Strategic Port Graph Rewriting : An Interactive Modeling and Analysis Framework

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GRAPHITE 2014, April 4, 2014

Motivation and approach

In the context of software development and analysis, we address two challenges :

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$$\underbrace{\text{<Graph, Set of Rules, Strategy>}}_{\textbf{Strategic Graph Program}}$$

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Complex Systems

<State, Evolution Step, Control>

<Graph, Set of Rules, Strategy>

Strategic Graph Program

- Preserve all computations and provide interactive visualisation tools to help analysis and debugging

Derivation tree analysis

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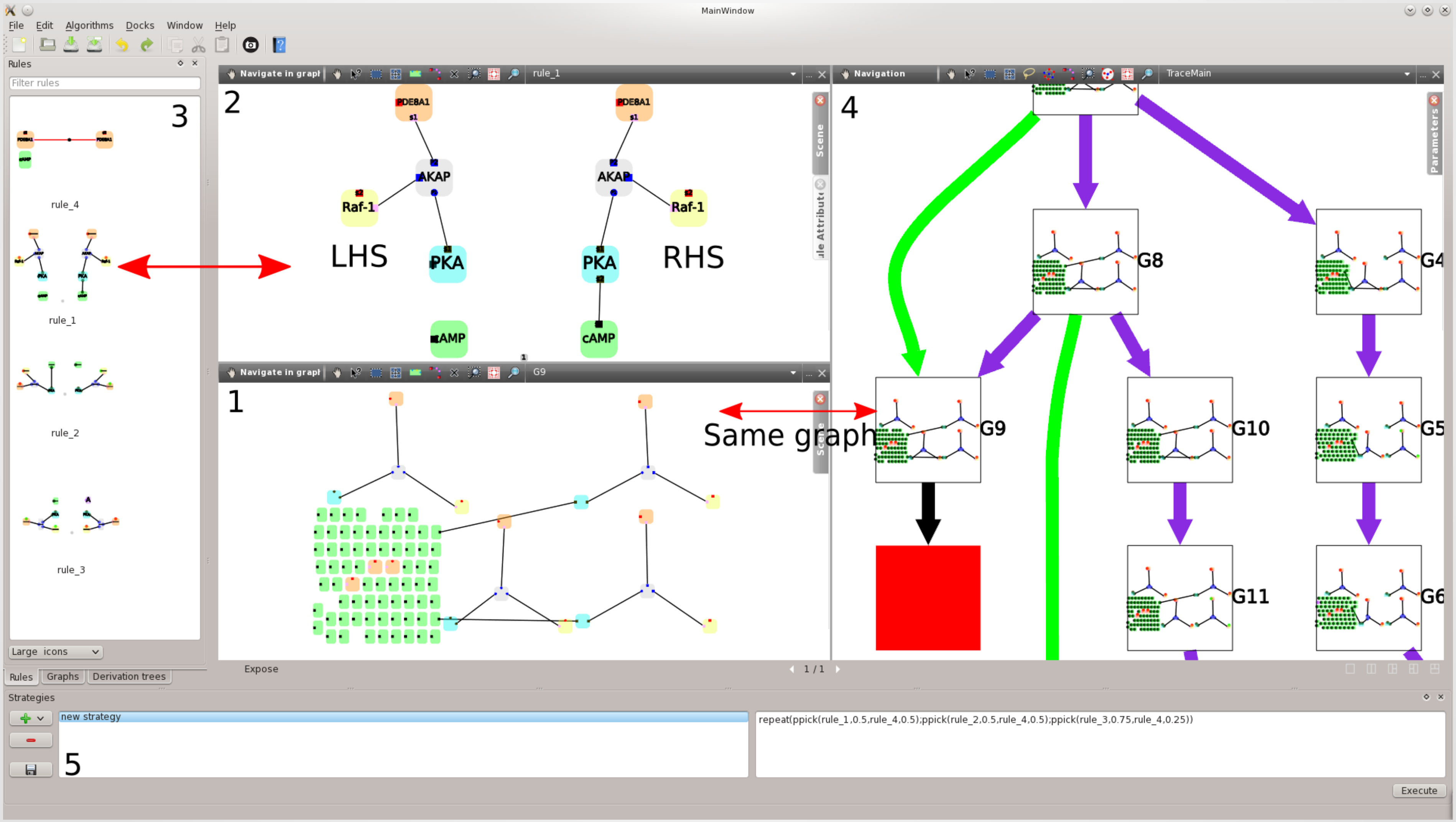
  - Non confluent,
  - Highly concurrent
- **A strategy language**
  - Some steps may be correlated (one followed by another),
  - Iterated until some condition is met,
  - or may occur only in some parts of the graph.
  - Non-deterministic choices: for simultaneous exploration of multiple rewriting scenarios and backtrack to test alternate strategies
- **A derivation tree**
  - History mechanism to record evolutions and choice points
  - Track properties along different scenarios

Porgy Overview

The PORGY environment features:

- Design port graphs and port rules and visualise them.
- Interactive application of a rule on a port graph.
- Creating and running a strategy.
- Exploration and analysis of a derivation tree.
  - Tooltips (get information)
  - Small multiples and animation (show the evolution of the graph)
  - Histograms (to follow graph parameter over rewriting operations)

Porgy Overview

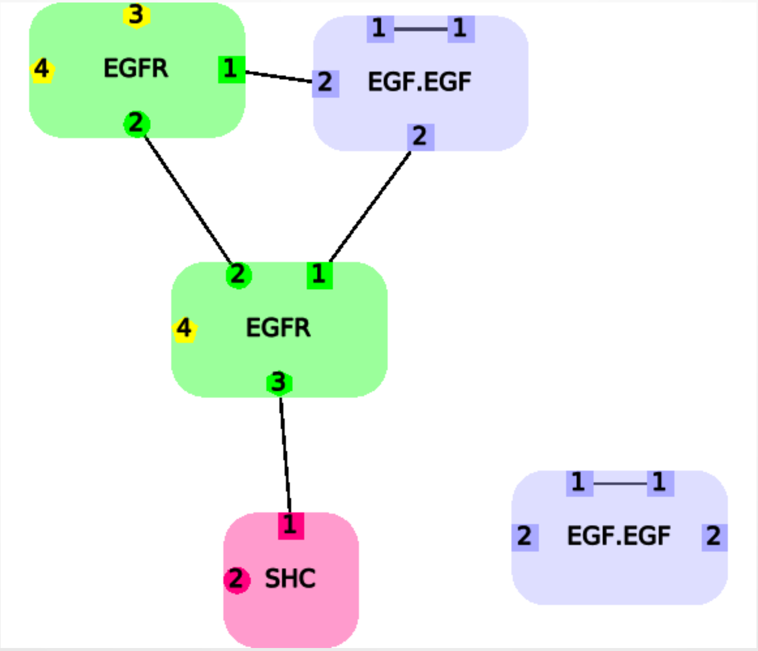


Port Graphs

[IbanescuBK03], [AndreiK07], κ-calculus [DanosL04], BioNetGen [BlinovYFH05]}

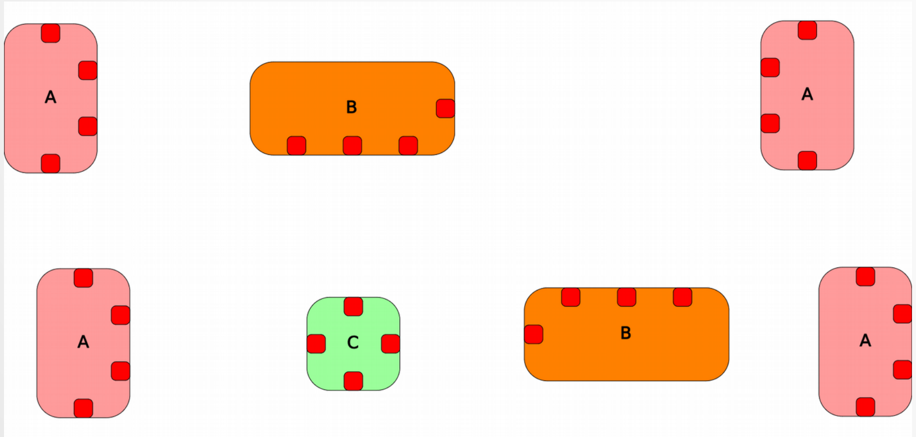
- Inspired by protein-protein interactions;
- Port graphs are graphs with multiple edges and loops, where:
  - Nodes have explicit connection points, called **ports**.
  - The edges attach only to ports of nodes.
  - Nodes, ports and edges have properties (ex: color, arity, boolean value, string, ...).

Actually equivalent to usual labeled graphs, but with more structure.

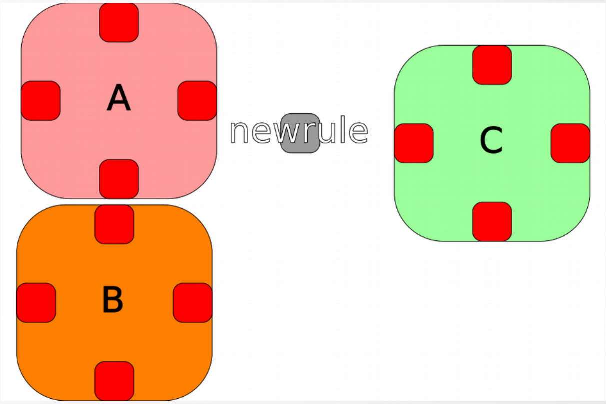


Notion of position: where to apply a rule in a graph?

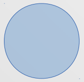
- Top-down or bottom-up traversals do not make sense.
- PORGY's solution is **located graphs** along with **located rewrite rules**.



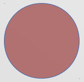
Goal : compute a morphism *g* of the left-hand side inside the graph



A rule called « newrule »



: position subgraph



: ban subgraph

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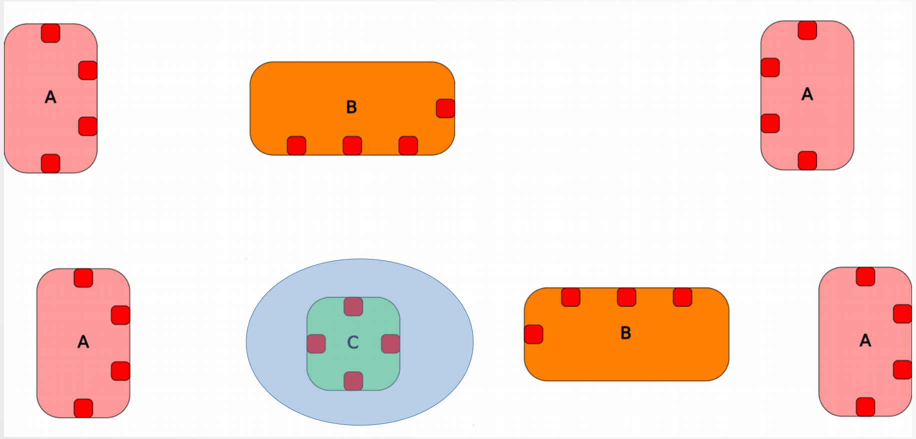

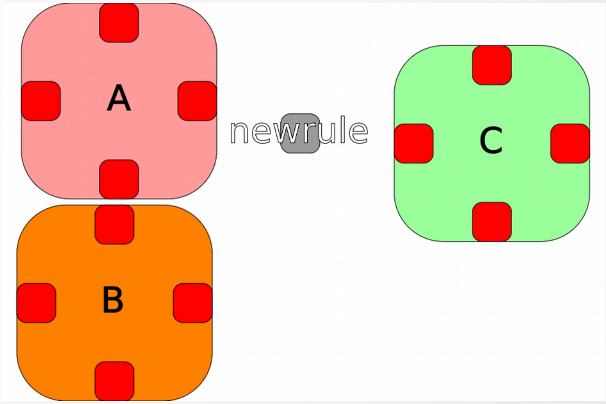

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NOK! There is no A or B nodes in the position subgraph

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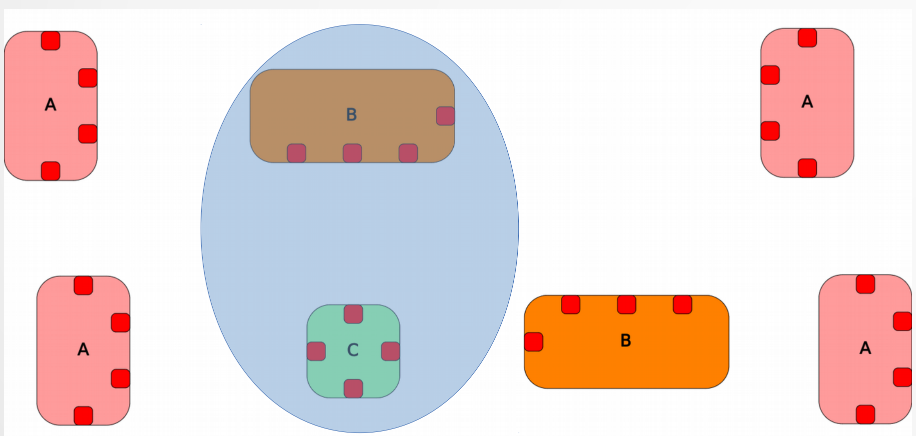

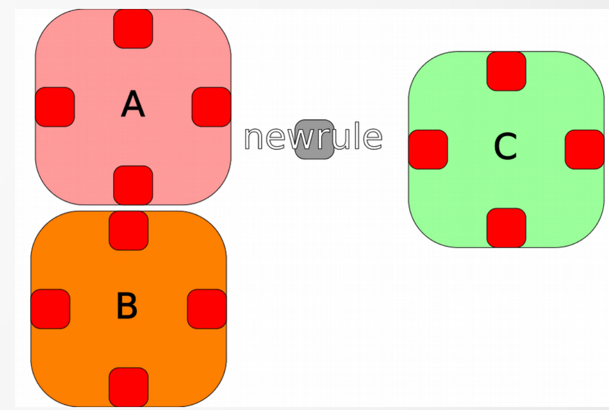

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OK! The matching will only be possible with the B node of the position subgraph

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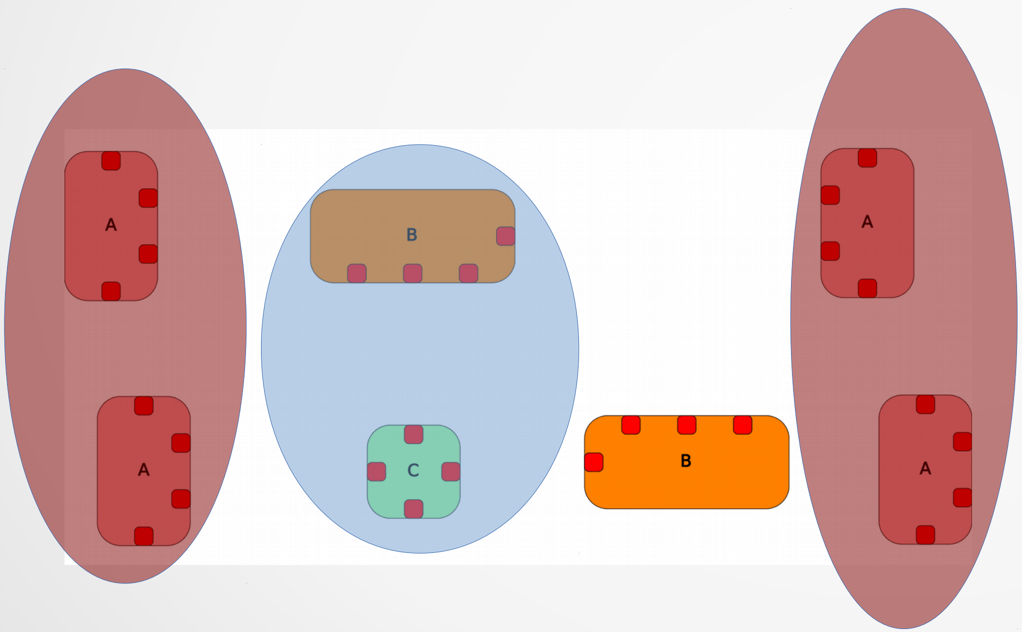

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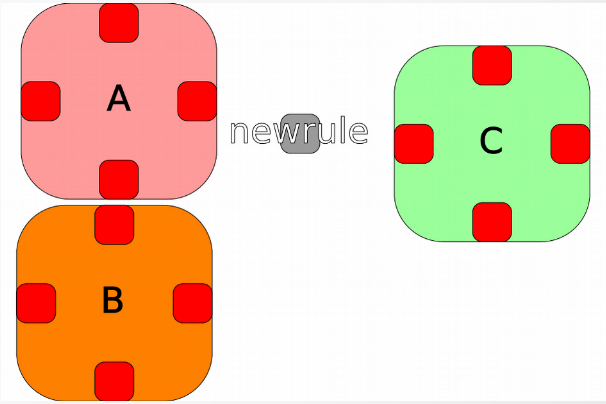


A rule called « newrule »

: position subgraph

: ban subgraph

NOK! All A nodes are banned

Located Graph and Located Rules

A ***located graph*** G_Q^P consists of a port graph *G* and two distinguished subgraphs *P* and *Q* of *G*, called resp. the ***position subgraph***, or simply ***position***, and the ***banned subgraph***.

A ***located rewrite rule*** consists of a port graph rewrite rule $L \Rightarrow R$ and two disjoints subgraphs *M* and *N* of *R*. It is denoted $L \Rightarrow R_M^N$.

- Rewriting must take place at least partially in *P* and not in *Q*.
- To apply a rule, $g(L) \cap P \neq \emptyset$ and $g(L) \cap Q = \emptyset$
- *G* is updated to $(G \setminus g(L)) \cup g(R)$
- *P* is updated to $(P \setminus g(L)) \cup g(M)$
- *Q* is updated to $Q \cup g(N)$

Grammar: rule applications and strategies

Let L, R be port graphs; M, N positions;

$$n \in \mathbb{N}; \, p_{i=1 \ldots n} \in [0,1]; \sum_{i=1}^{n} p_i = 1$$

(Transformations) $T ::= L \Rightarrow R_M^N$

(Applications) $A ::= \mathtt{Id} \mid \mathtt{Fail} \mid \mathtt{all(T)} \mid \mathtt{one(T)}$

(Strategies) $S ::= A \mid S \,;\, S \mid \mathtt{repeat}(S) \mid \mathtt{while}(S)\ \mathtt{do}\ (S)$
$\mid (S)\mathtt{orelse}(S) \mid \mathtt{if}(S)\ \mathtt{then}\ (S)\ \mathtt{else}\ (S)$
$\mid \mathtt{ppick}(S_1, p_1, \ldots, S_n, p_n)$
$\mid U$

Grammar 2/2: position updates

Let *attribute* be an attribute label;
n a valid value for the given attribute label;
function-name the name of a built-in or user-defined function.

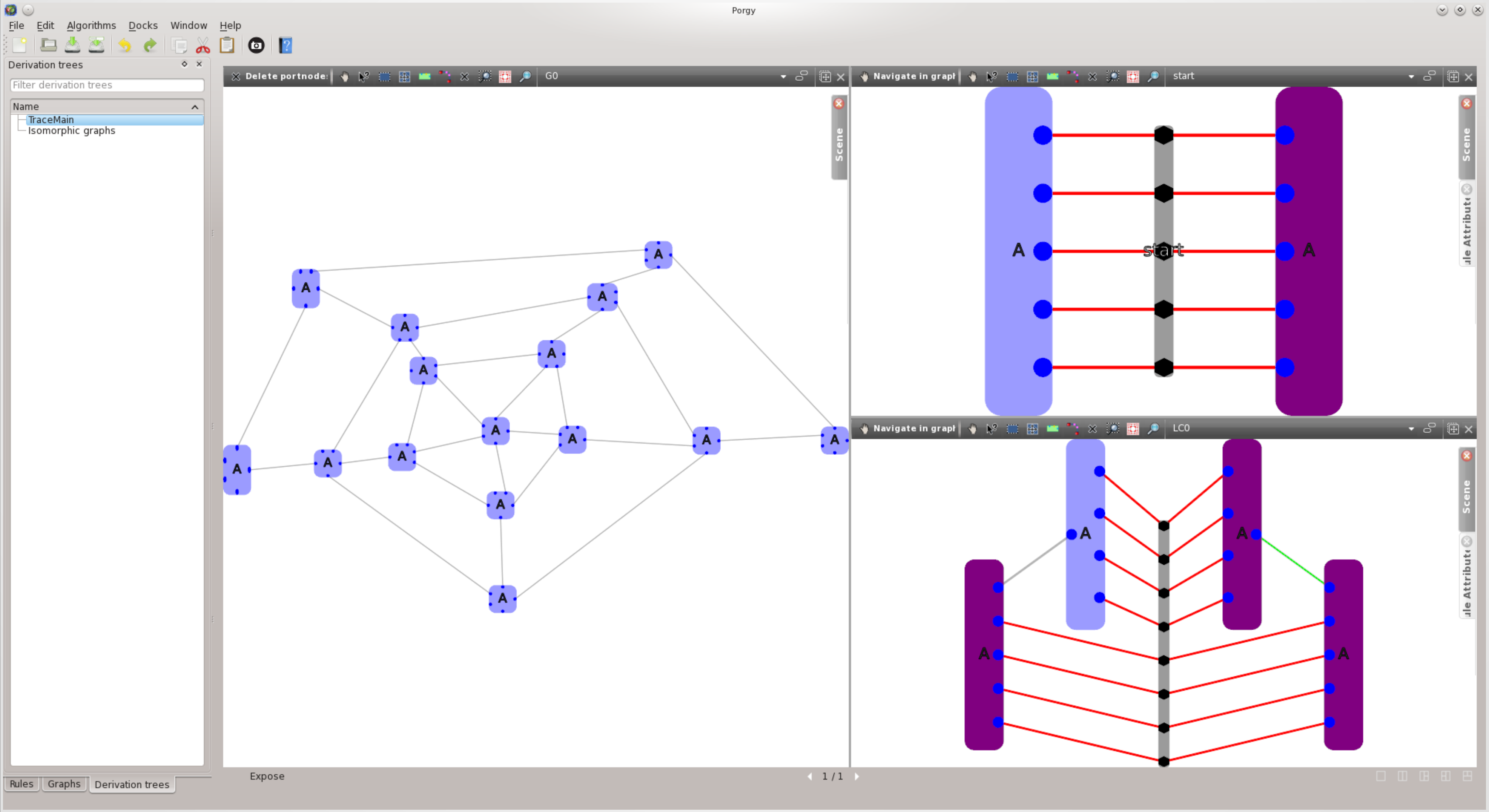
(Position Update) *U* ::= `setPos`(*F*) | `setBan`(*F*) | `isEmpty`(*F*)

(Focusing) *F*::= `CrtGraph` | `CrtPos` | `CrtBan` | `AllNgb`(*F*)
| `OneNgb`(*F*) | `NextNgb`(*F*)
| $F \cup F$ | $F \cap F$ | $F \setminus F$ | $\emptyset$
| `Property`(ρ, *F*)

(Properties) ρ := (*Elem*, *Expr*) | (Function,*function-name*)
Elem := Node | Edge | Port
Expr := Label == *n* | Label ! = *n* | *attribute Relop attribute*
| *attribute* Relop *n*
Relop := == | ! = | > | < | >= | <=

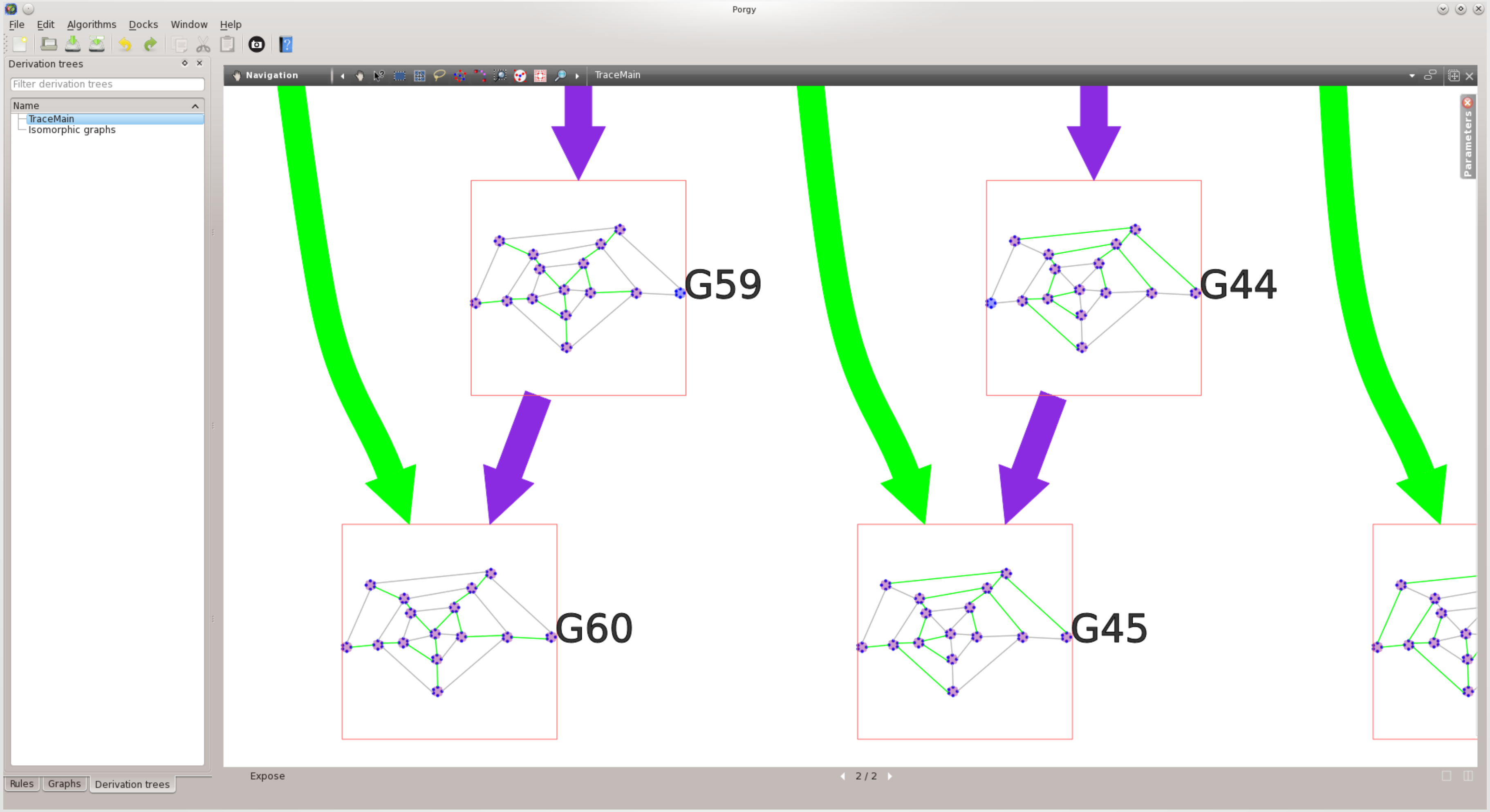
Other constructs : not(S):= if(S)then(Fail)else(Id)
try(S):= (S) orelse (Id)

Examples : spanning tree computation



Examples : spanning tree computation

Very simple strategy for one solution: ***one(start);repeat(LC0)***
Strategy to find all solutions (*all()* not fully implemented yet) : ***all(start);repeat(LC0)***



Examples: simple connectivity test

The strategy code with only one rule which mark a visited node :

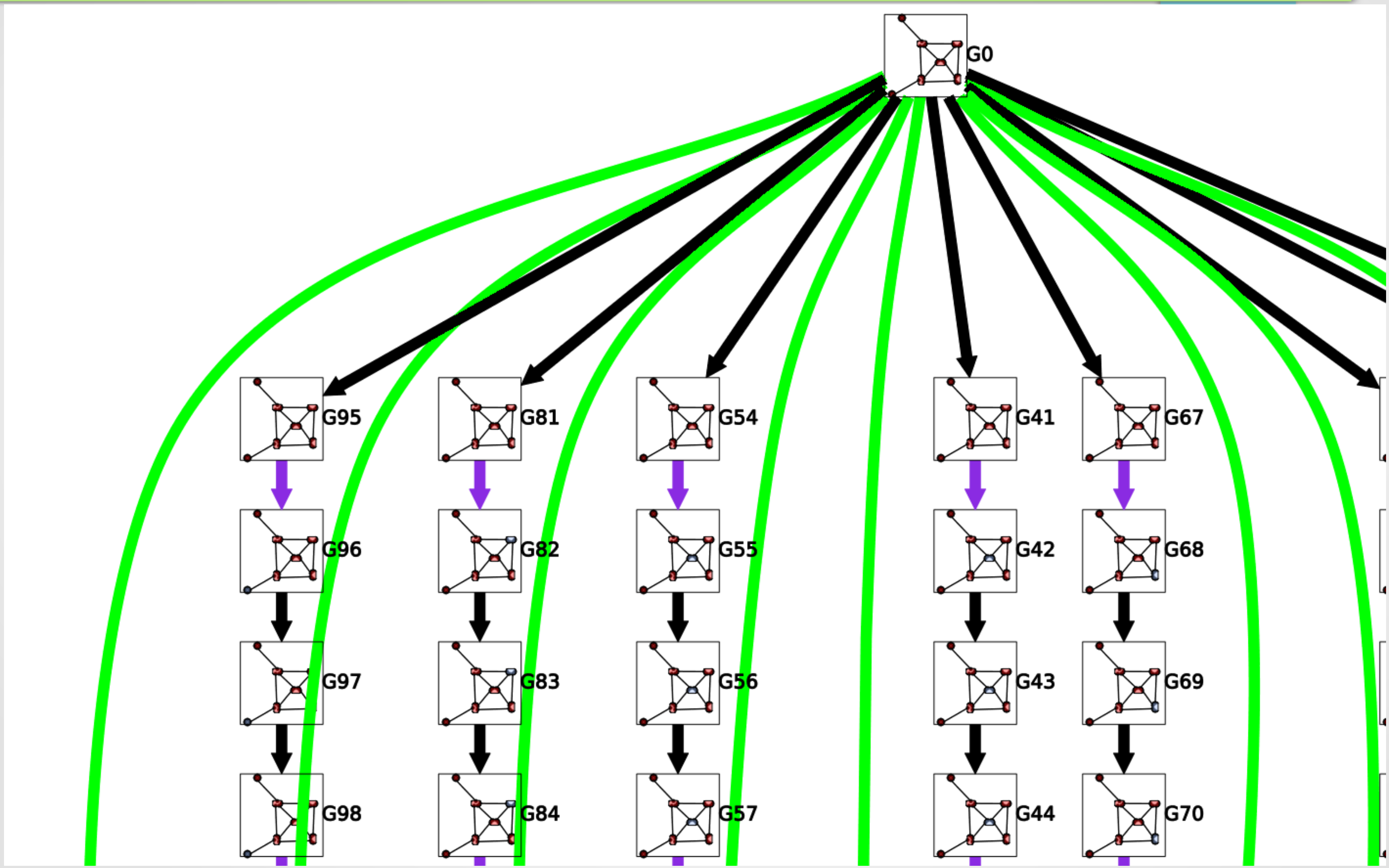
```
setPos(CrtGraph);
one(newrule);

setPos(Property(Node, "state"=="true", CrtGraph));
setPos(AllNgb(CrtPos));

while(not(isEmpty(CrtPos))) do (
if(newrule) then (
newrule
) else (
setPos(AllNgb(CrtPos)\Property(Node, "state"=="true", CrtGraph))
)
);

setPos(CrtGraph);
not(newrule)
```

Examples: simple connectivity test



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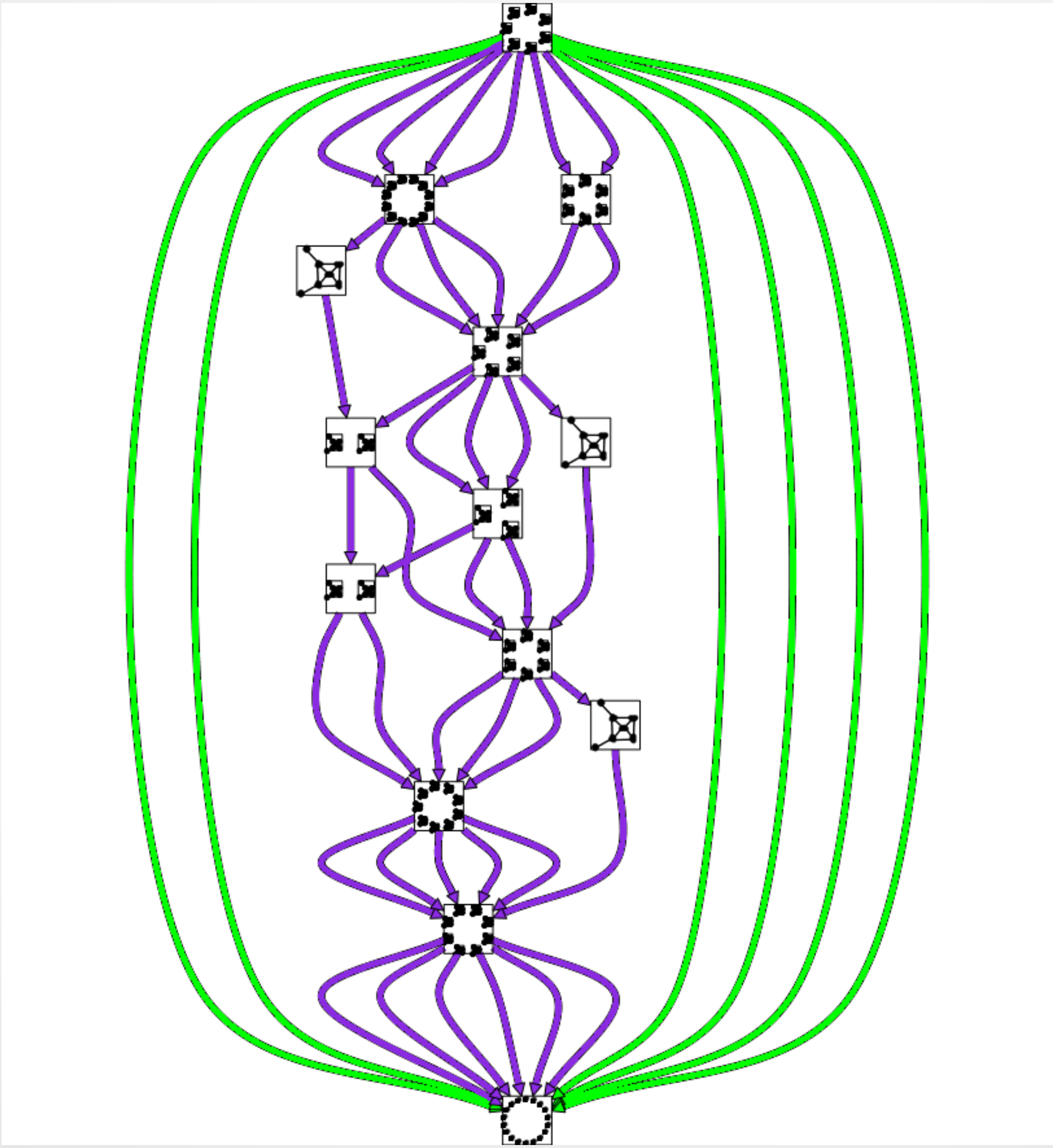

Semantics and Properties 1/2

- A *strategic graph program* is given by a set of port graph rewrite rules $\mathfrak{R}$, a strategy expression *S* (built from $\mathfrak{R}$) and a located graph G_P^Q. We denote it $[S_{\mathfrak{R}}, G_P^Q]$, or simply $[S, G_P^Q]$ when $\mathfrak{R}$ is clear from the context.
- In the paper, we give rule based semantics of the strategy language: small step operational semantics, specified using transition rules on configurations (multisets of strategic graph programs)
- Some properties:
  - $[S, G_P^Q]$ is *terminating* (Id or Fail) if there is no infinite transition sequence from the initial configuration $[S, G_P^Q]$.
  - The sublanguage that excludes the *while* and *repeat* constructs is terminating.

Semantics and Properties 2/2

Characterisation of Terminal Configurations:
For every strategic graph program $[S, G_P^Q]$ where $S \neq Id$ and $S \neq Fail$, there exists a configuration *C* such that $[S, G_P^Q] \to C$.

$[S, G_P^Q]$, if terminating, reduces to configurations that contain graph programs of the form $[Id, G'^{Q'}_{P'}]$ or $[Fail, G'^{Q'}_{P'}]$ (called values).

Each strategic graph program in the sublanguage that excludes non-deterministic operators (*OneNgb*, *one*, *ppick*, *orelse*) and r*epeat* has at most one *program result* which is a set of values (*Id* / *Fail*).

Conclusion

PORGY, an interactive visual environment for port graph transformation.
Programming with rules and strategies, including focusing capabilities.
Simple and intuitive visualisation and interaction.

Porgy is a set of Tulip plugins, about 20 000 lines of C++ code (with Qt library for GUI).
Tulip is a graph visualisation and manipulation framework (see http://tulip.labri.fr)

Strategy developed with the Boost Spirit library (only 1 500 lines of code).

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Other on-going applications:

Encoding Interaction Nets [laffont:90] programs

Specification/modelling biochemical systems and other complex systems.

Social Network Analysis (SNA, propagation models)

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QUESTIONS????

Feel free to ask for a live demo!!!