Provenance-aware Versioned Dataworkspaces

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Introduction

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- **Data preparation, curation, and analysis**
  - Interactive, iterative process with ample *uncertainty*
    - What datasources to use?
    - How to clean them?
    - How to integrate heterogeneous sources?
  - Requires a lot of backtracking and propagation of changes
    - e.g., find mistake in a previous curation step and correct it
- **How to support user in this process?**

Our Vision

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- **Build a model and system implementing the model that supports:**
- **1) Incremental workflow construction with immediate feedback**
  - Any change to a curation workflow is immediately reflected in the data
- **2) Regret-free exploration through sandboxing**
  - Any past choice can easily be undone/changed
  - Derived data is automatically refreshed
- **3) Full accountability through provenance tracking**
  - All data and transformations are versioned
  - Workflow provenance as well as fine-grained data provenance

Our Vision

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- **4) Automatic conflict detection and resolution**
  - Detect conflicts during automatic refresh of derived data
  - Provide a toolbox of automated resolution techniques for conflicts
- **5) Merging of transformation pipelines**
  - Update an analysis result if the input data is refreshed
- **6) Uncertainty as a first-class concept**
  - Expose and propagate uncertainty that naturally arises in data curation

Virtual **V**ersion **G**raph Model

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- Version control mechanism for **data** and **transformations**
  - Multiple parallel histories can co-exit
  - Explicit tracking of transformations
  - Automatic refresh of derived data
  - A principled and non-invasive way of changing past transformations
  - A lightweight way to represent data and versions
  - Enables data to be materialized on-demand

PVDs

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- **P**rovenance-aware **V**ersioned **D**ataworkspaces
  - A sandboxed environment for data curation and analysis backed up by the VVG model
  - Can be implemented on top of existing data processing platforms (e.g., relational DBMS)

Virtual **V**ersion **G**raph Model

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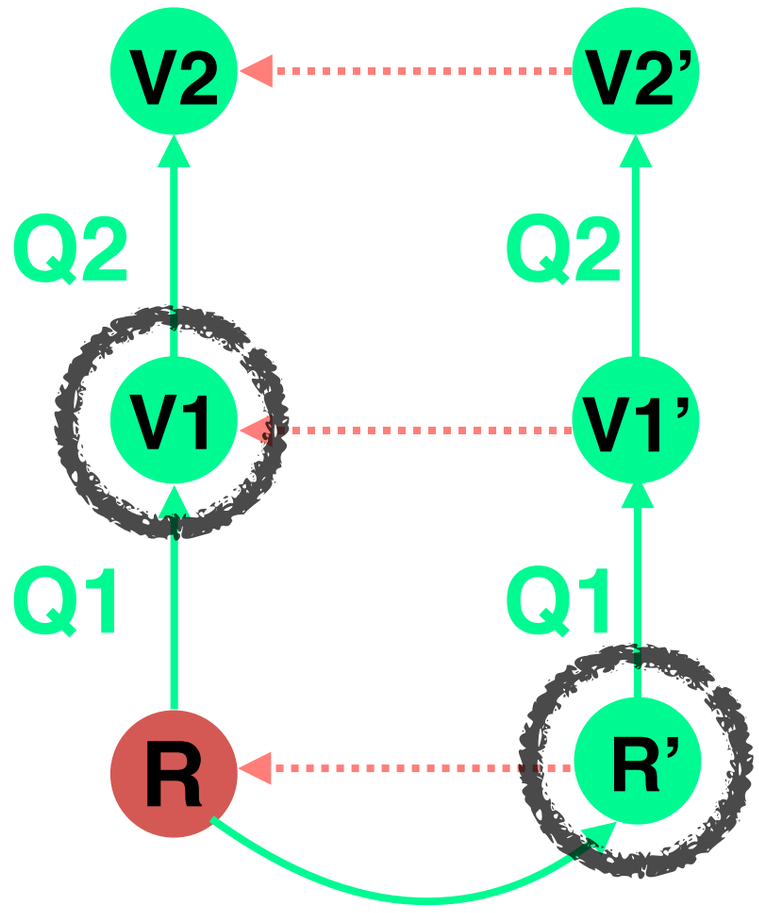
- A directed acyclic hyper-graph
  - Nodes are relation versions
  - Edges are data transformations
- Two types of edges
  - Derivation hyper-edge (**Green edge**)
  - Version edge (**Red edge**)



Running Example

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```
{"Treatment" : [
  {
 "Patient": "John",
 "Disease": "Lung Cancer",
 "Doctor": "Xing",
 "Treatment": "Chemotherapy",
 "Suc:" false,
 "Finish:" true
 },
 {
 "Patient": "Bob",
 "Disease": "Stomach Cancer",
 "Doctor": "Bahareh",
 "Treatment": "Radiation",
 "Suc:" false,
 },
 …
]}
```

Json Document J

Alex: “I want to build a workflow to determine the success rate of different treatments for lung cancer .”

Jason Document J
->
- add node **J**

J

Running Example

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Alex: “Extract data into table T.”

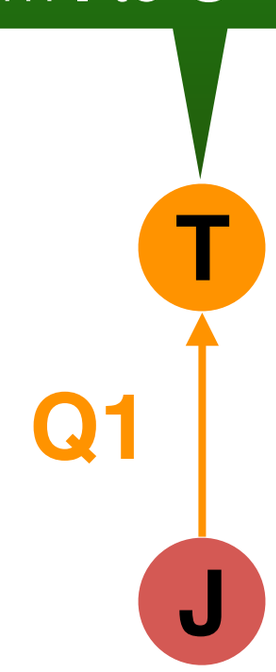
Treatment	Disease	Success
Chemotherapy	Lung Cancer	TRUE
Chemotherapy	Stomach Cancer	TRUE
Surgery	Lung Cancer	FALSE
Radiation	Lung Cancer	FALSE

Relation **T**

For every transformation **Q** with
input **I**
output **O**

->

- add node **O**
- add derivation edge labelled **Q** from **I** to **O**



Running Example

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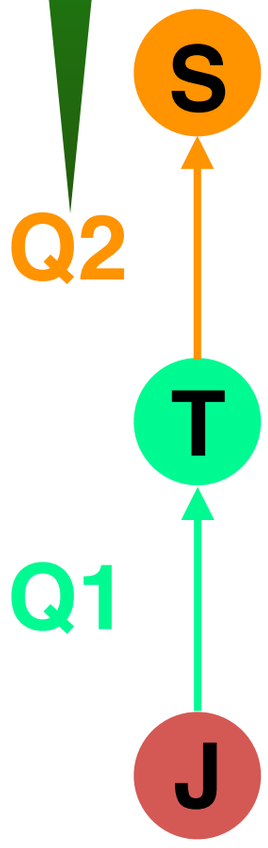
Alex: “Calculate the success rate of different treatment methods for Lung Cancer.”

```
SELECT SUM (CASE WHEN Success = TRUE
            THEN 1 ELSE 0 END / count(*))
AS SuccessRate
FROM T
WHERE Disease = “Lung Cancer”
GROUP BY Treatment
```

Query **Q2**

Queries are transfromations that create new relations



Running Example

Alex: “Calculate the success rate of Lung Cancer.”

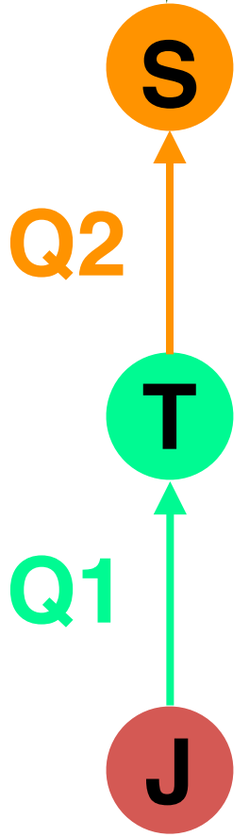
For transformation **Q2** with
input **T**
output **S**

->

- add node **S**
- add derivation edge labelled **Q2** from **T** to **S**

SuccessRate
1/3

Result Relation **S**



Running Example

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Alex: "*&@#!, I made a mistake when extracting data from the JSON doc. I retrieved the values of attribute **Success** from the field **Finish** in the JSON document."

```
{"Treatment" : [
  {
 "Patient": "John",
 "Disease": "Lung Cancer",
 "Doctor": "Xing",
 "Treatment": "Chemotherapy",
 "Suc:" false,
 "Finish:" true
 },
 {
 "Patient": "Bob",
 "Disease": "Stomach Cancer",
 "Doctor": "Bahareh",
 "Treatment": "Radiation",
 "Suc:" false,
 },
 …
]}
```

Json Document J

Treatment	Disease	Success
Chemotherapy	Lung Cancer	TRUE
Chemotherapy	Stomach Cancer	TRUE
Surgery	Lung Cancer	FALSE
Radiation	Lung Cancer	FALSE

Running Exam

When modify existing transformation **Q** to **Q'** with input **I** and output **O'** (the new version of **O**)

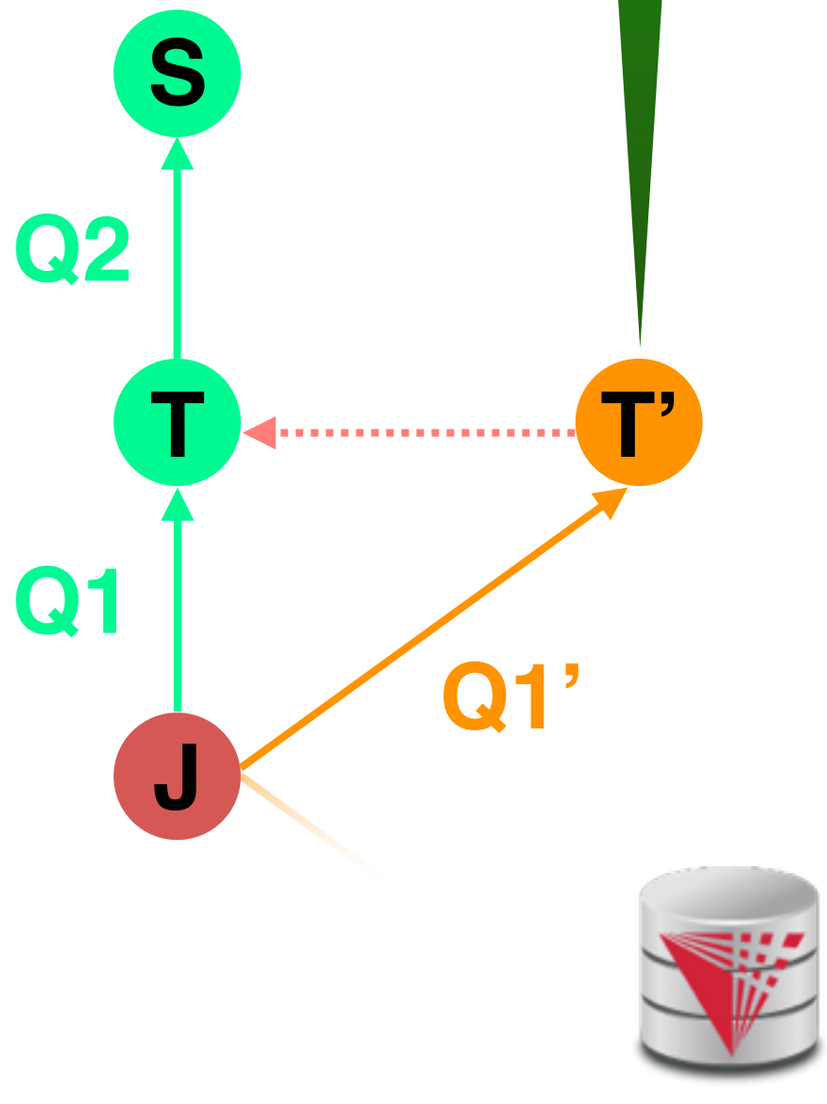
->

- add node **O'**
- add derivation edge labelled **Q'** from **I** to **O'**
- add version edge (dash line) from **O'** to **O**

Alex: "I correct the qu
Q1 to **Q1'**."

Treatment	Disease	Success
Chemotherapy	Lung Cancer	FALSE
Chemotherapy	Stomach Cancer	TRUE
Surgery	Lung Cancer	TRUE
Radiation	Lung Cancer	TRUE

Relation **T'**



Run

Automatic refresh of derived relations

Create new versions of relations (**S**) derived from modified relation (**T**).

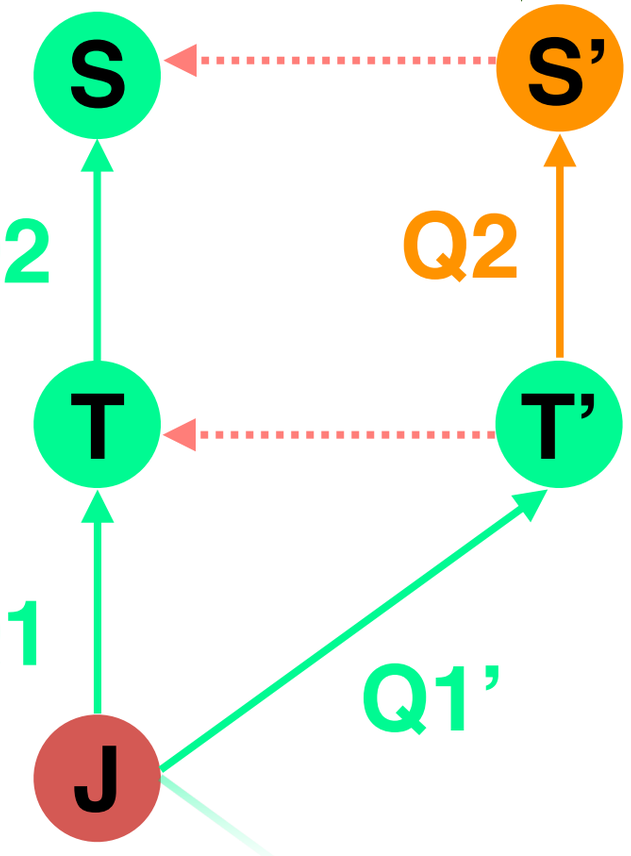
- In this case, create new version (**S'**)

->

- add node **S'**
- add derivation edge labelled **Q** from **T'** to **S'**
- add version edge (dash line) from **S'** to **S**

A

relations can be **automatic refreshed**."



SuccessRate
2/3

Result Relation **S'**

Running Example

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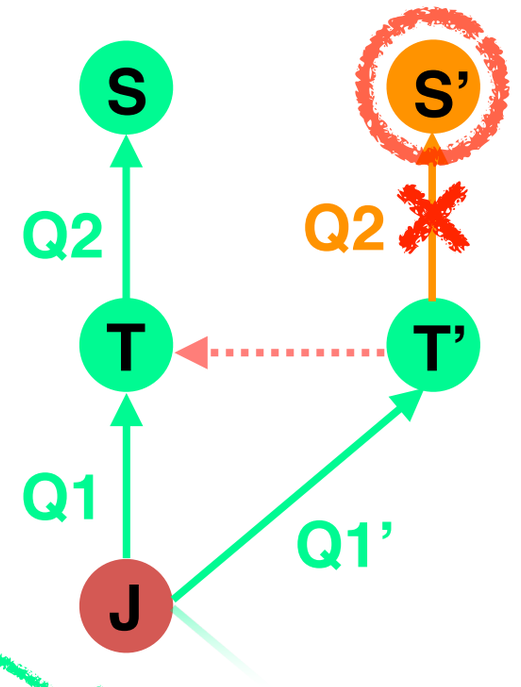
- **Conflict**
  - Retrieve values of attribute **Success <— Patient**
  - Success : **“TRUE“** or **“FALSE”**
  - Patient : Just **strings**
  - Running **Q2 —> Conflicts**




```
{"Treatment" : [
  {
  "Patient": "John",
  "Disease": "Lung Cancer",
  "Doctor": "Xing",
  "Treatment":
"Chemotherapy",
  "Suc:" false,
  "Finish:" true
  },
  ……
]}
```

“true” or “false”

Treatment	Disease	Success
Chemotherapy	Lung Cancer	John
Chemotherapy	Stomach Cancer	Bob
Surgery	Lung Cancer	Kile
Radiation	Lung Cancer	Bill

Strings

Runn

GY

Detecting and Dealing with conflicts

Automatic refresh => ill-defined relation versions

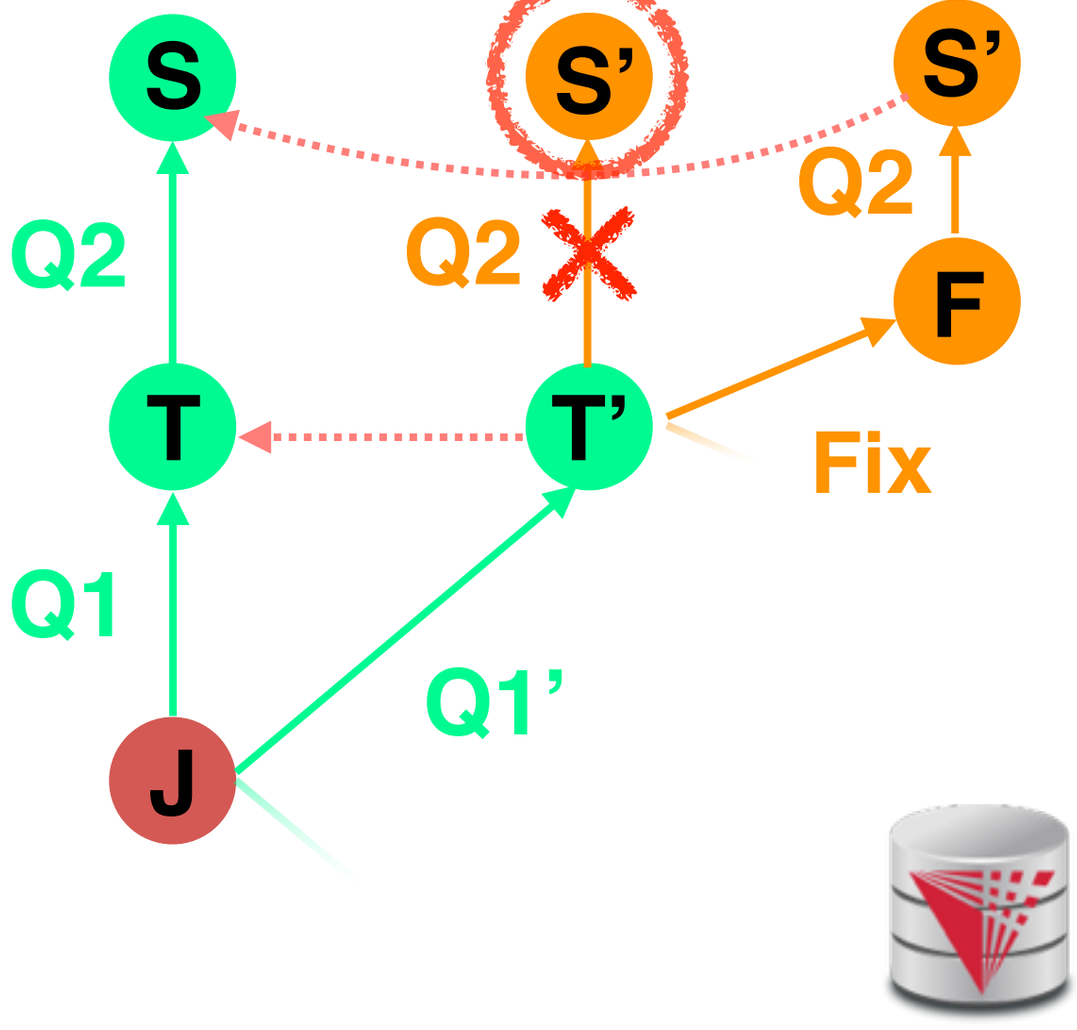
- Mark this relation as invalid
- Make semi-automatic and automatic conflict detection
- Provide available resolution strategies

Alex
doing **automatic refresh**."

In this case, fix the relation **T'** firstly, then do automatic refresh (**Q2**) based on the fixed relation **F.**

->

- add node **F** (fixed relation)
- add node **S'**
- add derivation edge labelled **Fix** from **T** to **F**
- add derivation edge labelled **Q2** from **F** to **S'**
- add version edge (dash line) from **S'** to **S**



Related Work

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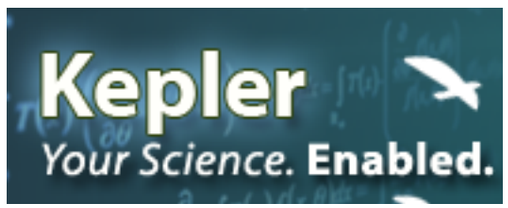
Version Control Systems

Scientific workflow management systems

Workflow and Database Provenance



PVD

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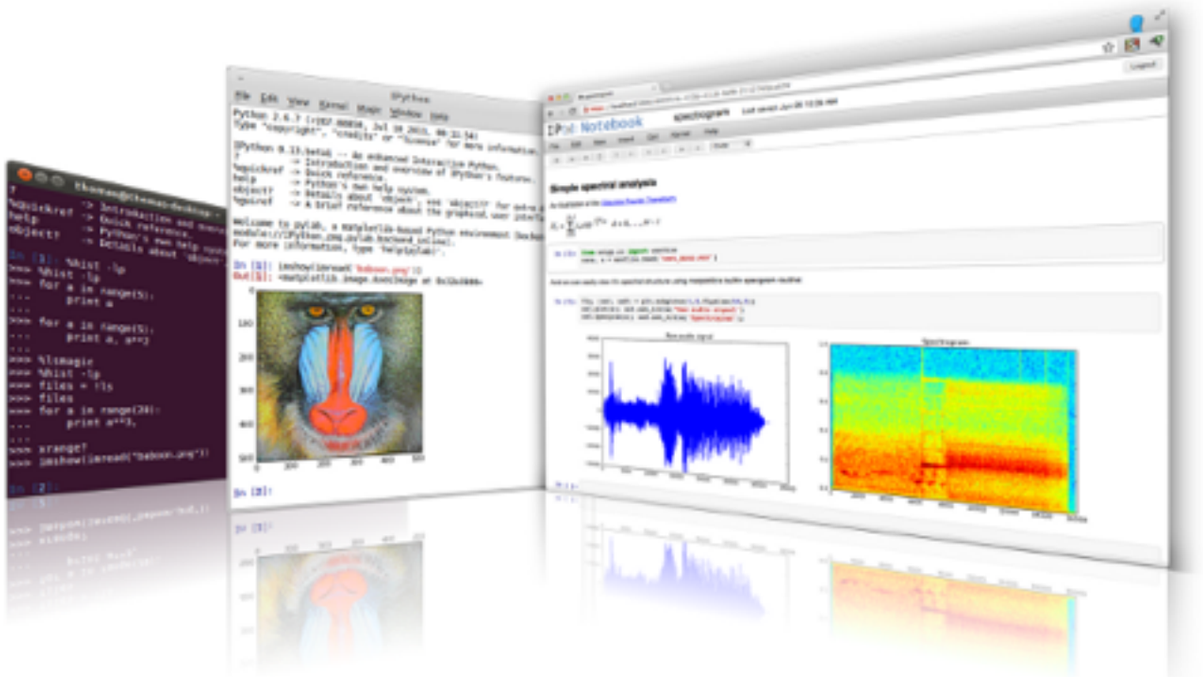
- An interface similar to **iPython**
- System maintains a VVG for the users actions
- Relation versions can be stored in, e.g., a DBMS
- Visualizations are represented as special VVG nodes



In [9]: display(i)

IP[y]: IPython
Interactive Computing

In [3]:
```
from IPython.display import SVG
SVG(filename='python-logo.svg')
```

Out[3]:

python™

PVD building blocks

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- **Data curation with lenses** [1]
  - Powerful uncertainty aware data curation operations
  - Uses probabilistic database techniques to keep track of uncertainty
- **Provenance tracking and reenactment for updates** [2]
  - Declarative replay technique
  - Retroactively compute provenance for updates
  - Translates an update into an equivalent query

1. Y. Yang, N. Meneghetti, R. Fehling, Z. H. Liu, and O. Kennedy. Lenses: an on-demand approach to ETL. PVLDB. 8(12):1578-1589,2015.
2. B. Arab, D. Gawlick, V. Radhakrishnan, H. Guo, and B. Glavic. A generic provenance middleware for database queries, updates, and transactions. In *TaPP*, 2014.

Implementation Challenges

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- Strategies for materializing
  - ☆ Which relation versions, when and how
- Methods for compressing VVGs
- Incremental view maintenance techniques
- Conflicts and merging VVGs

Conclusion

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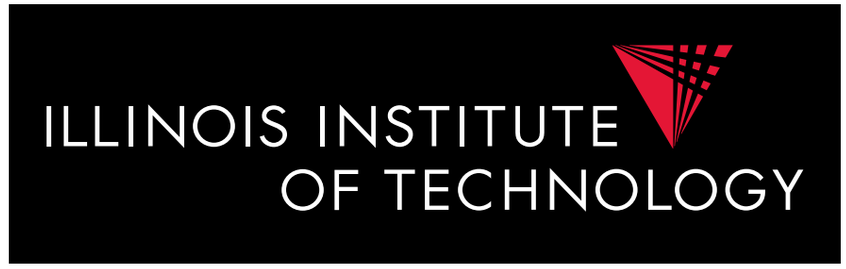
- A novel version model (**VVG**) and system vision (**PVDs**)
  - Keep all track of users' operations and data provenance
  - Supports exploratory application of data curation and analysis operators
- **Features**
  - Simple and clean model
  - Automatic refresh
  - Past transformations can be modified
  - Automatic conflict detection (and resolution)

Questions?



- **My Webpage**
  - http://www.cs.iit.edu/~dbgroup/people/xniu.php
- **Our Group's Webpage**
  - http://cs.iit.edu/~dbgroup/research/index.html
- **GProM**
  - http://www.cs.iit.edu/~dbgroup/research/gprom.php
- **Mimir**
  - http://odin.cse.buffalo.edu/research/mimir/
- **Vizier (The ODIn Lab)**
  - http://www.vizierdb.info