approach to “read” changes in evolving graphs

  Archambault, Purchase, Pinaud (2010) IEEE TVCG

- Individual preference is key in user performance

  Purchase, Samra (2008) Diagrams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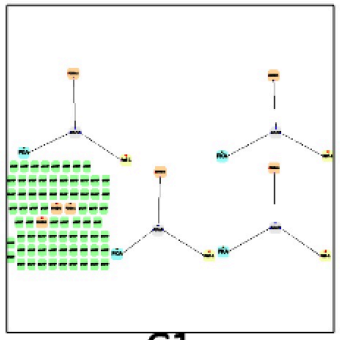
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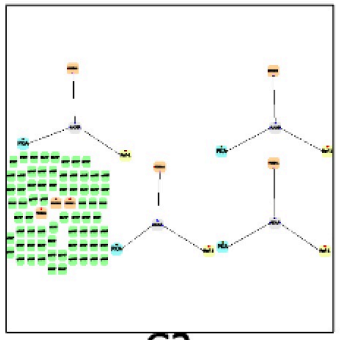
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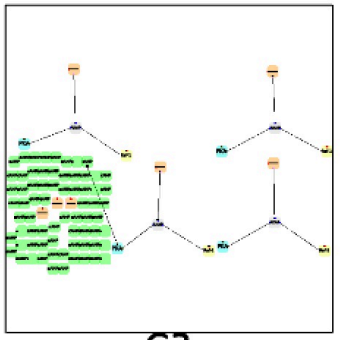
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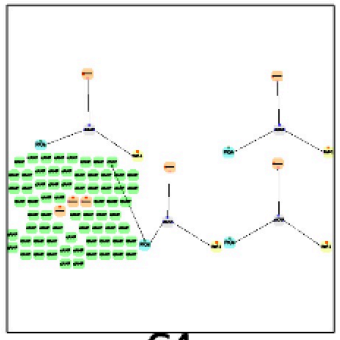
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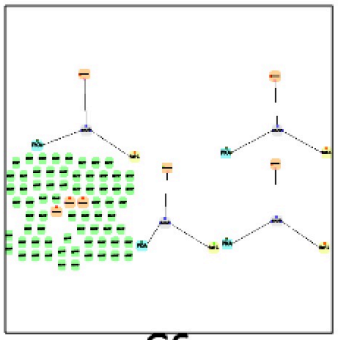
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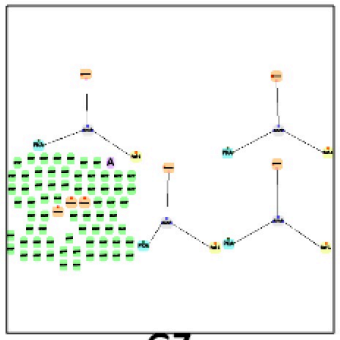
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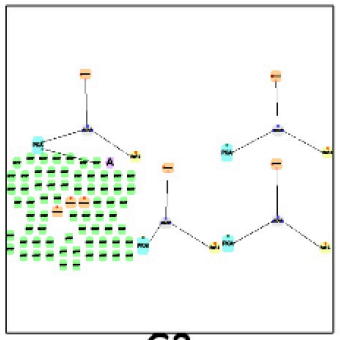
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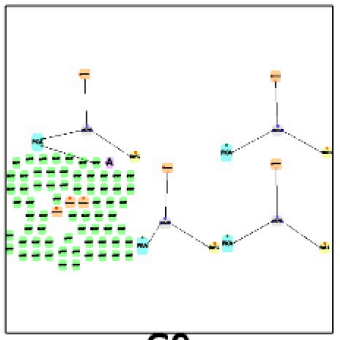
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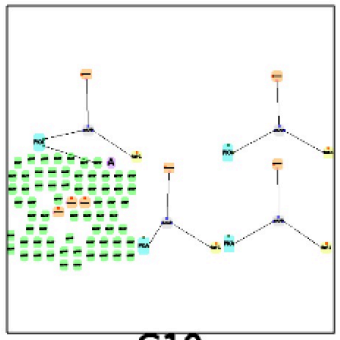
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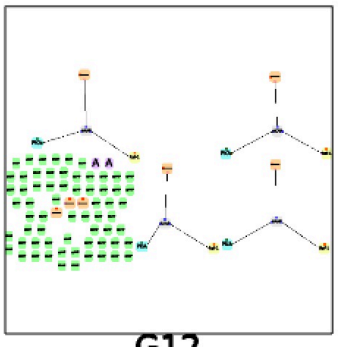
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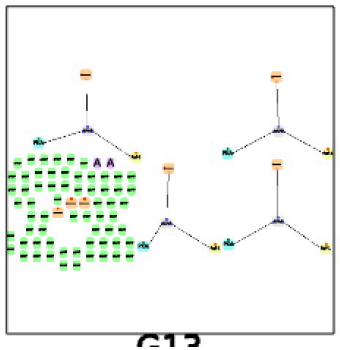
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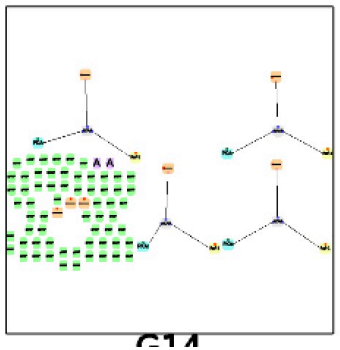
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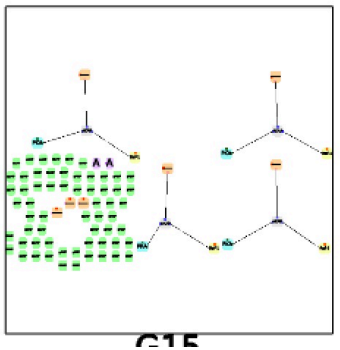
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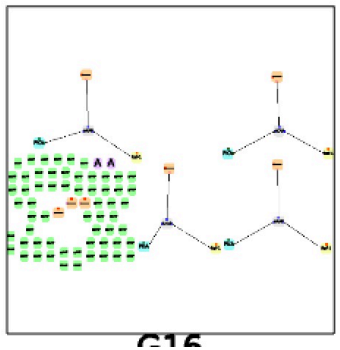
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VALIDATING RULE-BASED MODELS

THE CHALLENGE - BIS

SYSTEM EVOLUTION – TESTING SCENARI

- Rules are only one piece of the puzzle
- Specify how rules are combined
  - Prioritize rules
  - Repeated applications of (sets of) rules
  - Stochastic scenarios (random selection of rules)
  - Select places where rules apply
  - Etc.

SYSTEM EVOLUTION – TESTING SCENARI

- Scenari are called « Rewriting strategies » and obey formal specifications

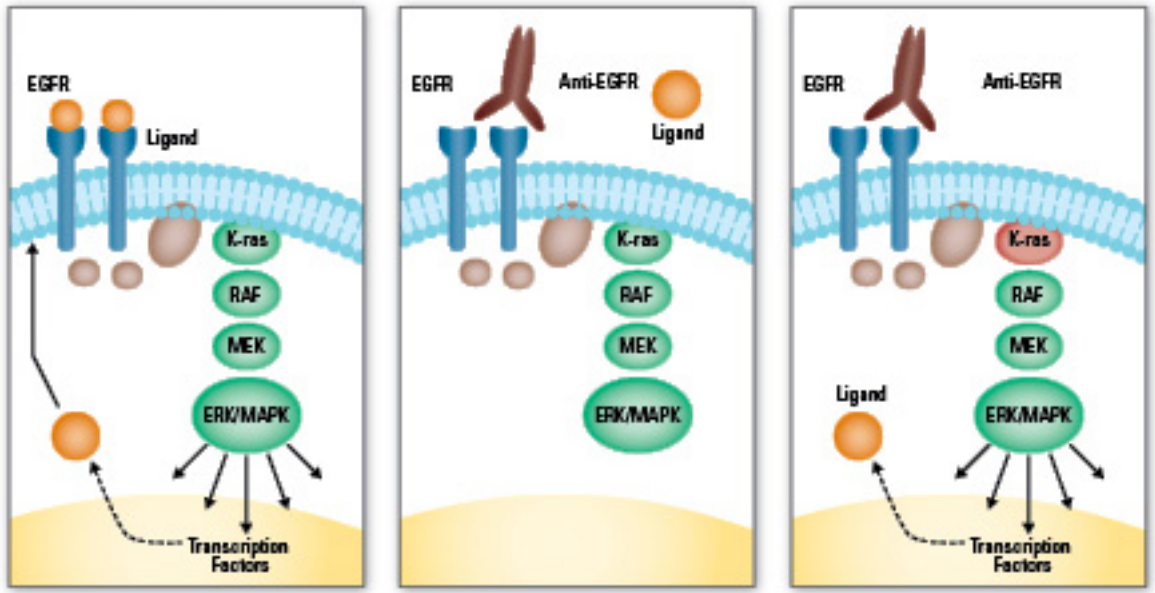
Fernandez, Kirchner, Pinaud (2014) EPTCS

Kirchner (2013) EPTCS

Kirchner, Namet, Fernandez (2011) LOPSTR

Andrei, Fernandez, Kirchner, Melançon, Namet, Pinaud (2011) TERMGRAPH

TRACK MODEL PARAMETER



EGRF model was post-validated using combined GRS and parameter tracking

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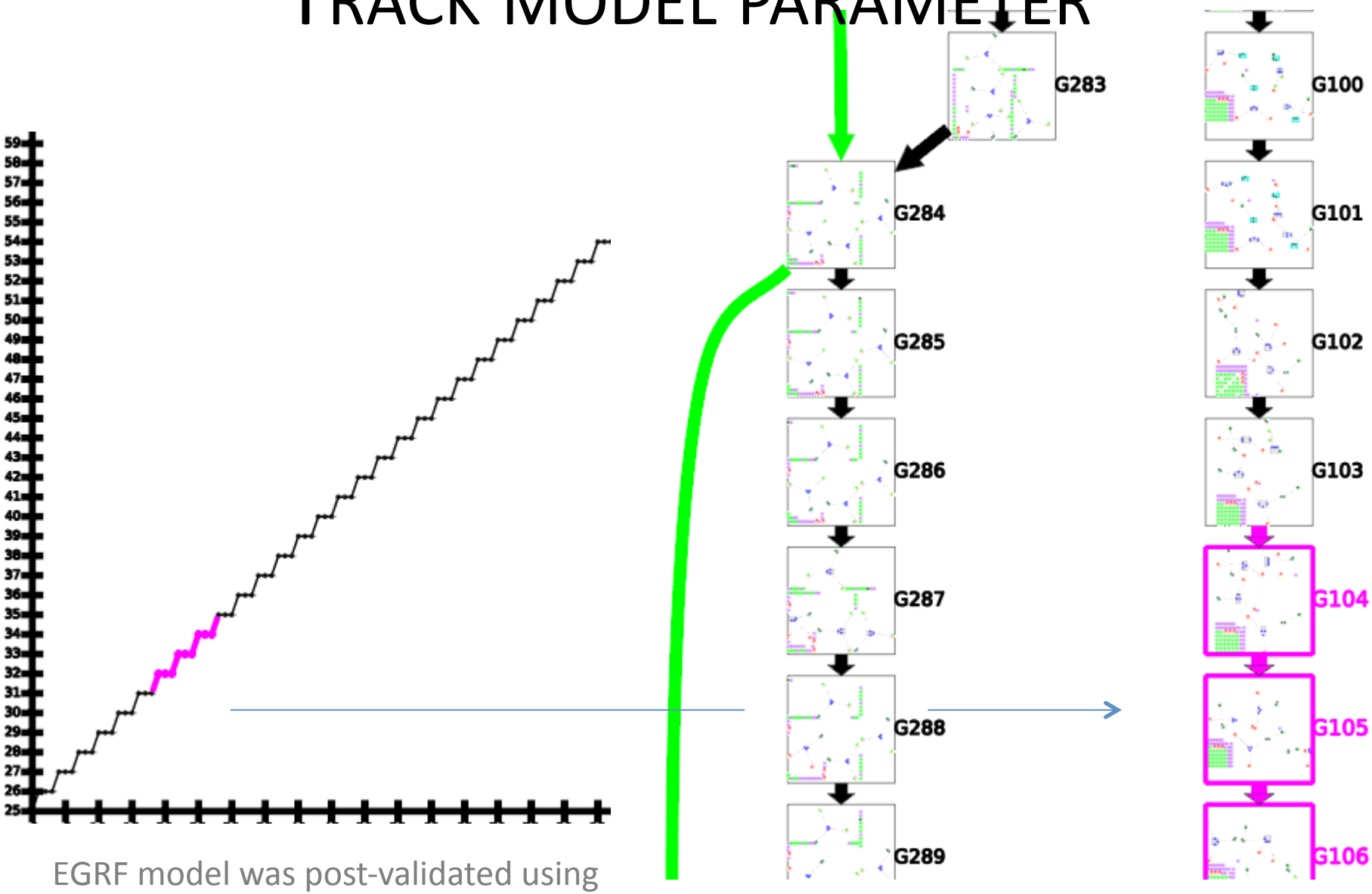

EGRF model was post-validated using combined GRS and parameter tracking

STRATEGIES

- Include macros to execute common sub-routines
  - Visit all neighbors of a node
  - Compute spanning tree
  - Execute local computations on node states
  - Etc.
- Makes model design easier

FUTURE WORK

TECHNICAL ISSUES

- Layout stability issues
  - Difficult because incremental change take place over a hierarchy
  - The drawing of rules often relies on implicit assumptions: no universal layout for rules
- Extend model tracking to multiple parameters
- Graph folding (confluence)
  - Scalability issues with subgraph isomorphism

EXTENDING THE REACH OF THE METHODOLOGY

- Port Graph Rewriting as a Universal Language to describe *Network Propagation models*

- Compare models
  - Expressiveness through complexity of rulesets
  - Computational efficiency through repeated simulations
  - Spot differences between models using PORGY

CONCLUSION

- PORGY is quite unique in offering simulation steering using a derivation tree
  - Visualization & Interaction vs text-based approaches
- Use-case
  - EGRF model was post-validated using combined GRS and parameter tracking
- PORGY's design relies on long term user experience, and on Munzner's formal approach to viz design
  - Potential impact on both GRS and domain application communities

CONCLUSION

- Visit PORGY
  - See Tulip's website

http://tulip.labri.fr/

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- Related work is discussed in papers

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