Querying and Creating Visualizations by Analogy

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Outline

- Provenance **reuse**
  - We have all this rich metadata - let's use it
- Query-by-example
- Visualization by Analogy
- (VisTrails intro)
  - **Transparent provenance tracking**

Related Work

- Visualization Systems and Libraries
  - AVS, DX, SCIRun, VTK
- History tracking and formalisms
  - Jankun-Kelly et al's pset-calculus
  - Kreuseler et al, VDM history
  - Brodlie's et al's GRASPARC
  - VisTrails

Provenance

- The “pedigree” of an artifact
  - Where did it come from? Who held it?

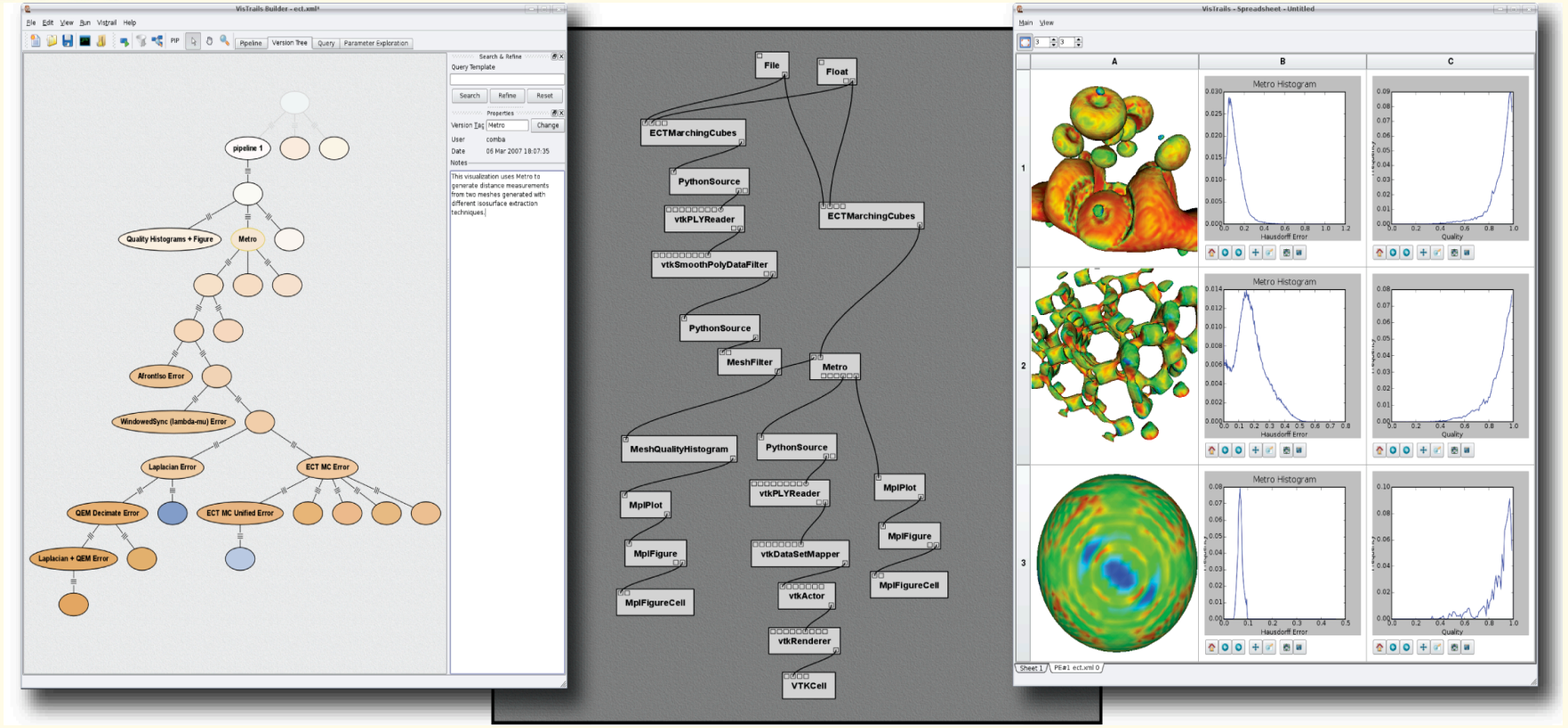
From the Tour: The Beginnings of Impressionist Landscape
Object 5 of 7

Provenance

From the artist 1890 to (Durand-Ruel, Paris and New York); sold 17 March 1892 to Adolphe A. Tavernier, Paris;[1] (Tavernier sale, Galerie Georges Petit, Paris, 6 March 1900, no. 74, as *Rue à Sèvres*); purchased by Berhend, Paris.[2] (Wildenstein & Co., London, New York and Paris).[3] Capt. Edward H. Molyneux [1894-1974], Paris, by 1948;[4] sold 15 August 1955 to Ailsa Mellon Bruce [1901-1969], New York; bequest 1970 to NGA.

[1]Dates of purchase and sale by Durand-Ruel according to François Daulte, *Alfred Sisley*, Paris, 1959, no. 44. [2]Annotated copy of sales catalogue in NGA curatorial files. [3]According to François Daulte, *Alfred Sisley*, Paris, 1959, no. 44. According to letter dated 18 June 1999, in NGA curatorial files, Wildenstein & Co. has no record of ever having owned this painting. [4]Lent by Molyneux to the 1948 Paris exhibition, *Huite Siècles*

Provenance in VisTrails



- **Process** provenance
- How was this visualization created?

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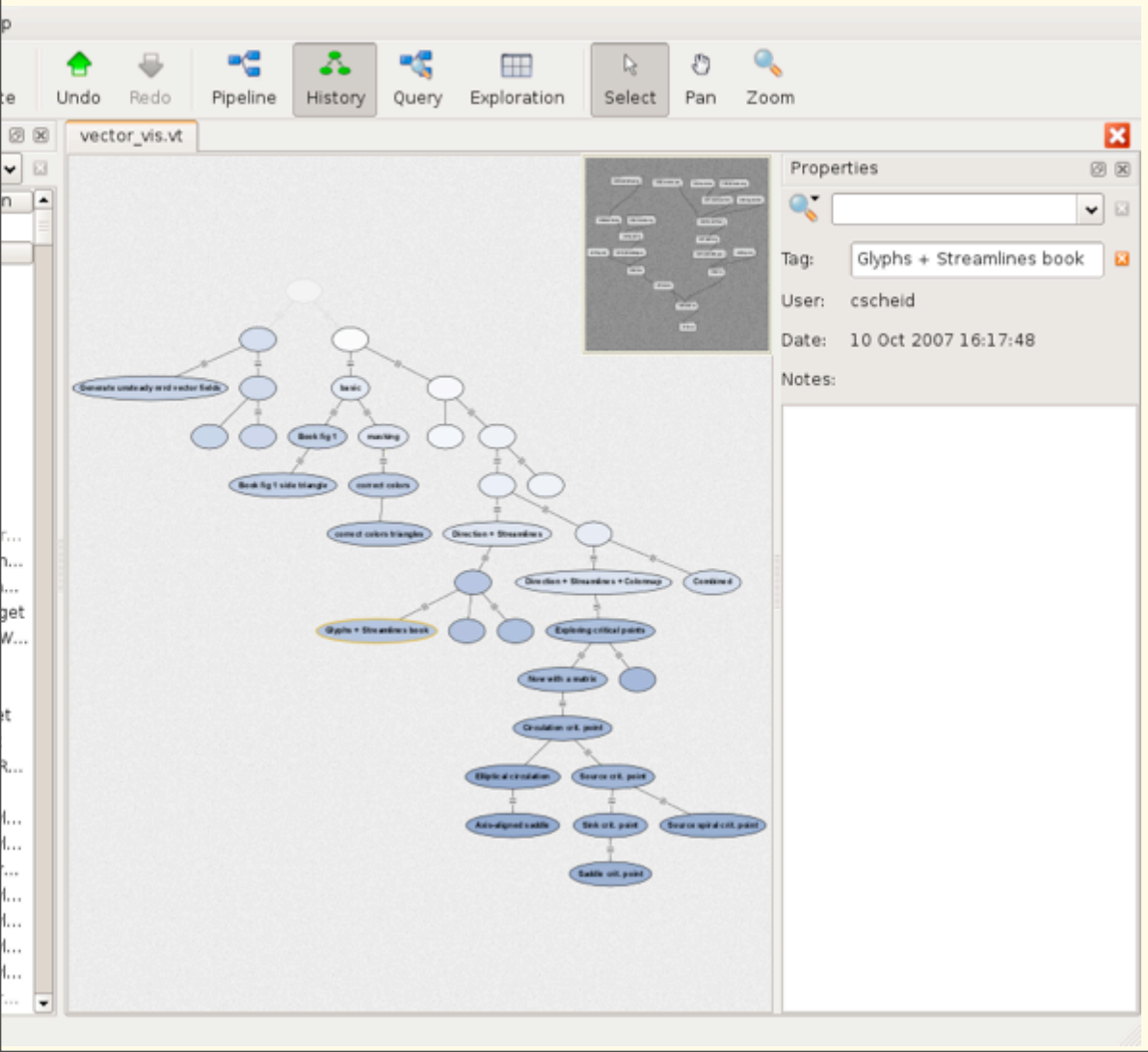
Version Tree



- Persistent
- Transparent
- **Reuse**
  - Can we do better than just presenting?

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Why not query languages?


```
Select ExecutableWorkflowId, Execution_Event.ExecutionId, Event.EventId,
Execution_Event.ExecutableWorkflow_ExecutableActivityId
from Execution, Execution_Event, Event, Event_Property_Value, Property, Va
where Value=Cast('C:\TEMP\atlas-x.gif' as binary) and
Event_Property_Value.PropertyId=Property.PropertyId and Event_Property_Va
and Event.EventId=Event_Property_Value.EventId and Execution_Event.EventI
Execution_Event.ExecutionId=Execution.ExecutionId;
```

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```

wf{*}: upstream(x) union x where
x.module = “SoftMean” and executed
(x) and y in upstream(x) and
y.module = “AlignWarp” and
y.parameter(“model”) = “12”

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```

This is still only mildly better than straight SQL... Does not expose mapping to relational schema

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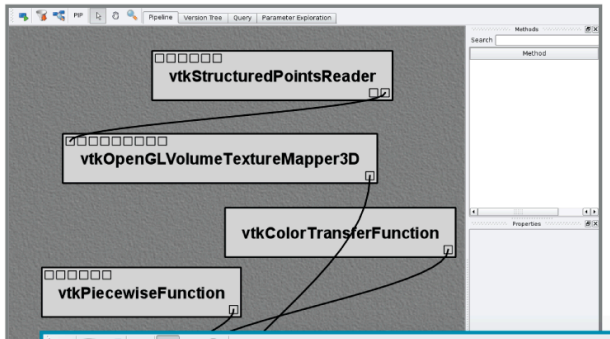
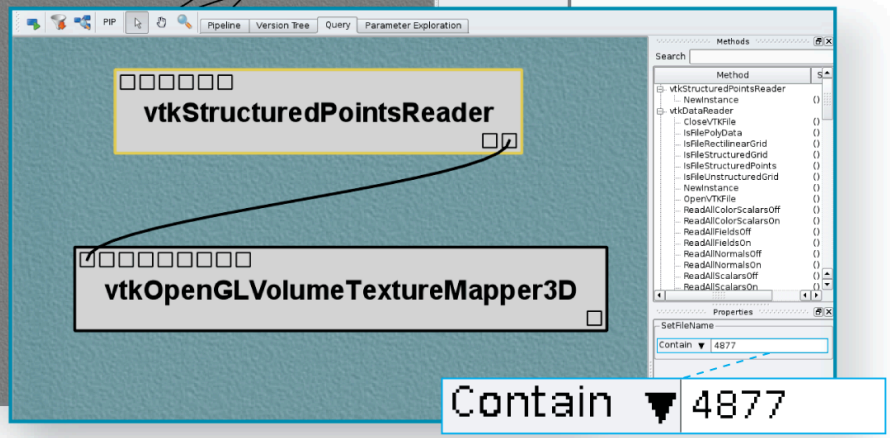
```

Query-by-Example

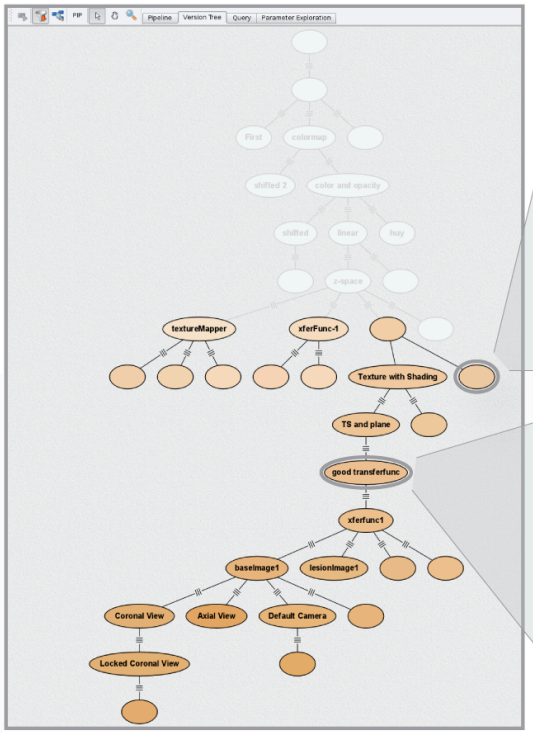
Pipeline Interface

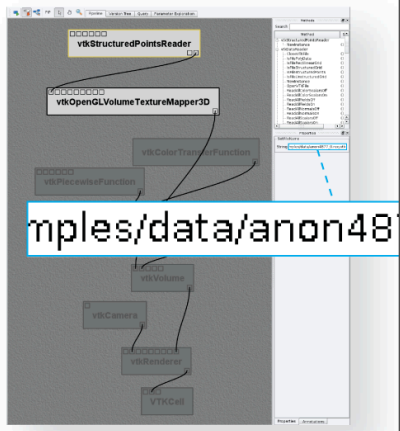


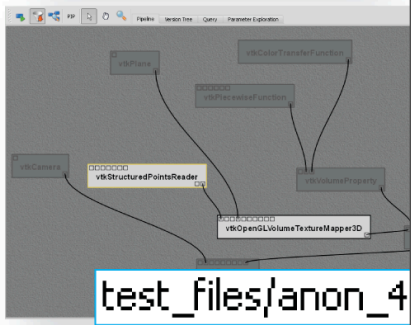
Query Interface



Query Result

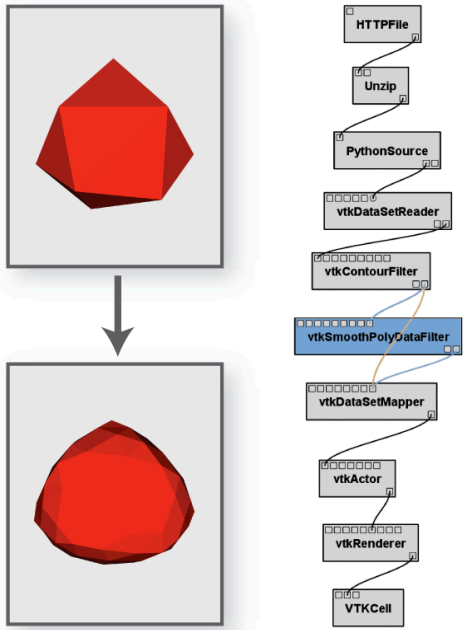




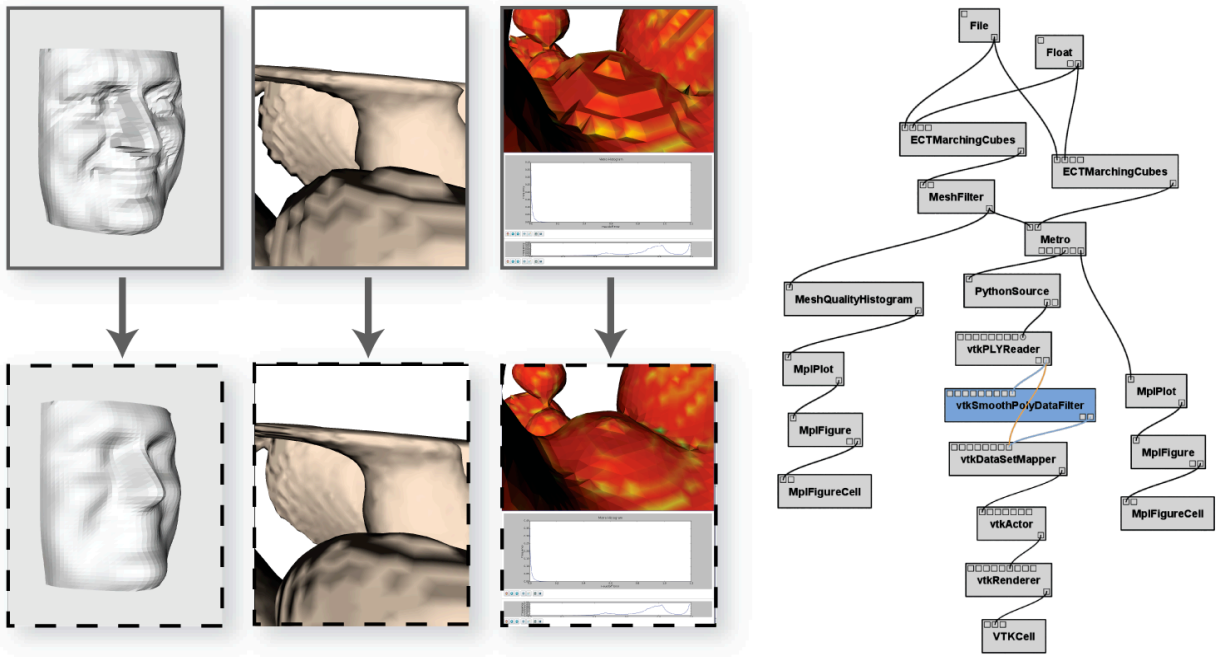


- Do not teach the user new forms of interaction!

Visualization by Analogy



Analogy Template



Automatically constructed visualizations

- Create new visualizations by saying "do as they did"
  - Specify **what**, not **how**

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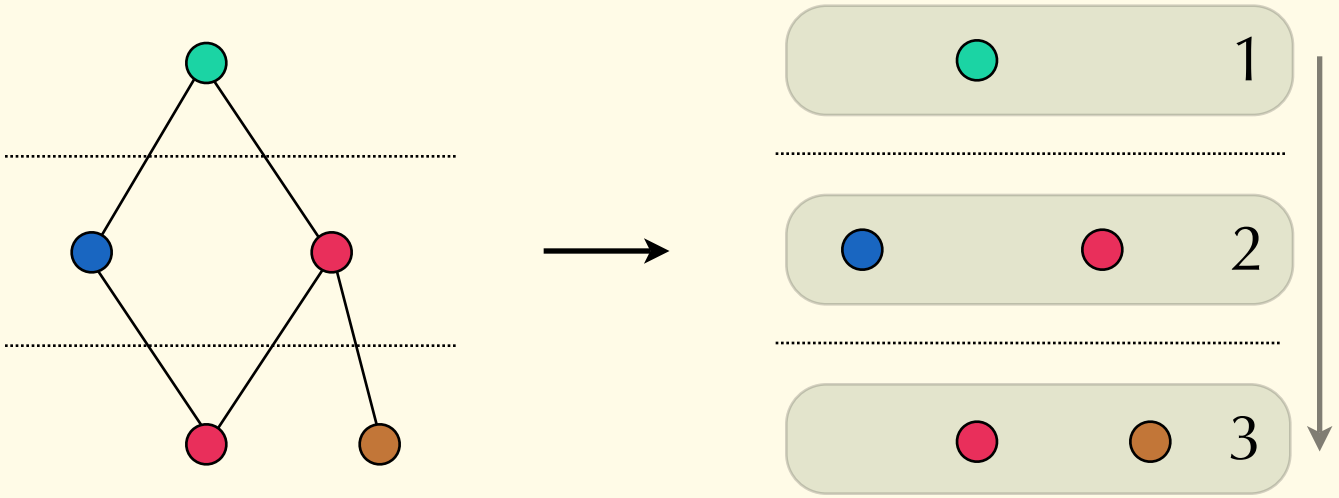
Query-by-Example

- Trivially reducible from MAX-CLIQUE
  - ... and MAX-CLIQUE is NP-Complete
  - ... and MAX-CLIQUE is fundamentally hard to approximate
- Solution: algorithm tailored to problem domain

Query-by-Example

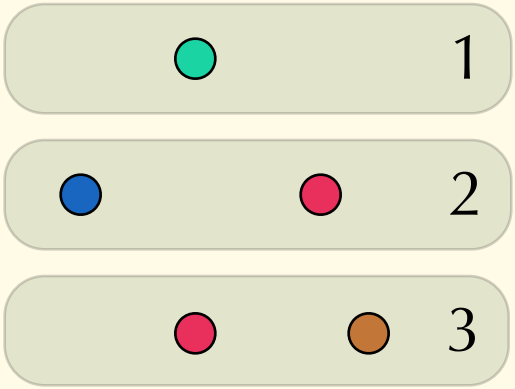
- Split every subgraph in topologically sorted layers
  - Ok, since all pipelines are DAGs in VisTrails



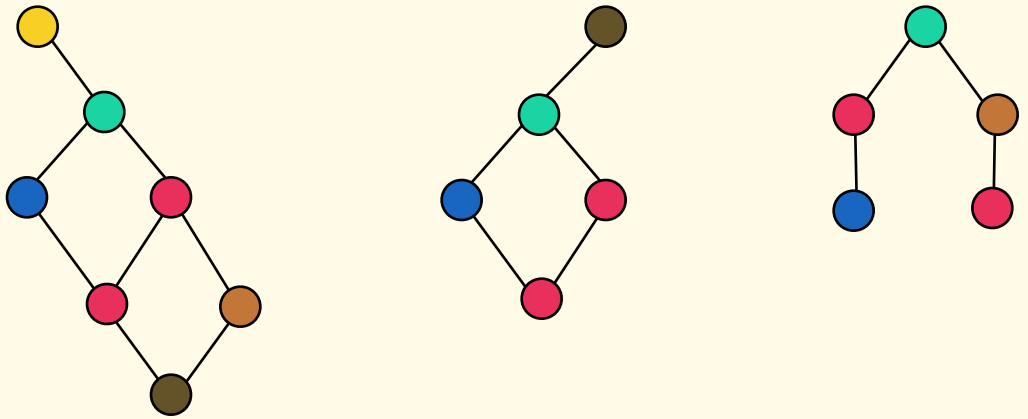
Query-by-Example

- Now search for layers that are connected in the same way in the database

Query



Database



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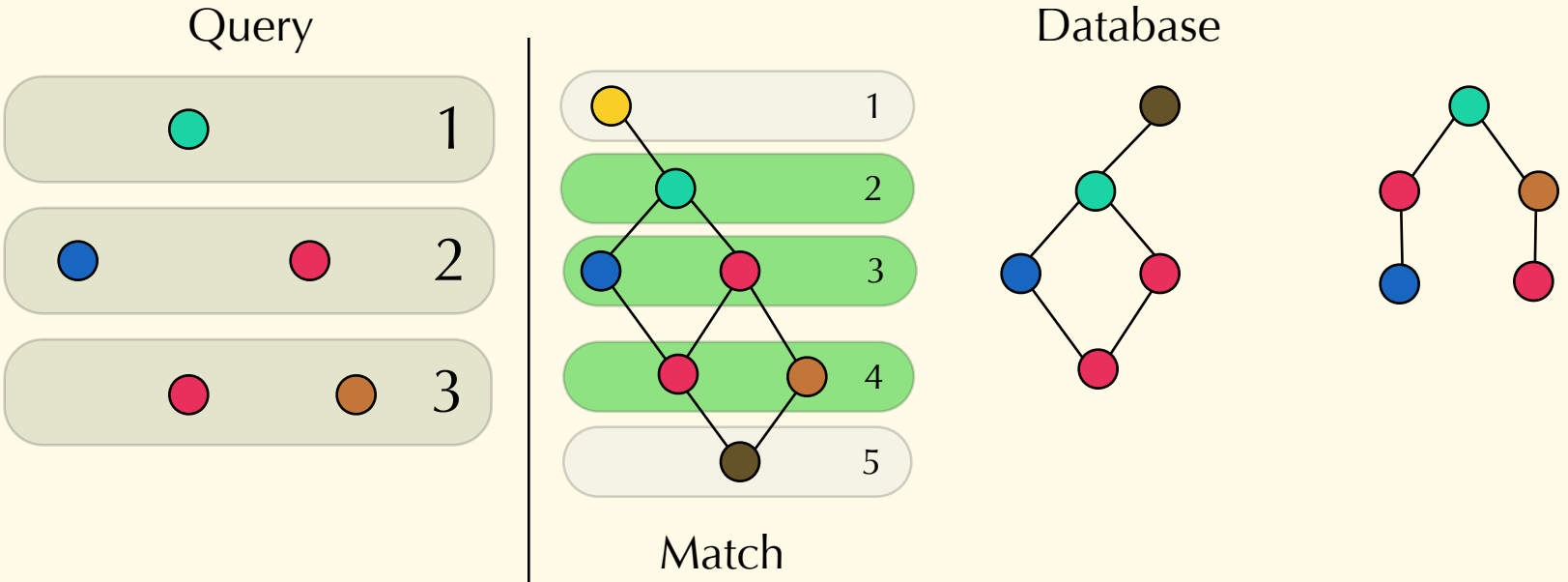

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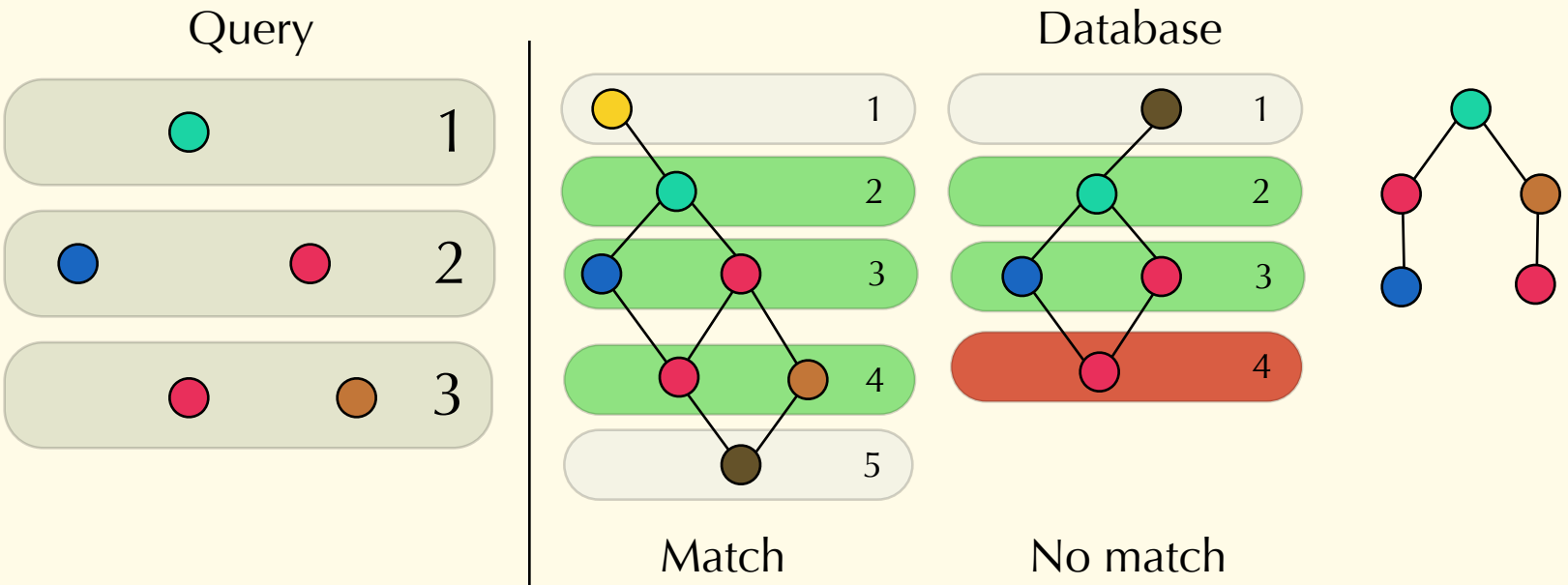

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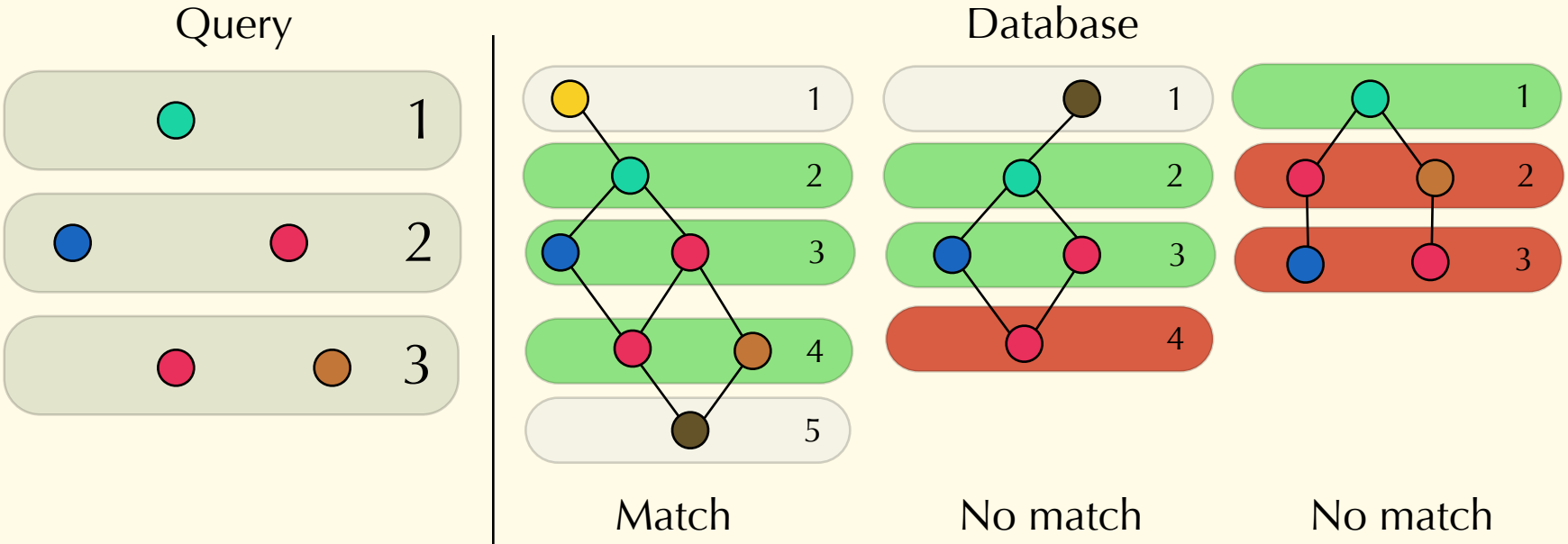
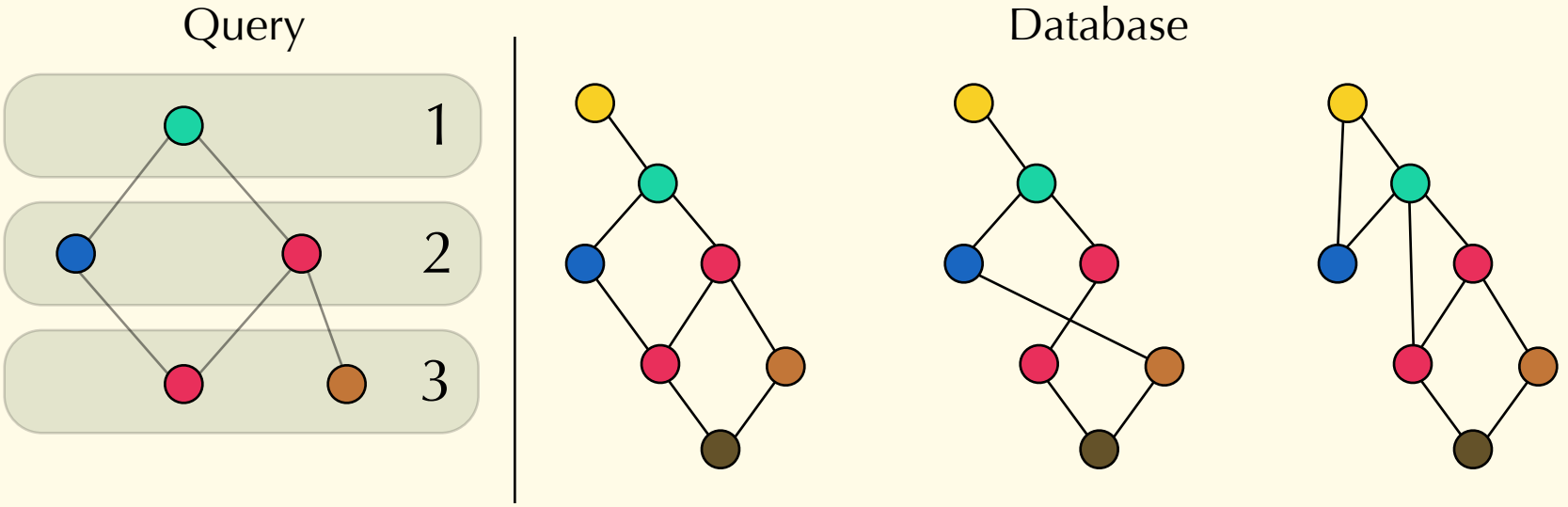


Query-by-Example

- Might return false positives - it ignores the particular connectivity between topological layers



- Not too harmful - most modules cannot connect to one another

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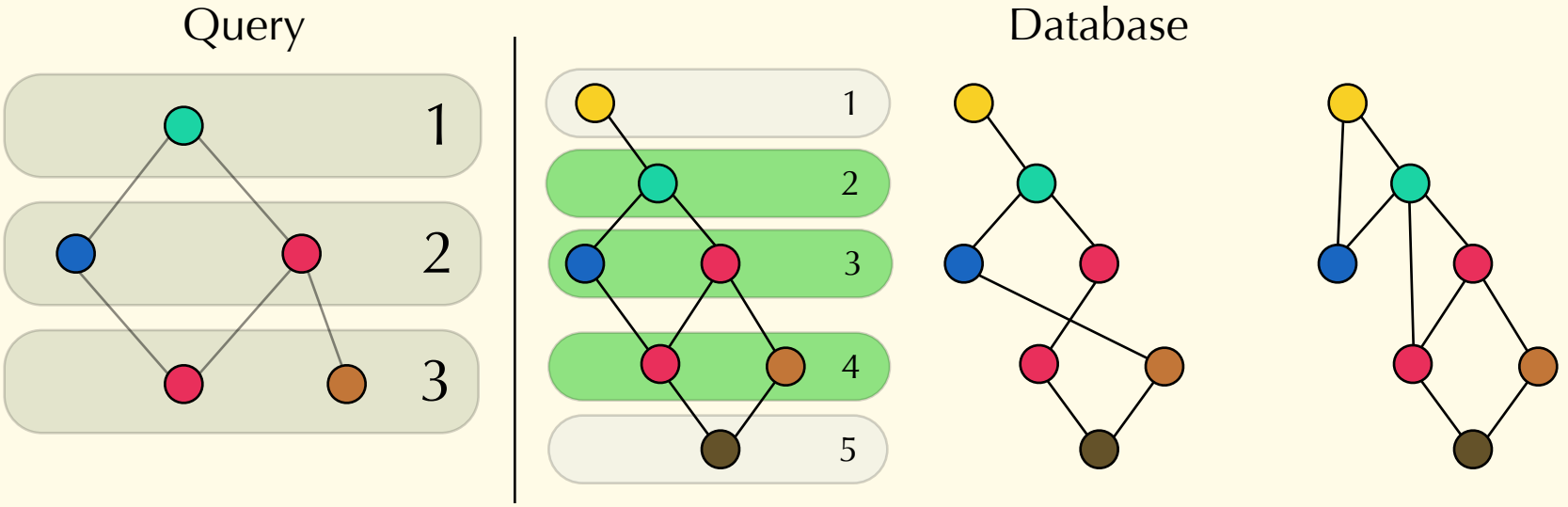

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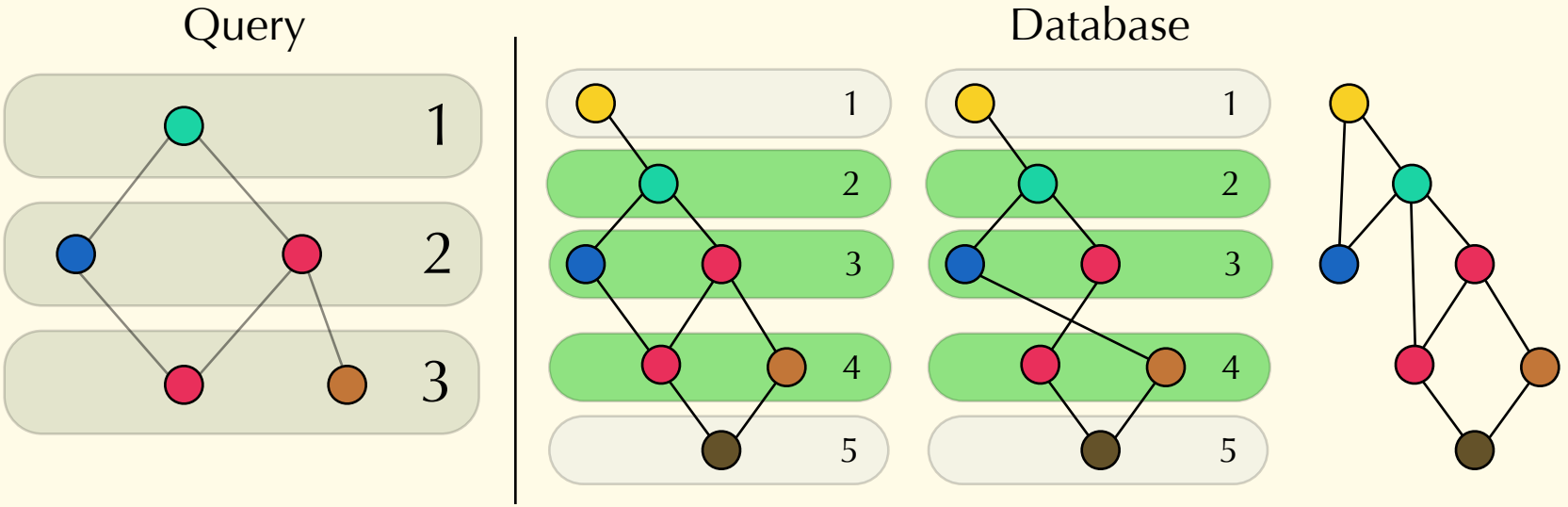

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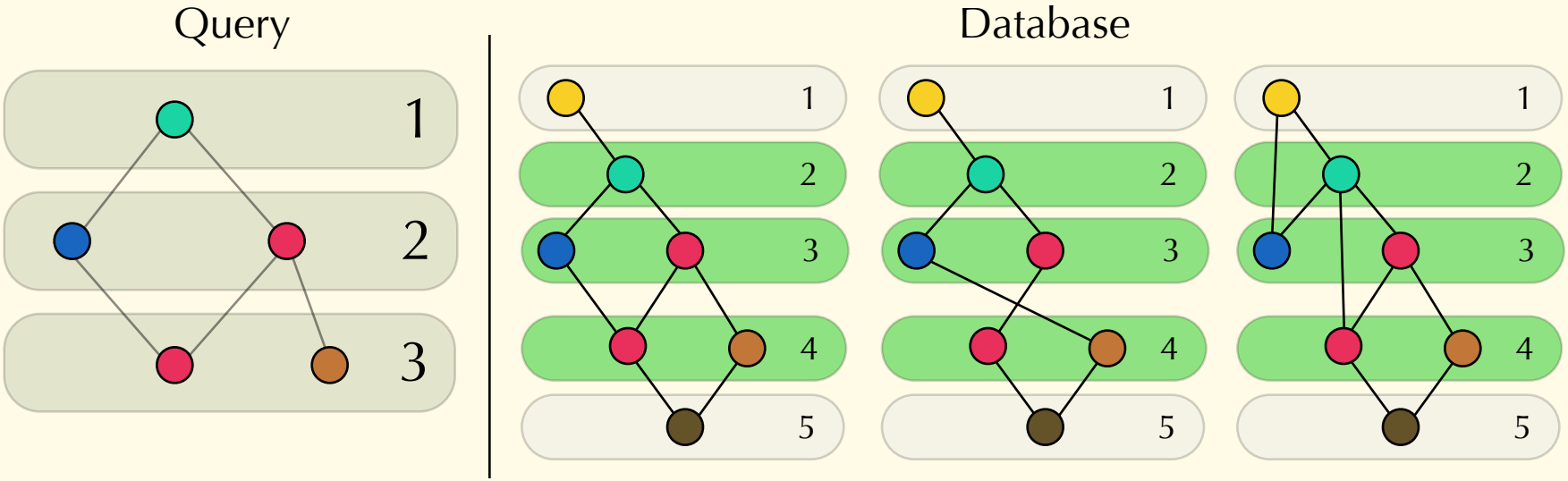


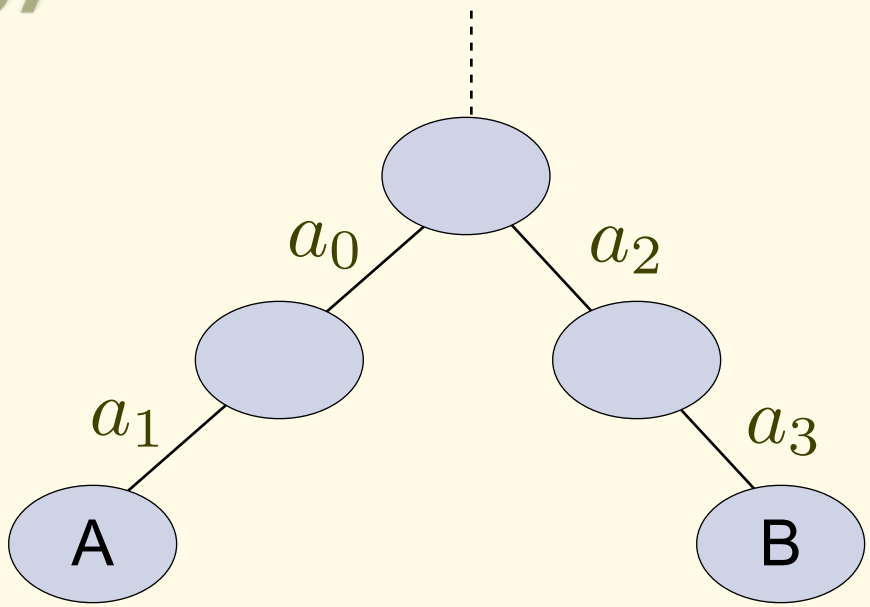
- Not too harmful - most modules cannot connect to one another

QBE Demo

Vistrail diffs

- A version tree stores a set of **actions**
  - Each action is a function on the set of all possible visualizations: $\mathcal{V} \rightarrow \mathcal{V}$
- $a_n \circ a_{n-1} \circ a_{n-2} \cdots \circ a_0$
- We can use those to determine the difference between visualizations
- Moving up, then down the version tree

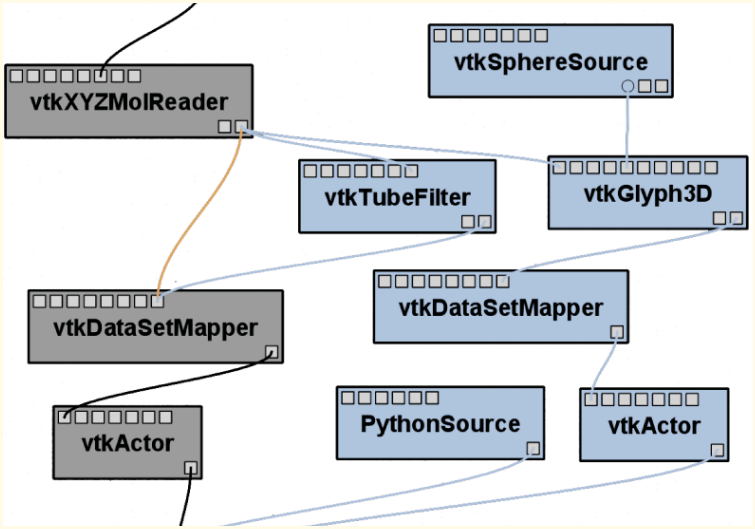
Vistrail diffs

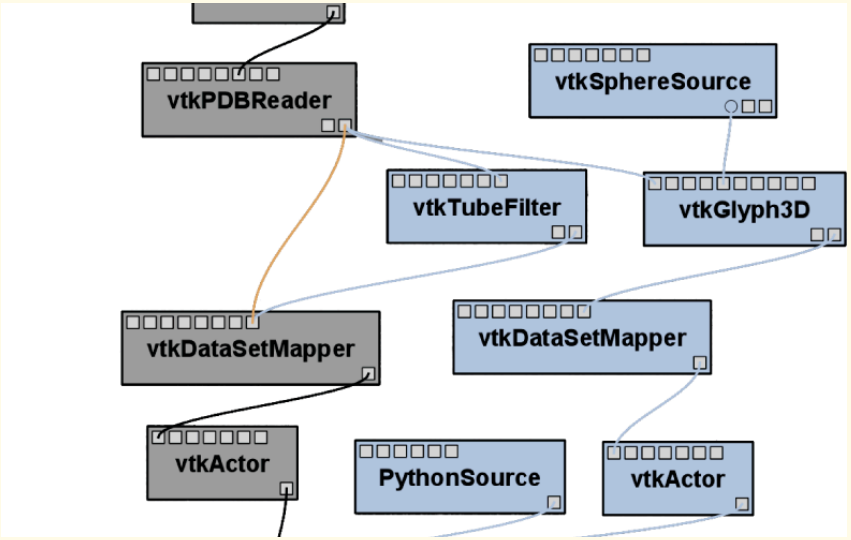


- Action to go from A to B is $a_3 \circ a_2 \circ a_0^{-1} \circ a_1^{-1}$

Visualization by Analogy

- A diff is a template: reapply it elsewhere





- How do we match two pipelines?

Algorithm Overview

- Compute the difference $\delta_{ab} = \Delta(p_a, p_b)$
- Compute the map $\mathsf{map}_{ac} = \mathsf{map}(p_a, p_c)$
- Apply map_{ac} to δ_{ab} $\delta^{\star}_{cb} = \mathsf{map}_{ac}(\delta_{ab})$
- Compute the new pipeline $p_d = \delta^{\star}_{cb}(p_c)$

Visualization by Analogy

- Simplest version is again reducible from MAX-CLIQUE
- We will now use a probabilistic argument to create a Markov chain

How does it work?

- Module compatibility: **prior**
  - $f : M^2 \rightarrow [0, 1]$
  - **Independent** of graph topology
- Probability of match between a pair
  - **Dependent** of graph topology
  - Linear combination of probability of match in the neighborhood pairs and data
- This is a Markov chain!

How does it work?

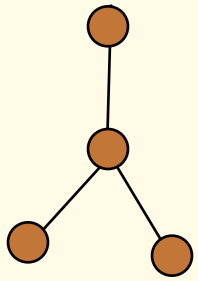
- Graph product G of the two input graphs
  - each vertex in G represents a possible match
  - similarity is then defined as

$$\pi = \alpha A(G)\pi + (1-\alpha)c(G)$$
$$= M_G\pi$$

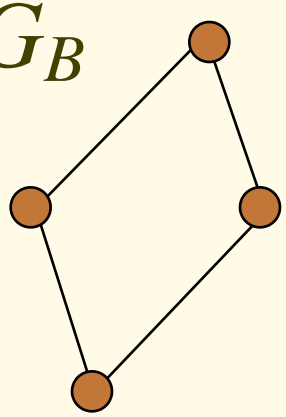
- π is an eigenvector of M_G
  - It is the limit distribution of the transition matrix

How does it work?

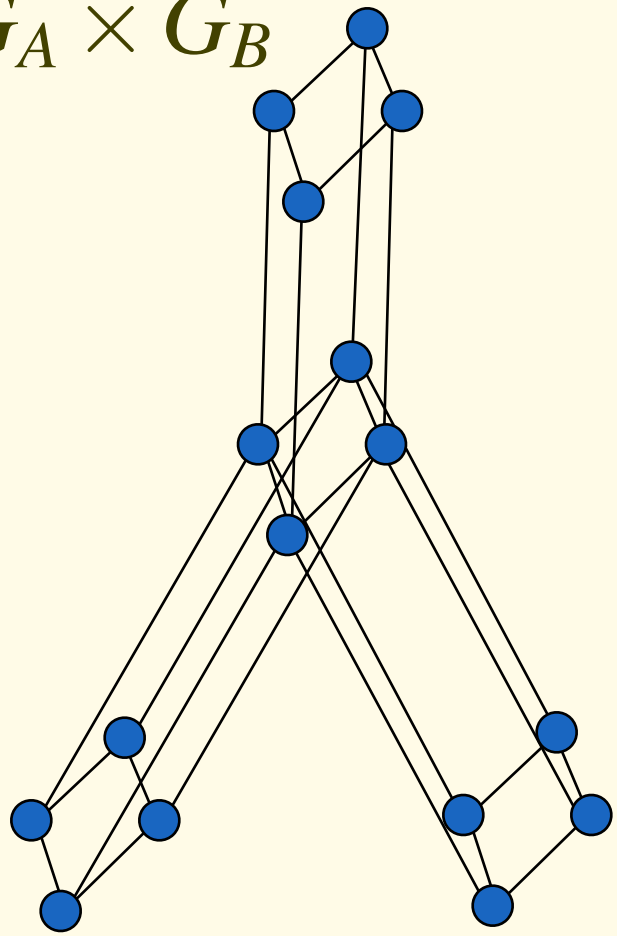
G_A



G_B



$G_A \times G_B$



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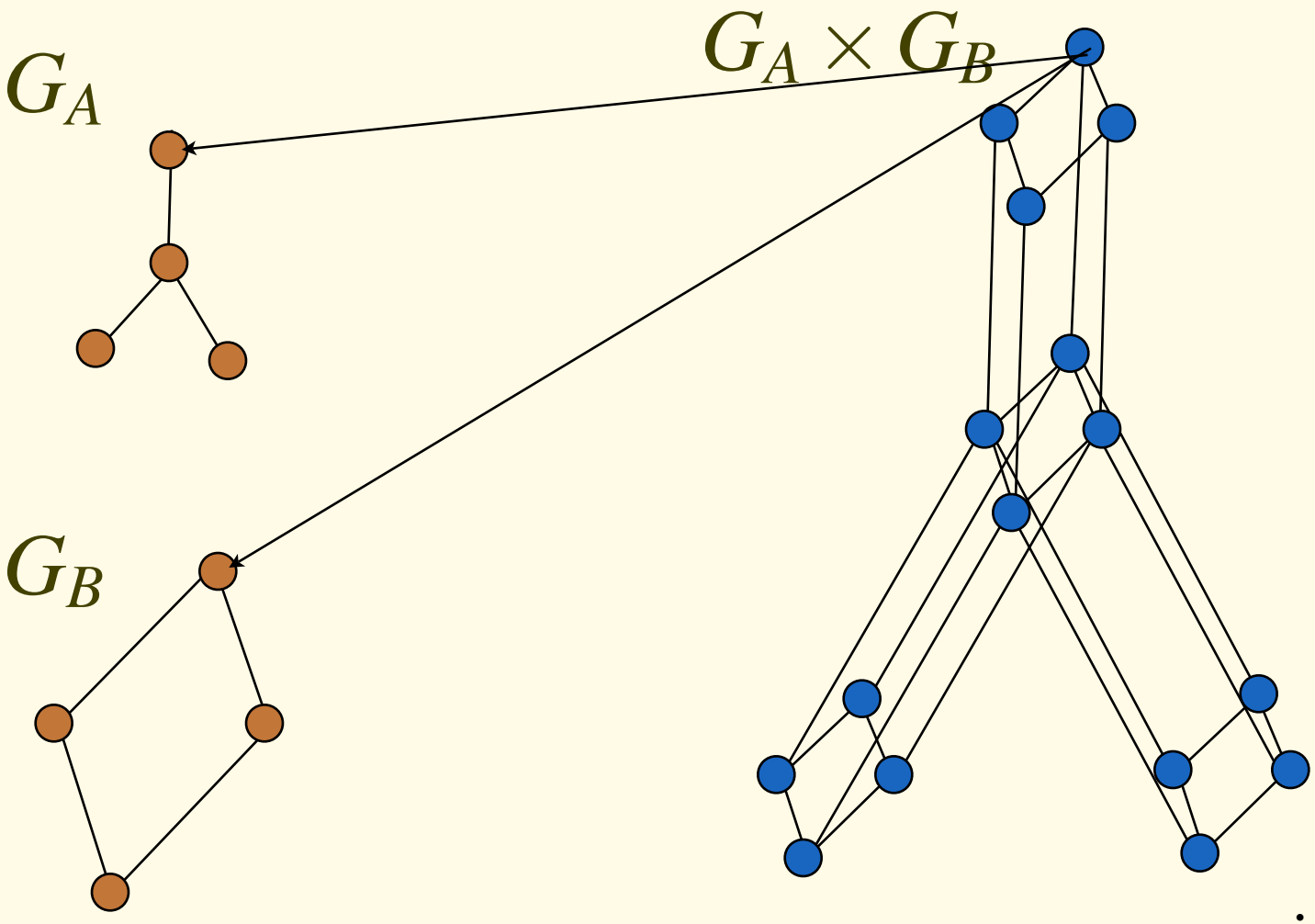

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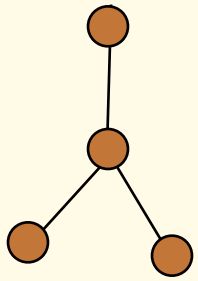

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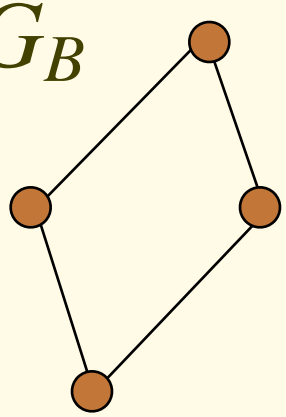

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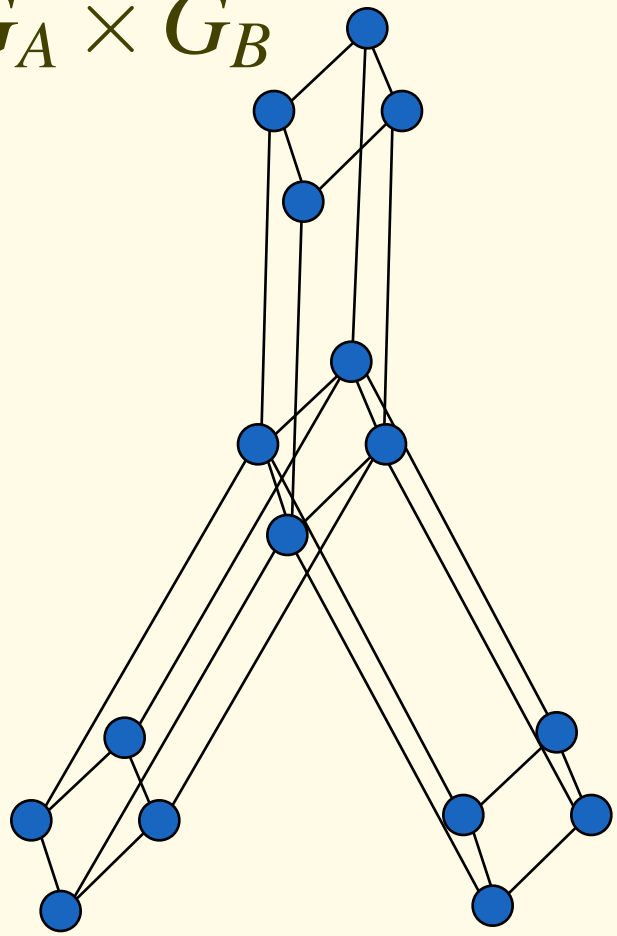

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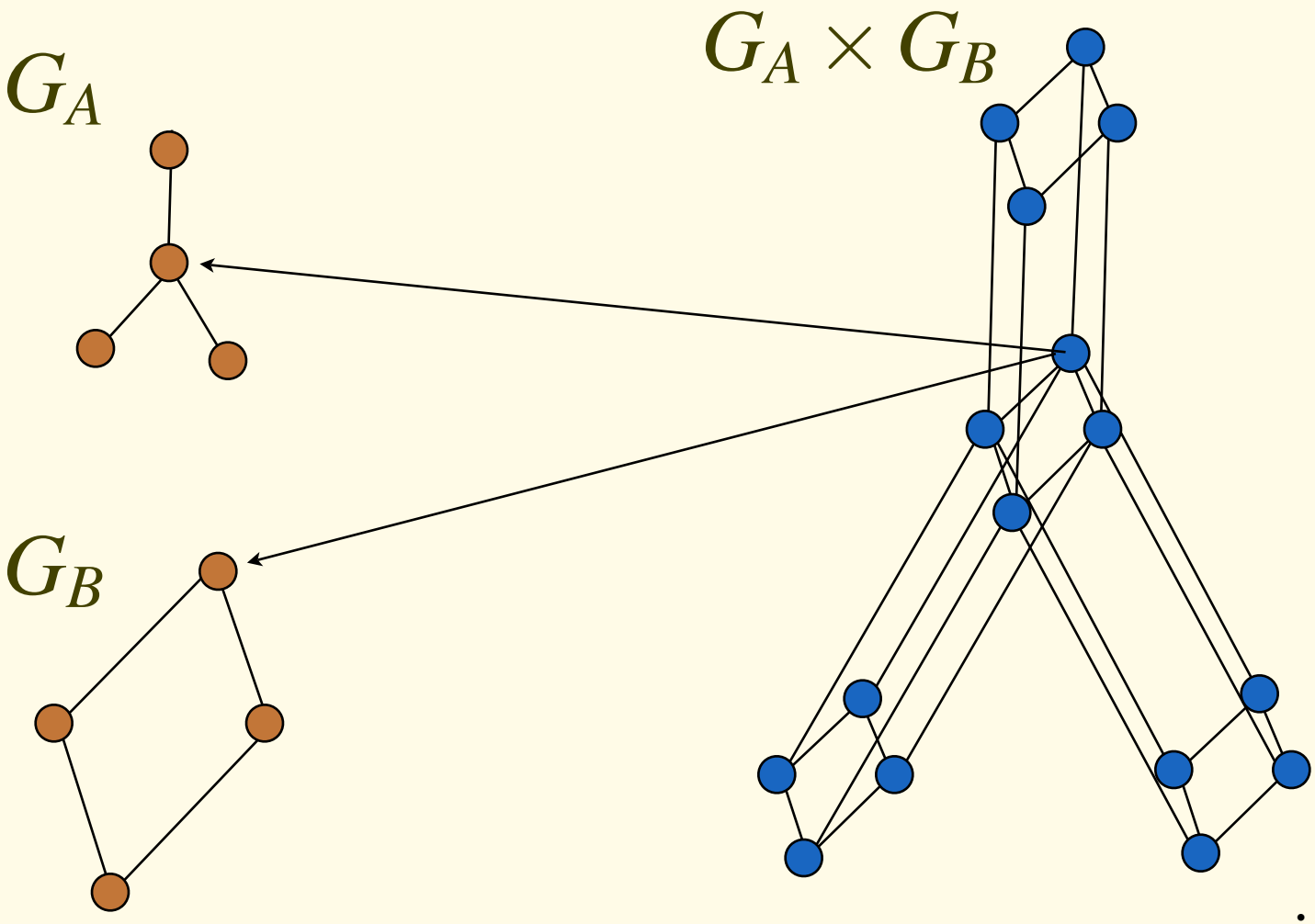

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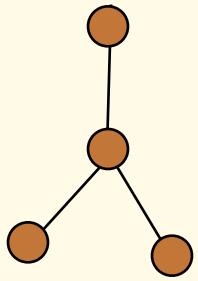
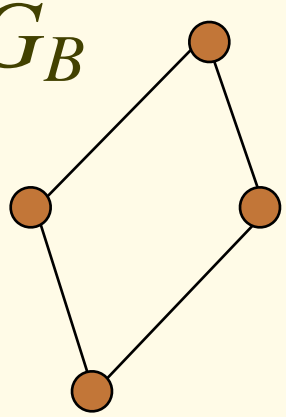


G_B



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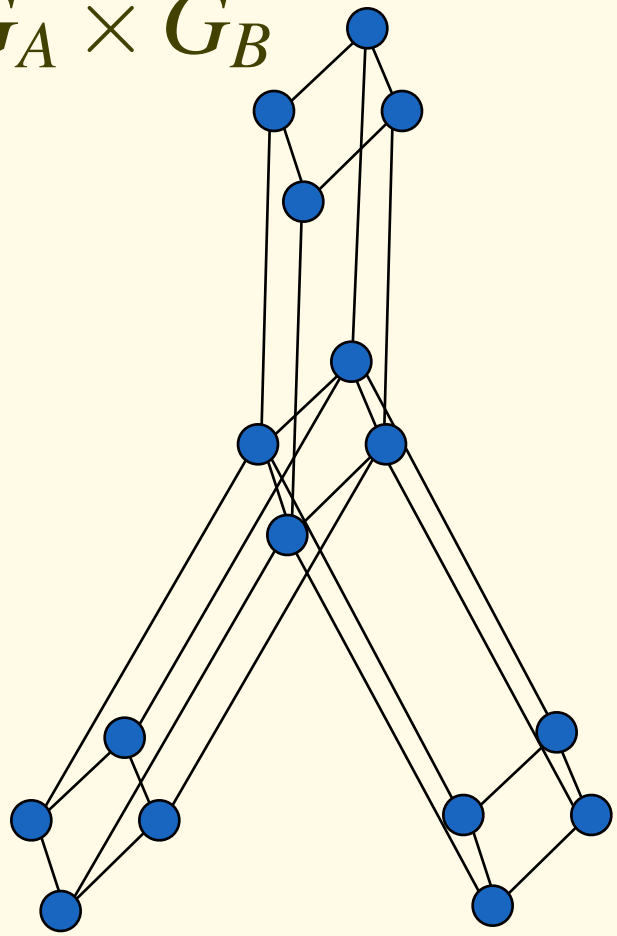

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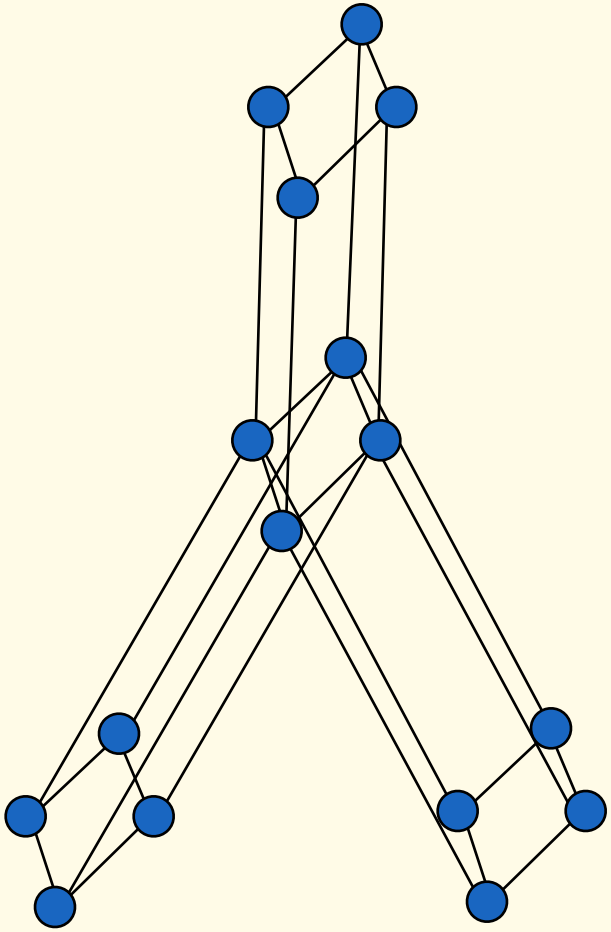
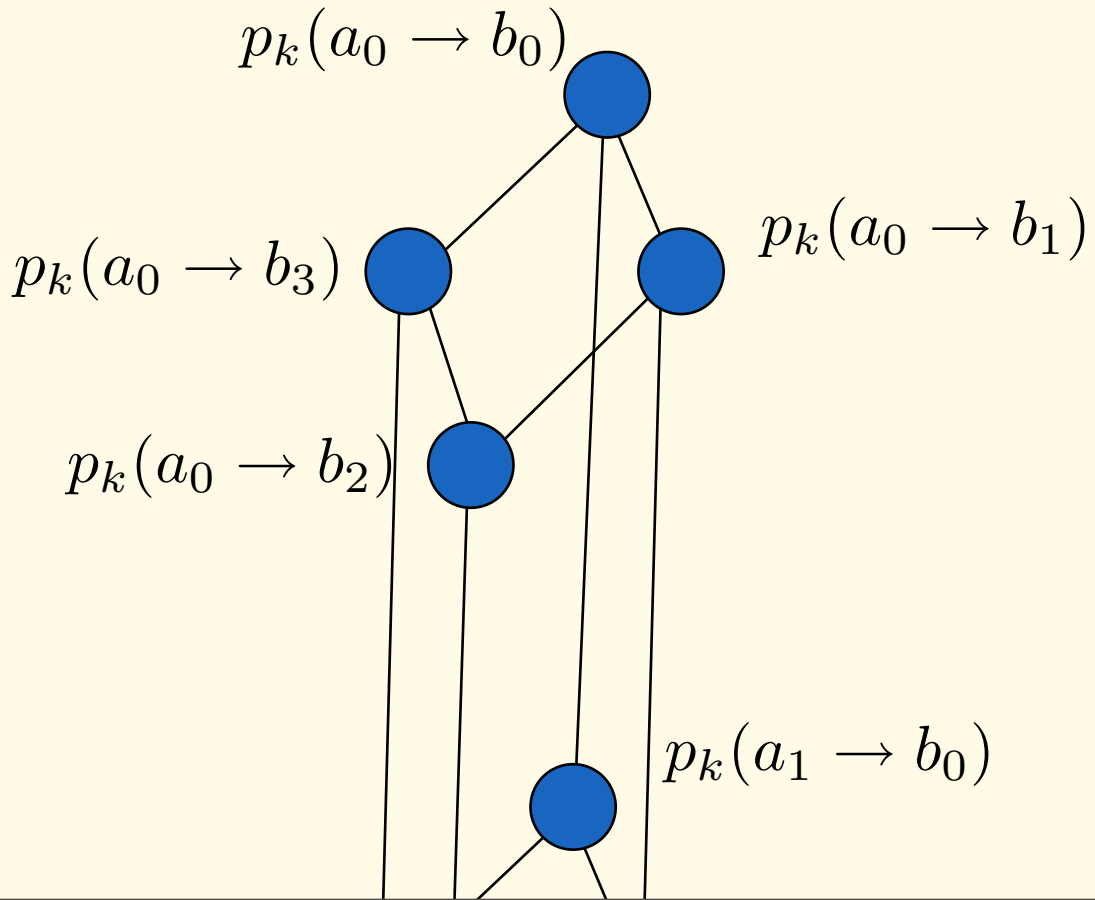


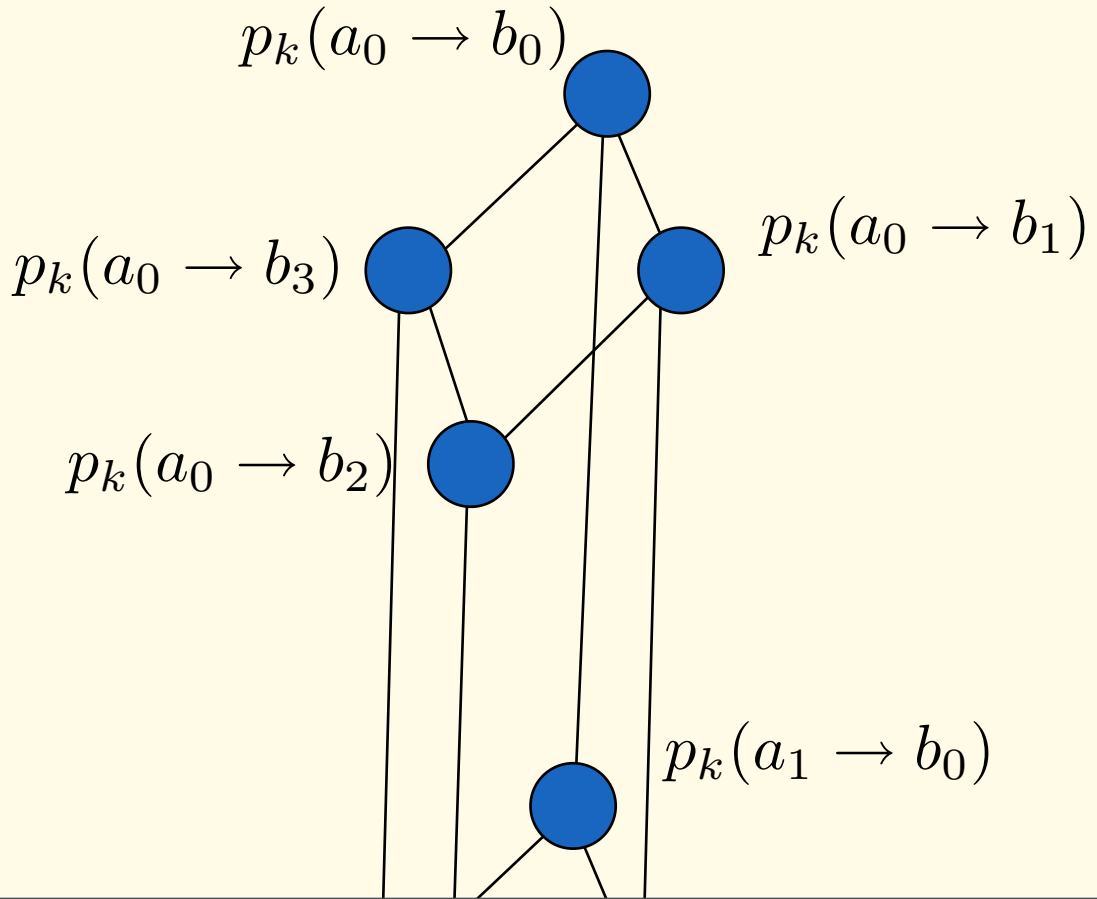
Each node is assigned some initial value. (It doesn't matter which, as long as the values sum to one!)

How does it work?



How does it work?

$$p_{k+1}(a_0 \to b_0) = (1-\alpha)c(a_0, b_0) + \alpha/3 \quad (p_k(a_0 \to b_3) + p_k(a_0 \to b_1) + p_k(a_1 \to b_0))$$



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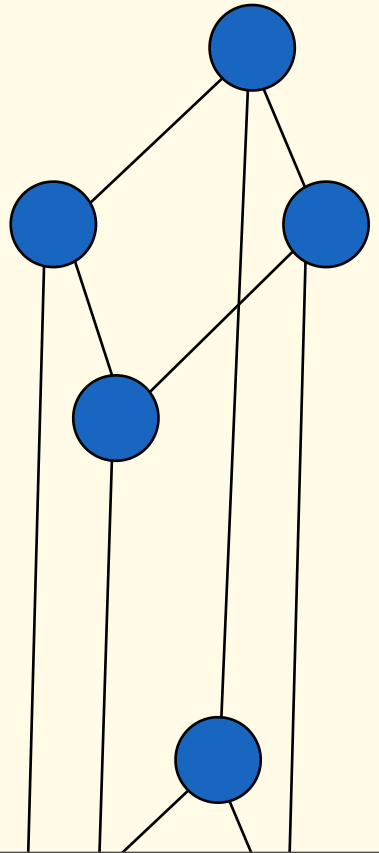

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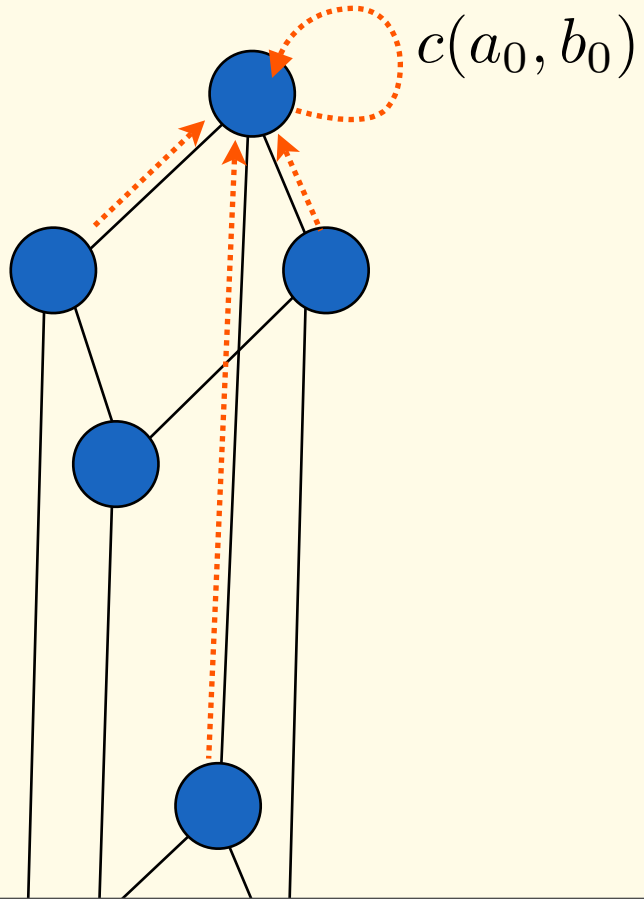

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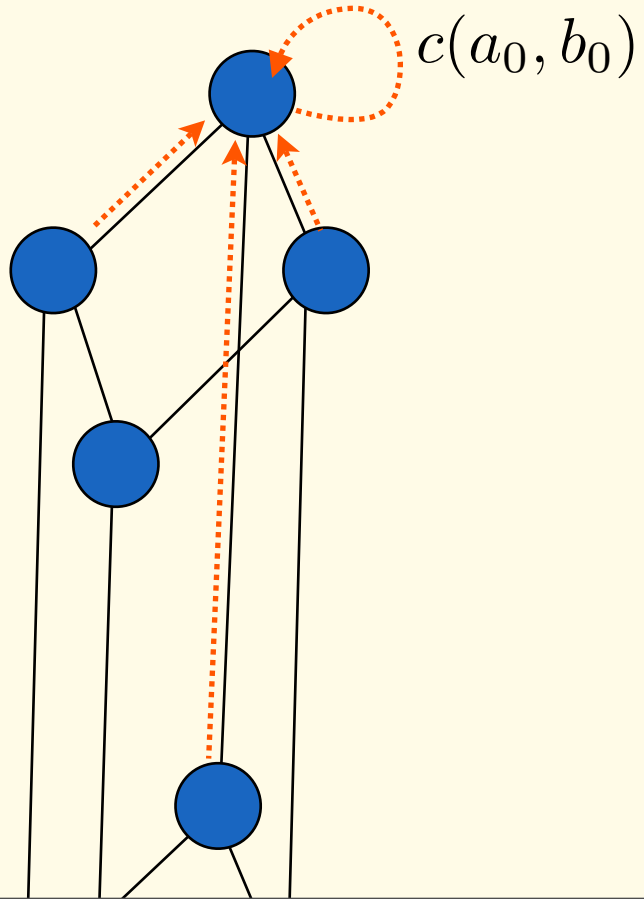


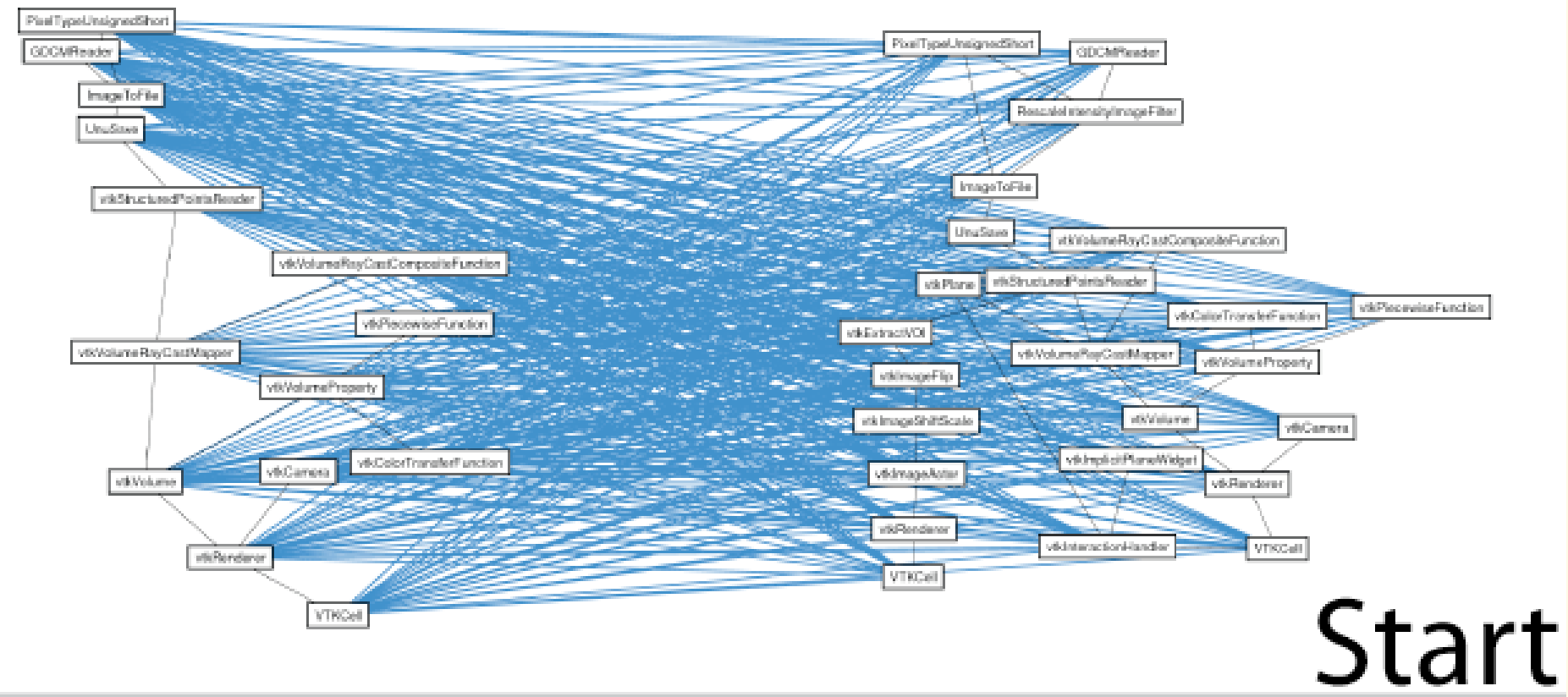
Do it for all nodes,
until convergence

How does it work?

- π is defined over graph product
- For each module in the second pipeline, pick maximal value of π on first pipeline: this is the match

- Many others possible

The matching algorithm



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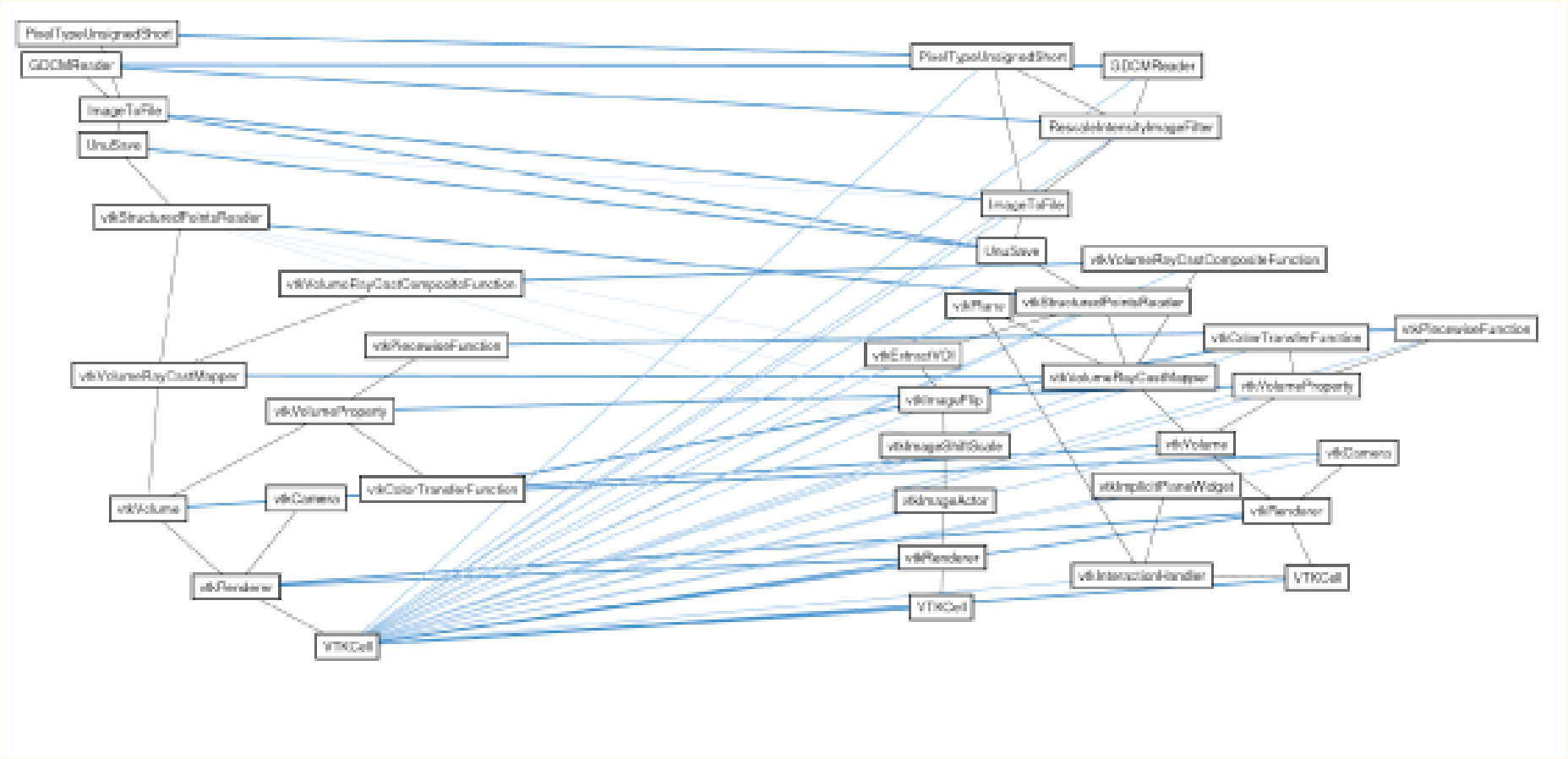

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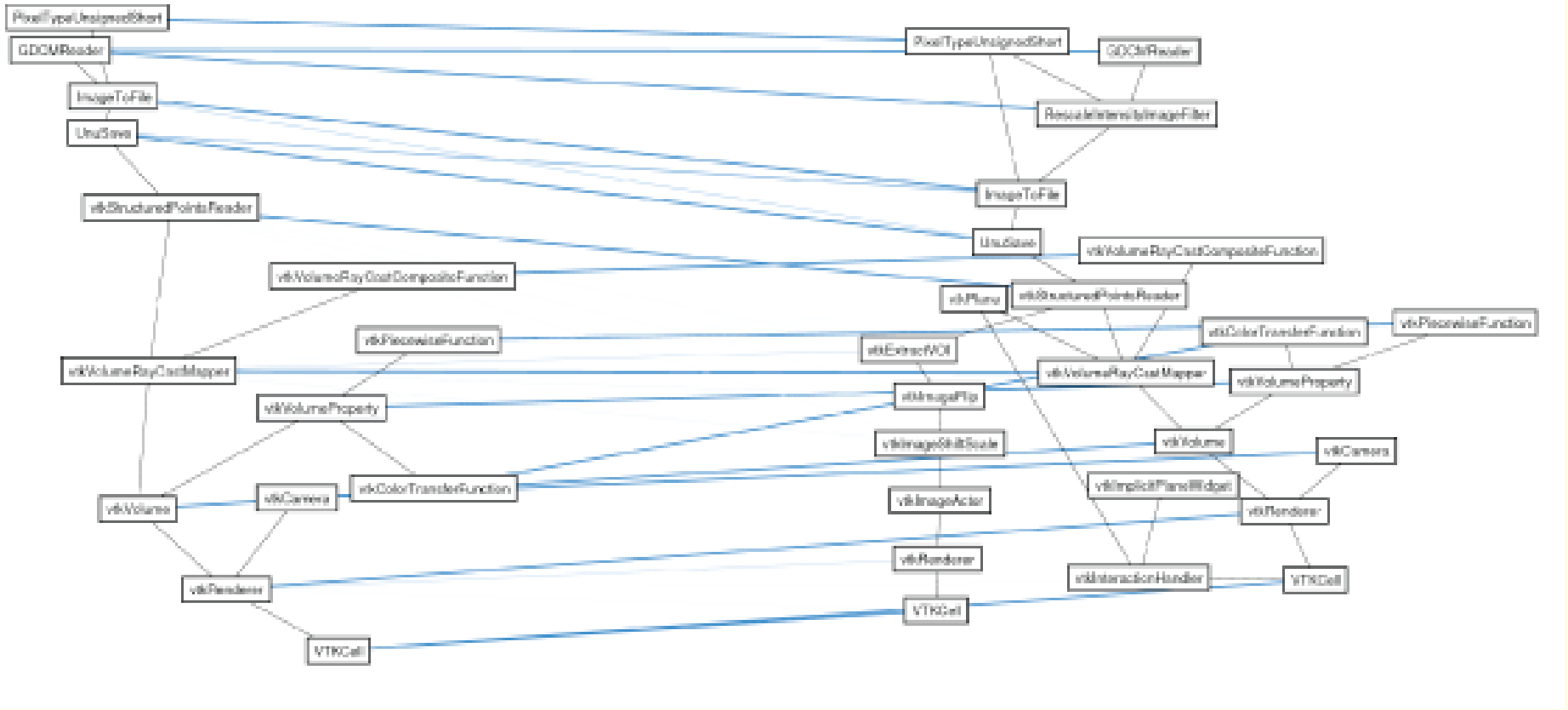

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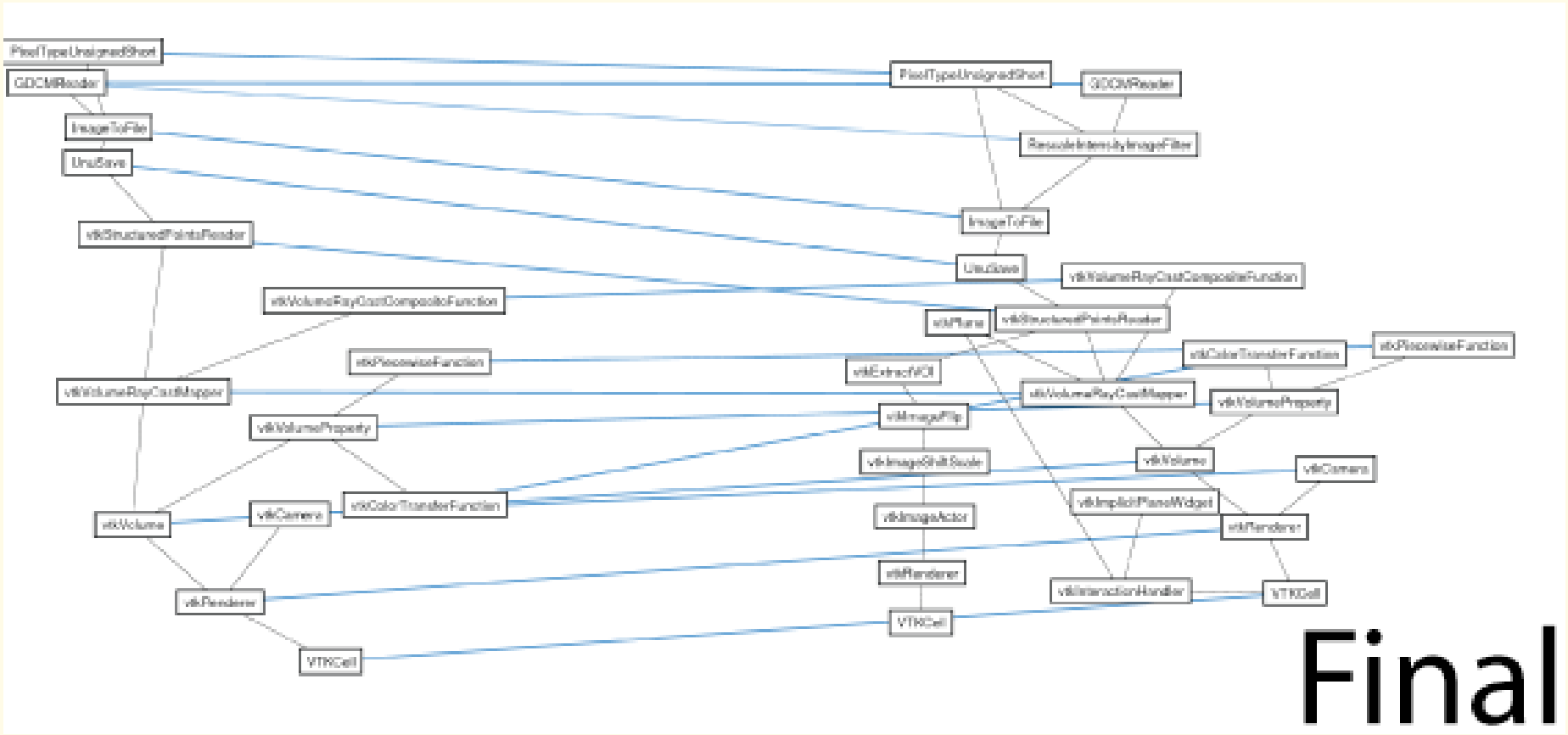
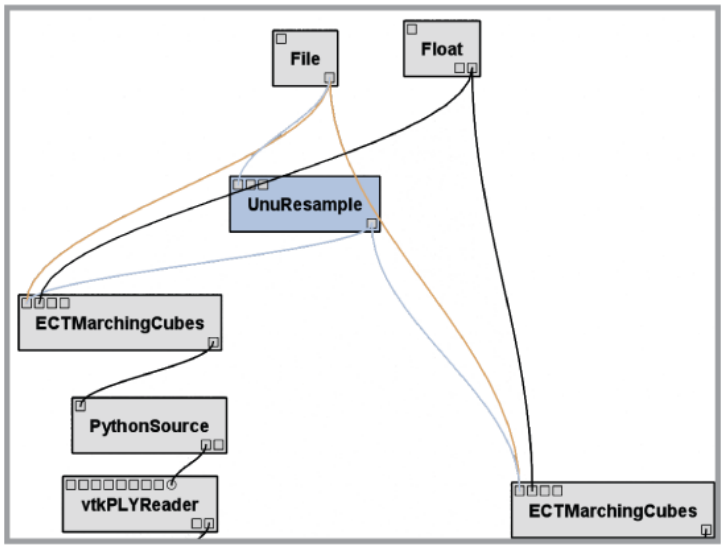
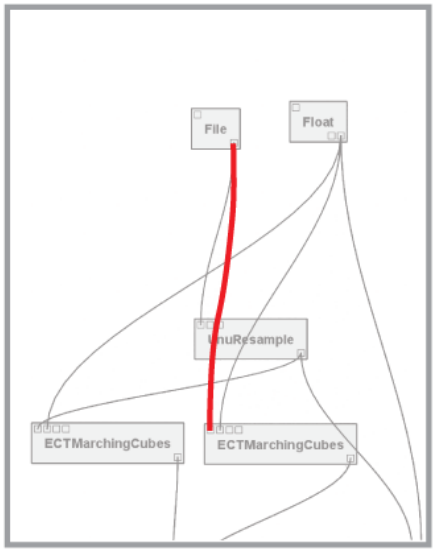
The matching algorithm



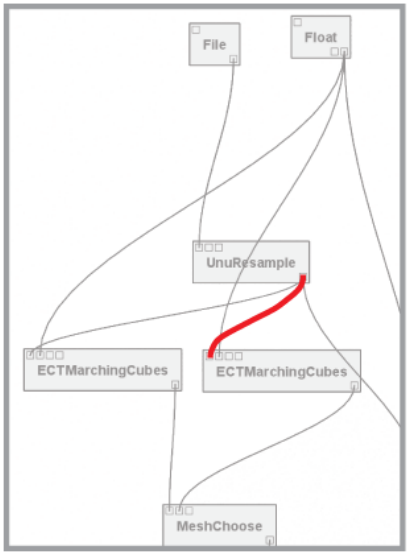
Failure Modes



Defined analogy



Produced result



Expected result

- Analogies are not fool-proof

Case study

- Creating a complex visualization out of simple ones

- (demo)

Discussion

- If your system can encode actions as functions on the space of objects of interest, store these explicitly
- That will be your "version tree" - everything else is just the same

- Easy to incorporate domain-specific knowledge in analogies: change $A(G)$ and $c(G)$

Acknowledgments

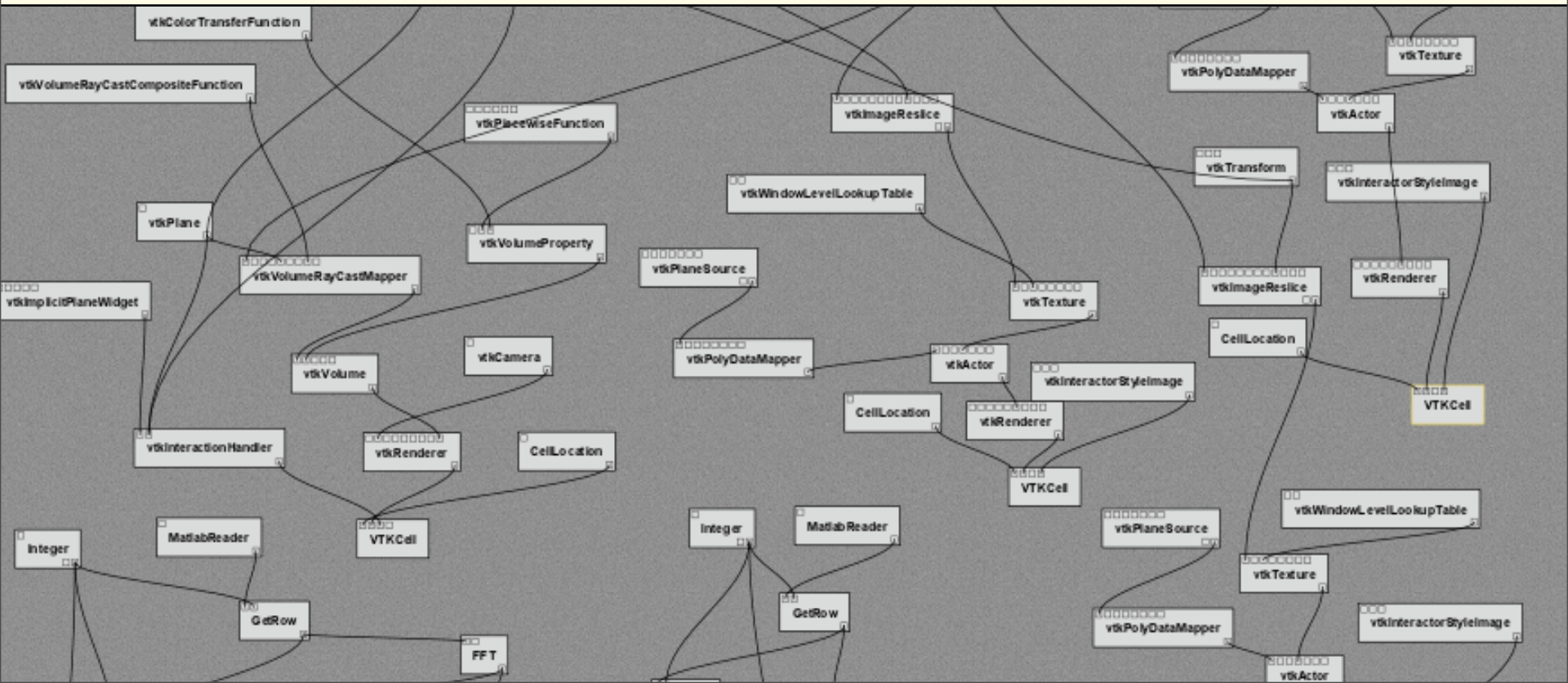
- Sarang Joshi, Suresh Venkatasubramanian, Erik Anderson, João Comba
- VisTrails dev team
- Many open source packages and devs: VTK, SciPy, teem, matplotlib
- VisTrails is open source! **http://www.vistrails.org**
  - **Shameless plug: Visit the SCI booth!**
- NSF, DOE, IBM Faculty Award

Thank you!

- Questions?

Too much data

- We are better off with visualization systems than without - but it's still pretty messy



Video

Creating and Querying Visualizations by Analogy

SCI Institute, School of Computing

UNIVERSITY OF UTAH