Provenance

Instituto de Computação
uff

Vanessa Braganholo

Agenda

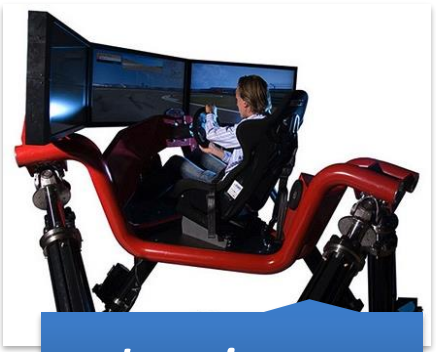
- What is Provenance?
- Types of Provenance
- Provenance Capture
- Provenance Representation
- Provenance Data x Data Provenance

QUICK REVIEW...

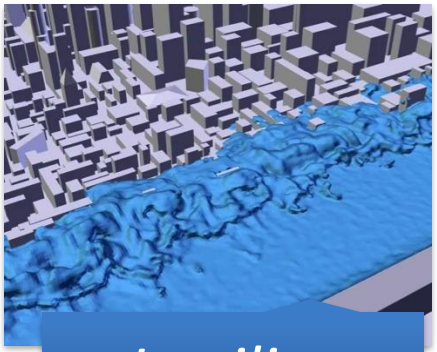
From in-vivo to *in-silico*

In-vivo

In-vitro



In-virtuo



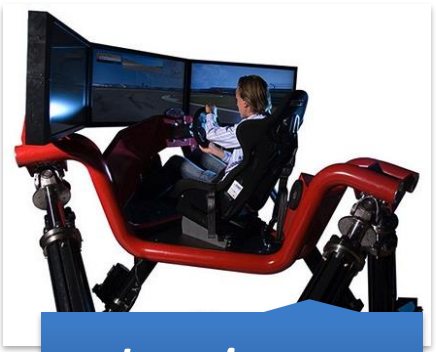
In-silico

Travassos and Barros "Contributions of in virtuo and in silico experiments for the future of empirical studies in software engineering." WSESE 2003

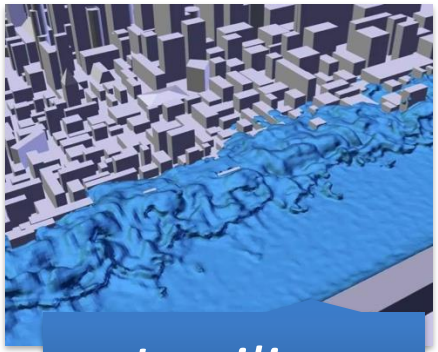
Dealing with produced data

In-vivo

In-vitro



In-virtuo



In-silico

Data volume

Travassos and Barros "Contributions of in virtuo and in silico experiments for the future of empirical studies in software engineering." WSESE 2003

How to reason from the data?

Why the same program generates different results?

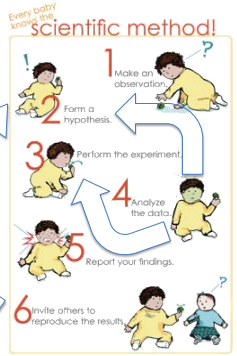
Which parameter values affected the results?

Which input files were relevant to the results?

Param.

Trials

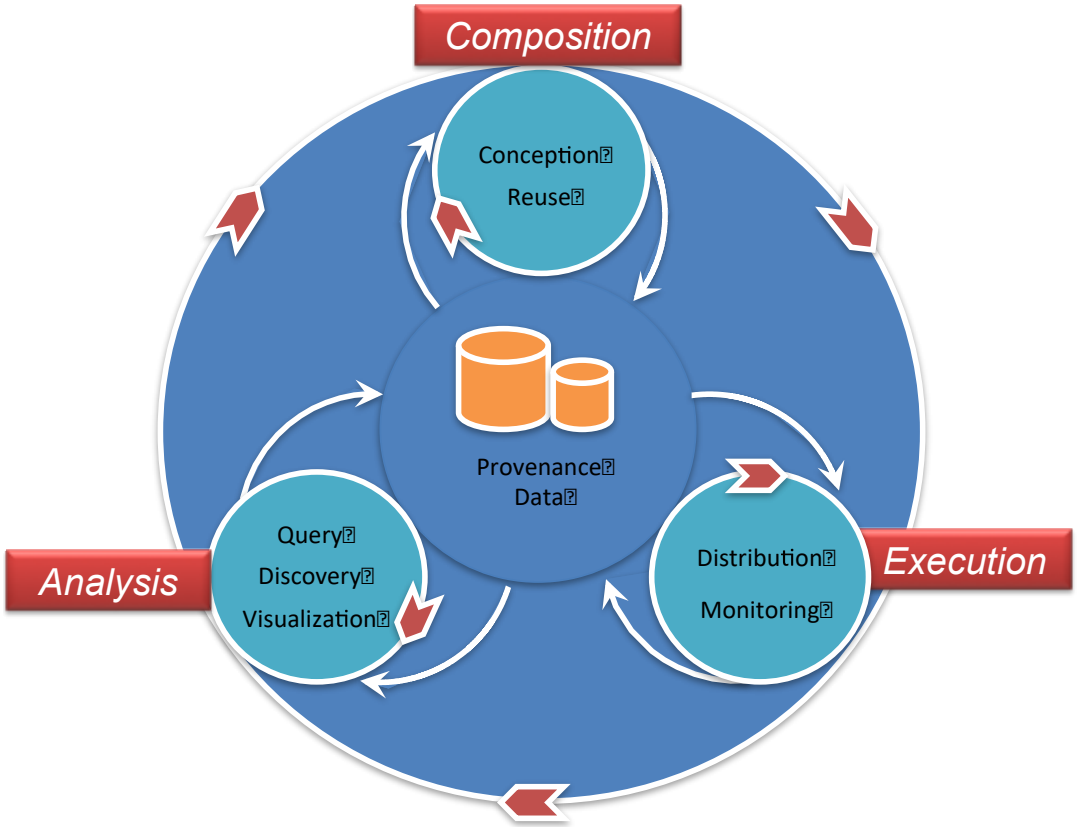
Inputs



Programs

Results

Provenance is the key!



Mattoso et al. "Towards supporting the life cycle of large scale scientific experiments." IJBPIM 5(1) 2010

The Word Provenance

The word Provenance comes from the French Word

Provenir (to come from)

Provenance in the Dictionaries

"**Origin**; source."

Merriam-Webster Online Dictionary

"The place of origin or earliest known **history** of something; origin; **derivation**; A record of **ownership** of a work of art or an antique, used as a guide to authenticity or quality"

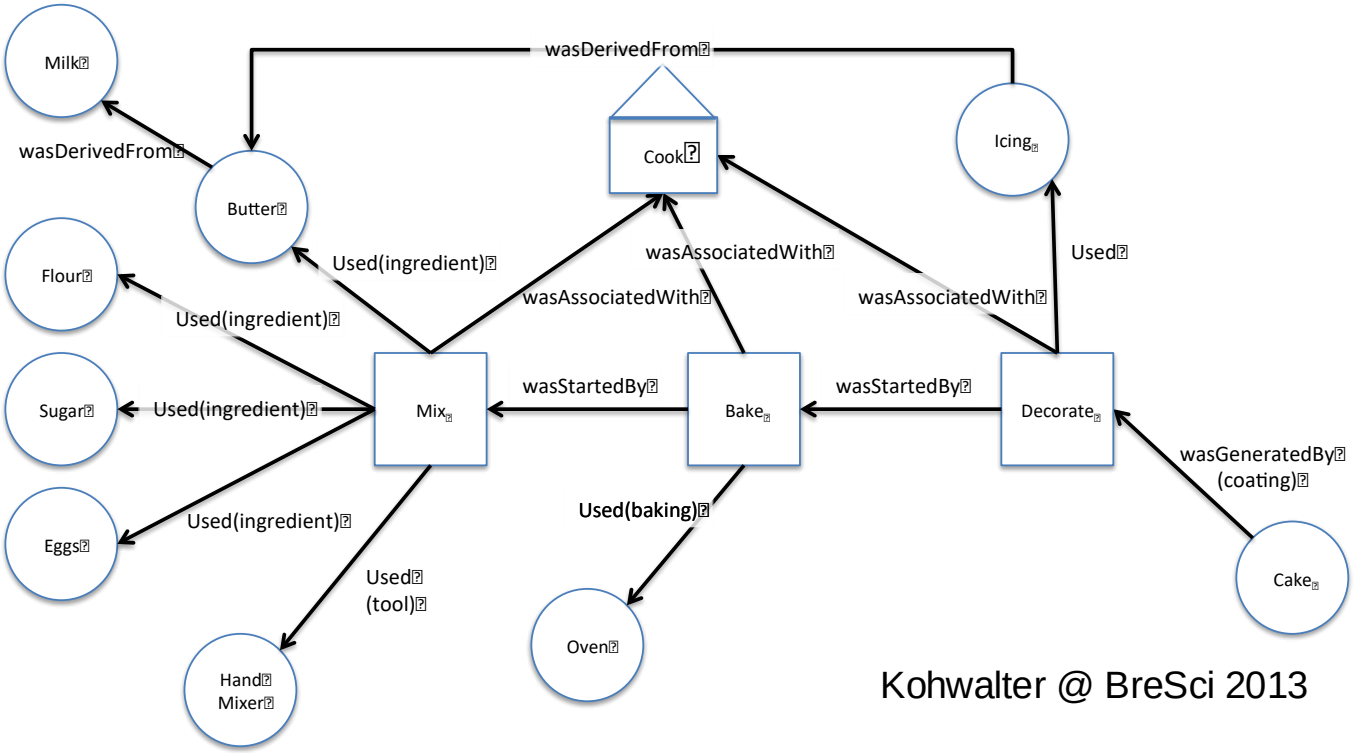
Oxford Dictionary

Diana and Actaeon by Titian has a full provenance covering its passage through several owners and four countries since it was painted for Philip II of Spain in the 1550s.

La Bella Principessa, a recent rediscovery said to be by Leonardo da Vinci, whose provenance is still the subject of research and controversy.

Source: https://en.wikipedia.org/wiki/Provenance

Example of Provenance



"Life can only be understood backwards; but it must be lived forwards."

Søren Kierkegaard, 1843.

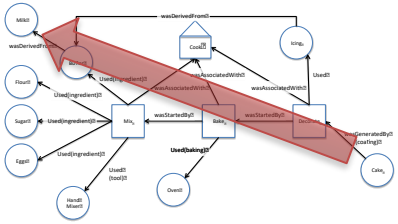
Provenance in E-Science

"The provenance (also referred to as the audit trail, lineage, and pedigree) of a data product contains **information about the process and data** used to derive the data product. It provides important documentation that is key to **preserving** the data, to **determining the data's quality** and **authorship**, and to **reproduce** as well as **validate** the results. These are all important requirements of the **scientific process**."

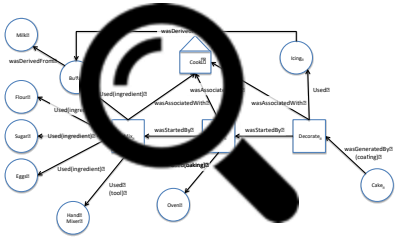
Davidson and Freire, SIGMOD 2008

(Tutorial)

Provenance is useful for…

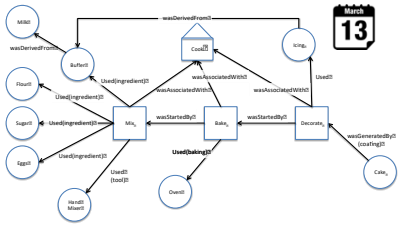


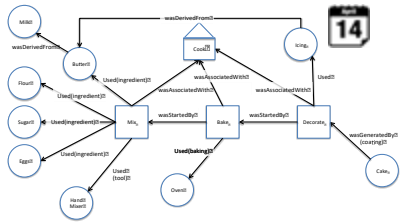
Interpreting and understanding results

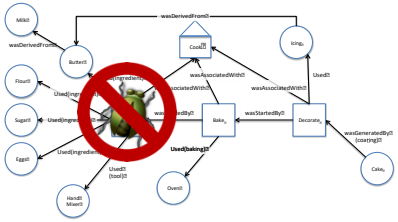


Auditing

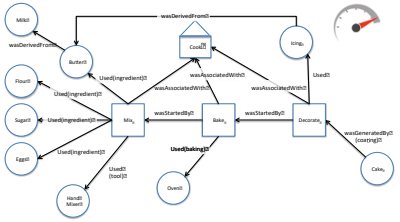
Reproducibility







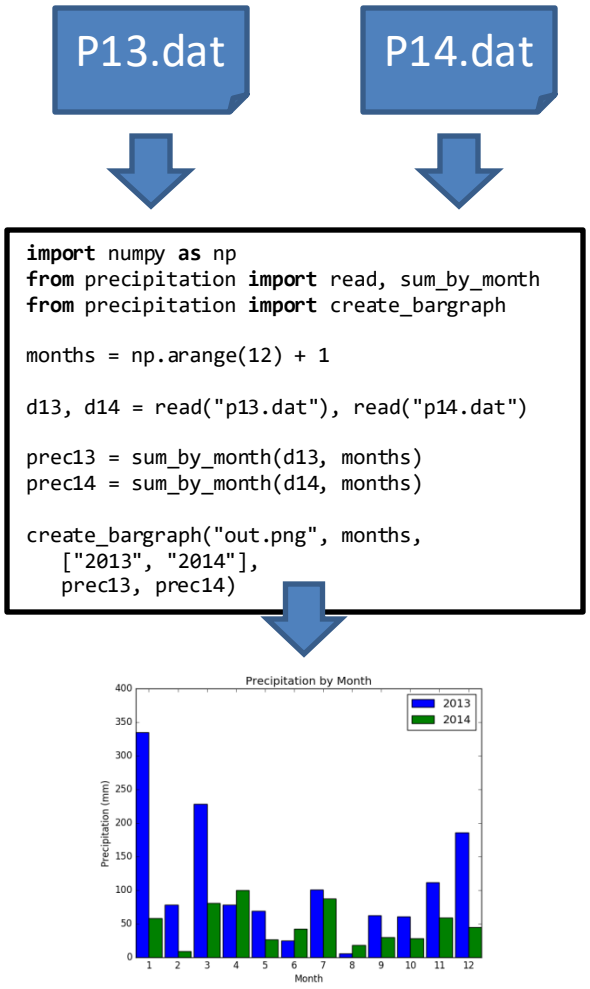
Debugging

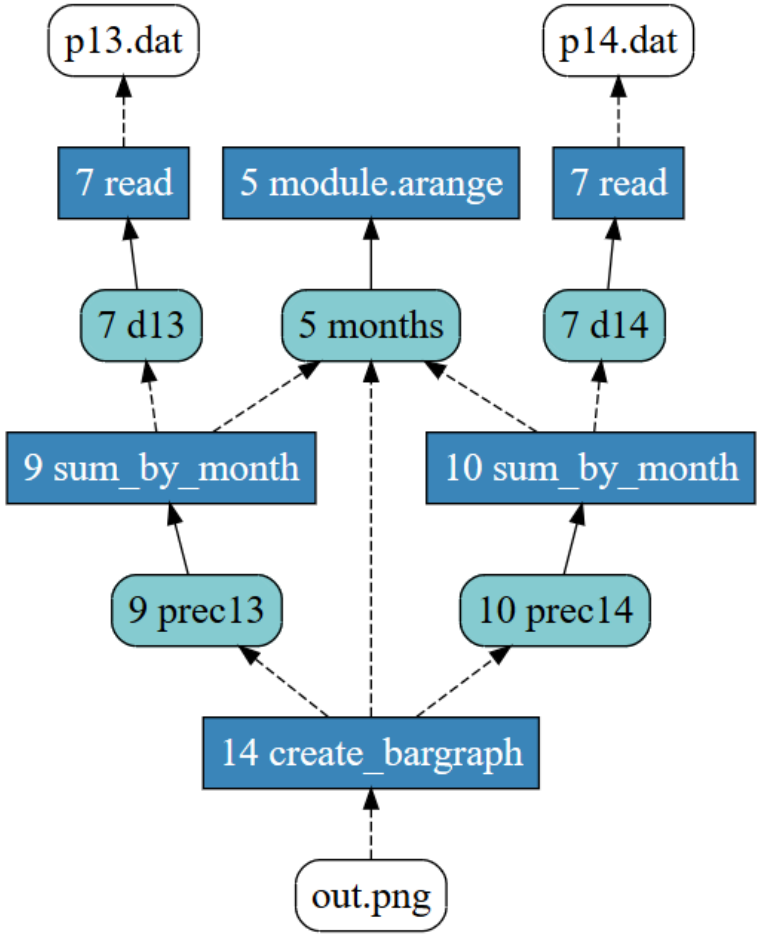


Caching

Among other applications (attribution, reuse, trustworthiness, sharing, …)

Example

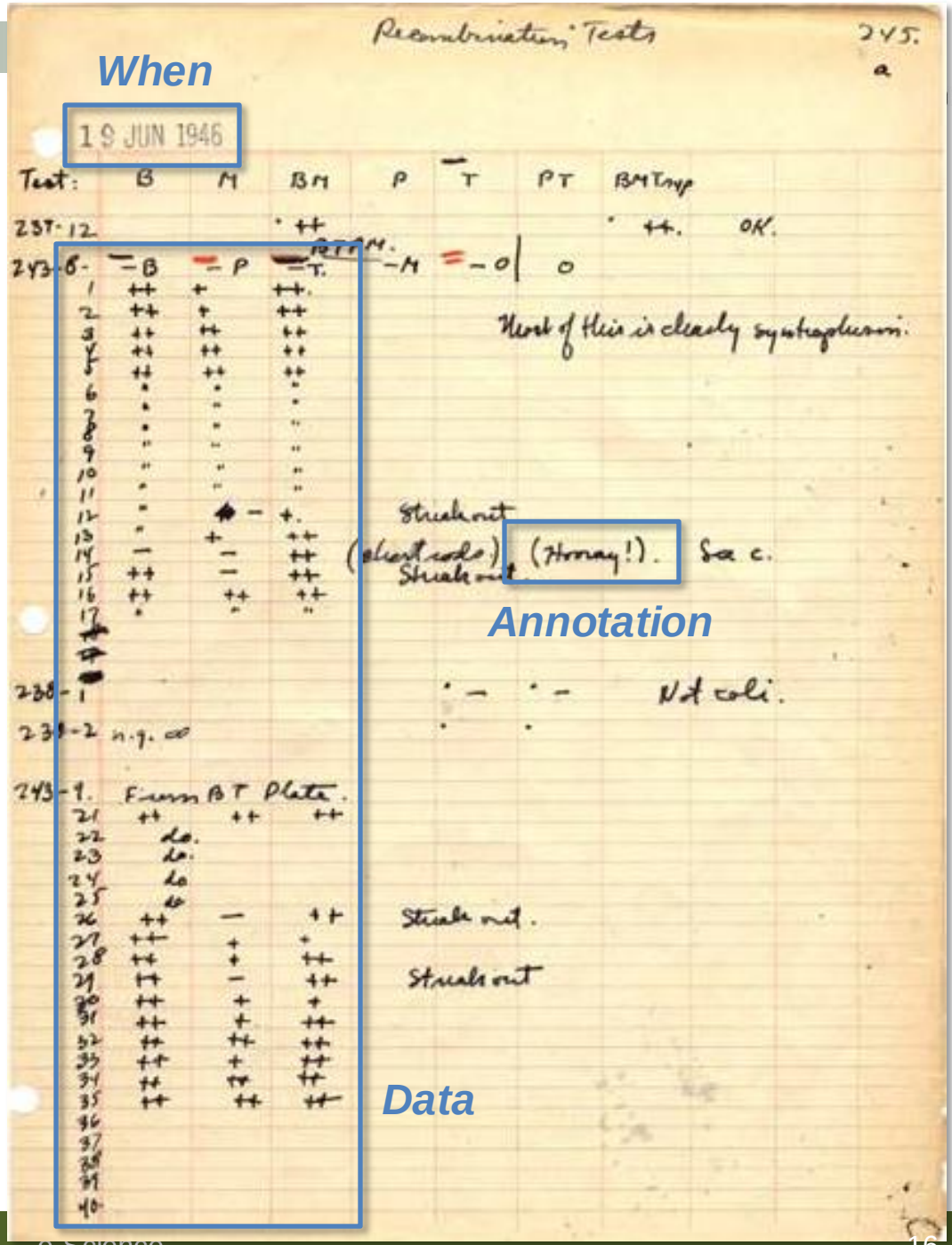

P13.dat
P14.dat
import numpy as np
from precipitation import read, sum_by_month
from precipitation import create_bargraph
months = np.arange(12) + 1
d13, d14 = read("p13.dat"), read("p14.dat")
prec13 = sum_by_month(d13, months)
prec14 = sum_by_month(d14, months)
create_bargraph("out.png", months,
["2013", "2014"],
prec13, prec14)
Precipitation by Month
2013
2014
Precipitation (mm)
Month

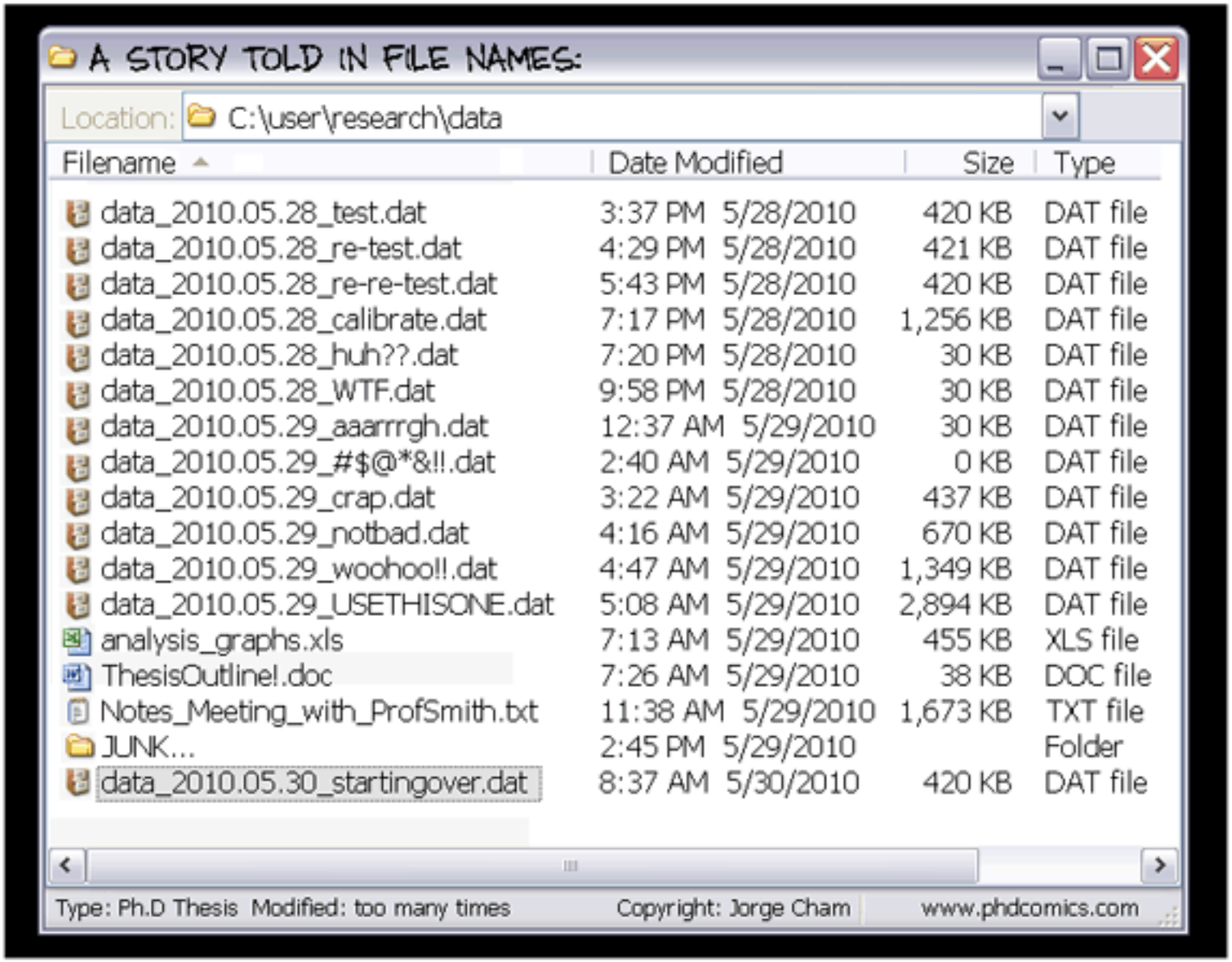

p13.dat
p14.dat
7 read
5 module.arange
7 read
7 d13
5 months
7 d14
9 sum_by_month
10 sum_by_month
9 prec13
10 prec14
14 create_bargraph
out.png

Provenance in Science is not new

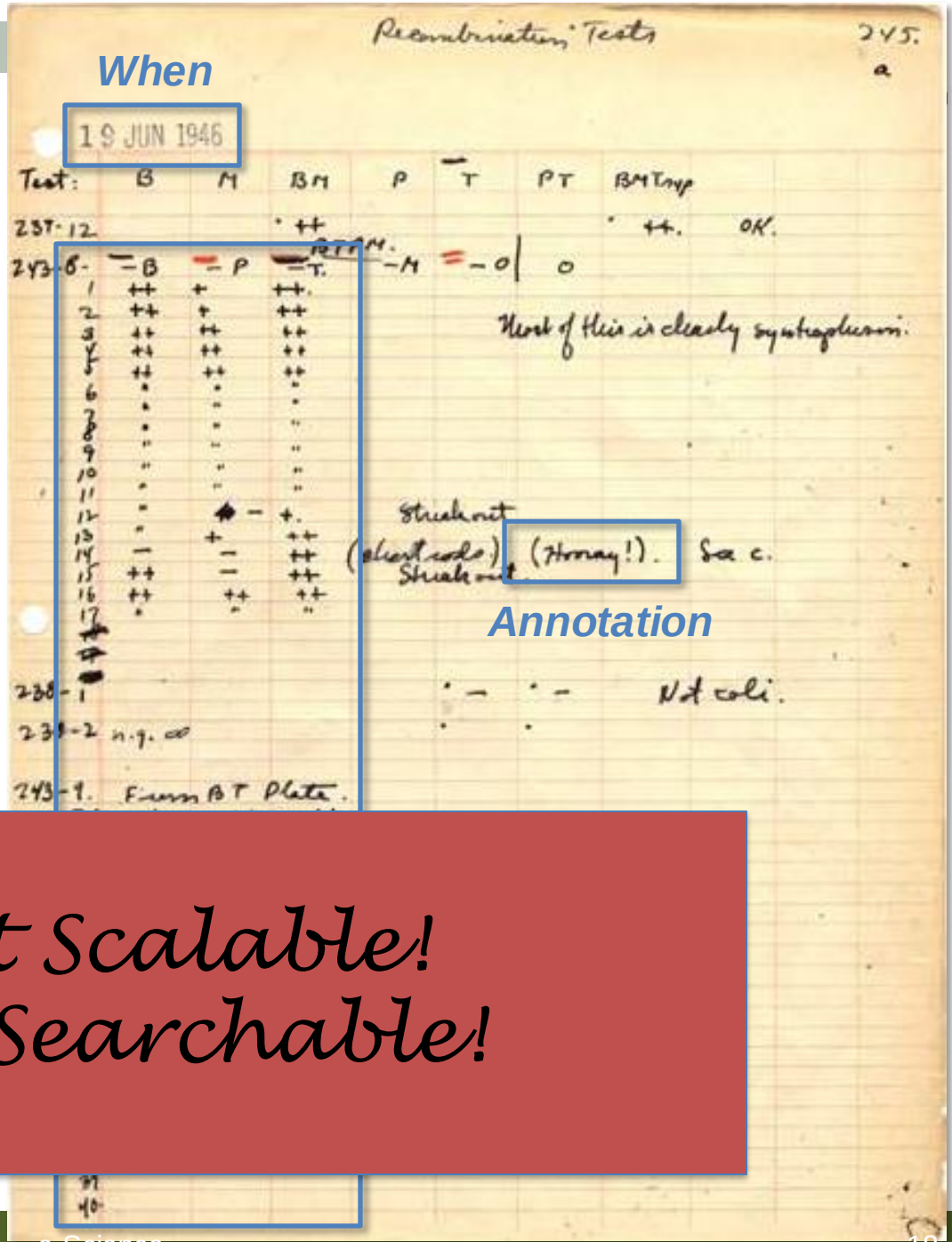
- Scientists have been registering provenance for a long time

DNA
Recombination
Experiments
(J. Lederberg, 1946)

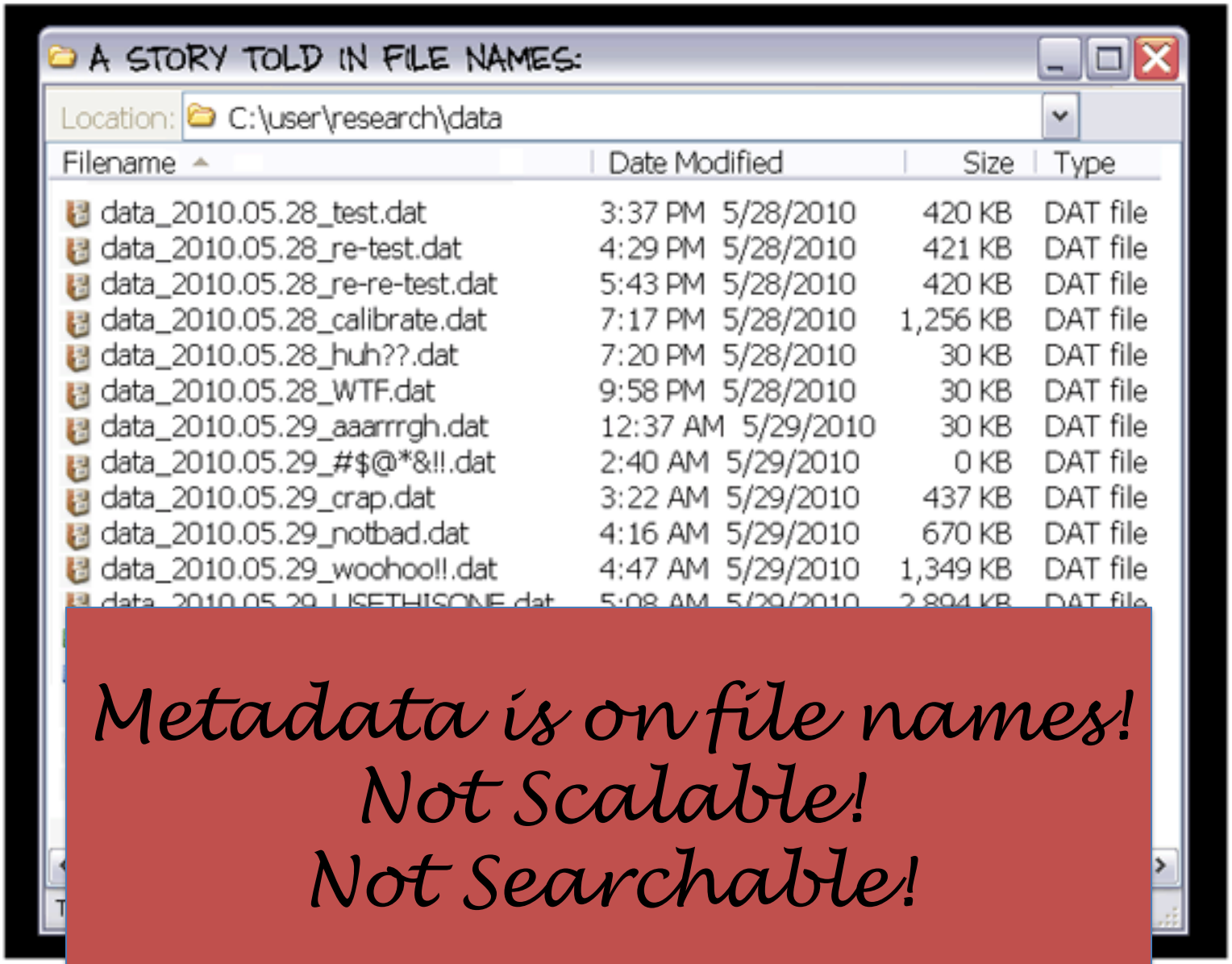



A STORY TOLD IN FILE NAMES:
Location: C:\user\research\data
Filename
Date Modified
Size
Type
data_2010.05.28_test.dat 3:37 PM 5/28/2010 420 KB DAT file
data_2010.05.28_re-test.dat 4:29 PM 5/28/2010 421 KB DAT file
data_2010.05.28_re-re-test.dat 5:43 PM 5/28/2010 420 KB DAT file
data_2010.05.28_calibrate.dat 7:17 PM 5/28/2010 1,256 KB DAT file
data_2010.05.28_huh??.dat 7:20 PM 5/28/2010 30 KB DAT file
data_2010.05.28_WTF.dat 9:58 PM 5/28/2010 30 KB DAT file
data_2010.05.29_aaarrrgh.dat 12:37 AM 5/29/2010 30 KB DAT file
data_2010.05.29_#$@*&!!.dat 2:40 AM 5/29/2010 0 KB DAT file
data_2010.05.29_crap.dat 3:22 AM 5/29/2010 437 KB DAT file
data_2010.05.29_notbad.dat 4:16 AM 5/29/2010 670 KB DAT file
data_2010.05.29_woohoo!!.dat 4:47 AM 5/29/2010 1,349 KB DAT file
data_2010.05.29_USETHISONE.dat 5:08 AM 5/29/2010 2,894 KB DAT file
analysis_graphs.xls 7:13 AM 5/29/2010 455 KB XLS file
ThesisOutline!.doc 7:26 AM 5/29/2010 38 KB DOC file
Notes_Meeting_with_ProfSmith.txt 11:38 AM 5/29/2010 1,673 KB TXT file
JUNK... 2:45 PM 5/29/2010 Folder
data_2010.05.30_startingover.dat 8:37 AM 5/30/2010 420 KB DAT file
Type: Ph.D Thesis Modified: too many times
Copyright: Jorge Cham
www.phdcomics.com

DNA
Recombination
Experiments
(J. Lederberg, 1946)



Not Scalable!
Not Searchable!



Metadata is on file names!
Not Scalable!
Not Searchable!

Placing order into the chaos

- In the past years, several tools appeared aiming at helping scientists conduct their experiments
- Several of them **automatically** capture different **types of provenance**

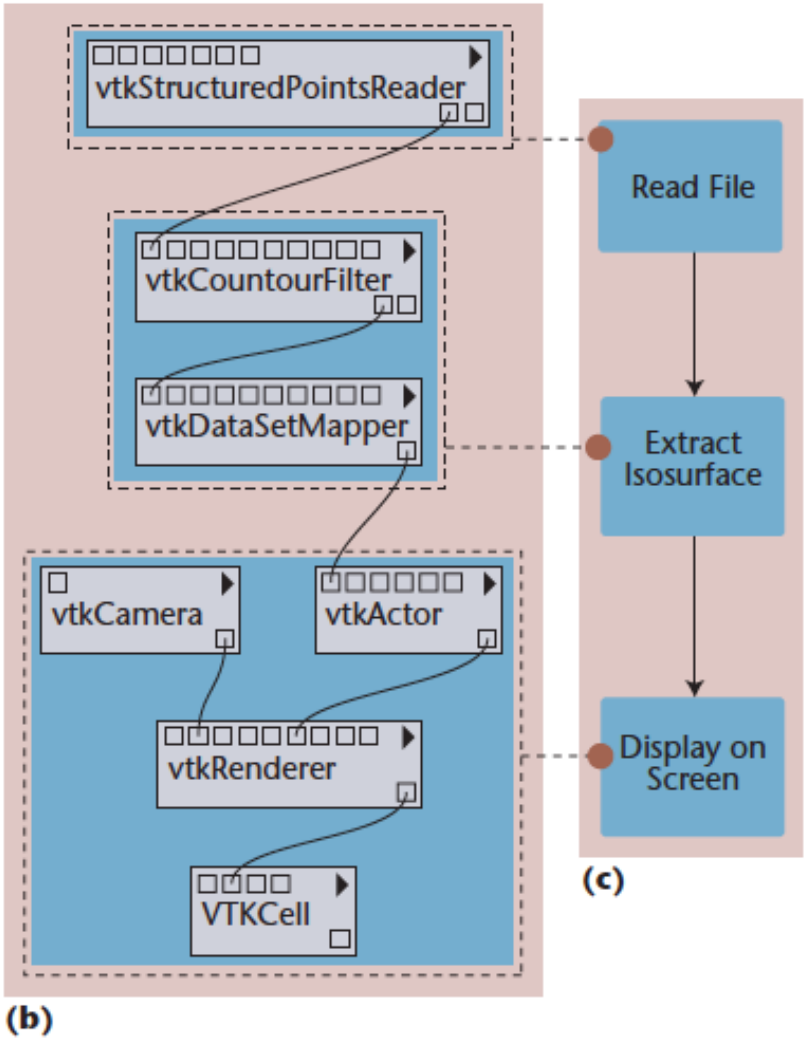
Types of Provenance

- **Prospective Provenance**
  - it captures a computational task's **specification** (whether it's a **script** or a **workflow**) and corresponds to the steps (or recipe) that must be followed to generate a data product or class of data products
- **Retrospective Provenance**
  - captures the **steps executed** as well as **information about the environment** used to derive a specific data product
  - it's a detailed log of a computational task's execution and the **data** (input/output) involved in the execution

Scripts and Workflows

- **Scripts** and **Workflows** are usually the ways in which scientists materialize their experiments
- Some scientists use also **regular programming languages** such as Fortran or C
- Some popular scripting language for science are Python, R and MatLab (among others)
- Popular workflow systems include Swift, Vistrails, Kepler, Taverna, SciCumulus (among others)

```
1  import vtk
2
3  data = vtk.vtkStructuredPointsReader()
4  data.setFileName("../../../examples/data/head.120.vtk")
5
6  contour = vtk.vtkContourFilter()
7  contour.SetInput(0, data.GetOutput())
8  contour.SetValue(0, 67)
9
10 mapper = vtk.vtkPolyDataMapper()
11 mapper.SetInput(contour.GetOutput())
12 mapper.ScalarVisibilityOff()
13
14 actor = vtk.vtkActor()
15 actor.SetMapper(mapper)
16
17 cam = vtk.vtkCamera()
18 cam.SetViewUp(0,0,-1)
19 cam.SetPosition(745,-453,369)
20 cam.SetFocalPoint(135,135,150)
21 cam.ComputeViewPlaneNormal()
22
23 ren = vtk.vtkRenderer()
24 ren.AddActor(actor)
25 ren.SetActiveCamera(cam)
26 ren.ResetCamera()
27
28 renwin = vtk.vtkRenderWindow()
29 renwin.AddRenderer(ren)
30
31 style = vtk.vtkInteractorStyleTrackballCamera()
32 iren = vtk.vtkRenderWindowIneractor()
33 iren.SetRenderWindow(renwin)
34 iren.SetInteractorStyle(style)
35 iren.Initialize()
36 iren.Start()
```



Source: Freire et al., 2008. Provenance for Computational Tasks: A Survey.

Extending the Types of Provenance to Accommodate Scripts

Prospective Provenance
(workflow structure)

Retrospective Provenance

Workflows

Scripts

Definition Provenance
(script structure, including function definitions, their arguments, and function calls)

Deployment Provenance
(execution environment, including info about the OS, environment variables, libraries in which the script depends on)

Execution Provenance
(function activations, argument values, return values, variable values)

Source: Freire et al., 2008. Provenance for Computational Tasks: A Survey.
Murta et al., 2014. noWorkflow: Capturing and Analyzing Provenance of Scripts

Managing Provenance

- A Provenance Management System consists of three main components
  - A capture mechanism
  - A representation model
  - An infrastructure (for storage, access and queries)

Managing Provenance

- A Provenance Management System consists of three main components
  - A **capture mechanism**
  - A representation model
  - An infrastructure (for storage, access and queries)

Capture Mechanisms

- A provenance capture mechanism needs access to a computational task's relevant details, such as its steps, execution information, and user-specified annotations
- Such mechanisms can be classified in three types
  - Operating System (OS)-based
  - Workflow-based
  - Process-based

OS-Based

- OS-based capture systems rely on the Operating System functionalities to capture provenance

(+) No modification to the experiment script or program is needed

(-) Provenance is captured in very fine grain

(-) Only retrospective provenance is captured

Source: Frew, J., Metzger, D., Slaughter, P., 2007. Automatic capture and reconstruction of computational Provenance.

Example of Provenance Captured by an OS-Based System (ES3)

```
...
<exec time="20060908T211419.747511Z" routine="/AIR5.2.5/bin/align_warp"
pid="22636">
  <io>
    <pipe read="true" id="std-in"/>
    <pipe write="true" id="std-out"/>
    <pipe write="true" id="std-err"/>
    <file read="true">/etc/ld.so.cache</file>
    <file read="true">/lib/libm.so.6</file>
    <file read="true">/lib/libc.so.6</file>
    <file read="true">/home/es3/provenance_challenge/anatomy1.hdr</file>
    <file read="true">/home/es3/provenance_challenge/reference.hdr</file>
</io>
...
```

Workflow-based

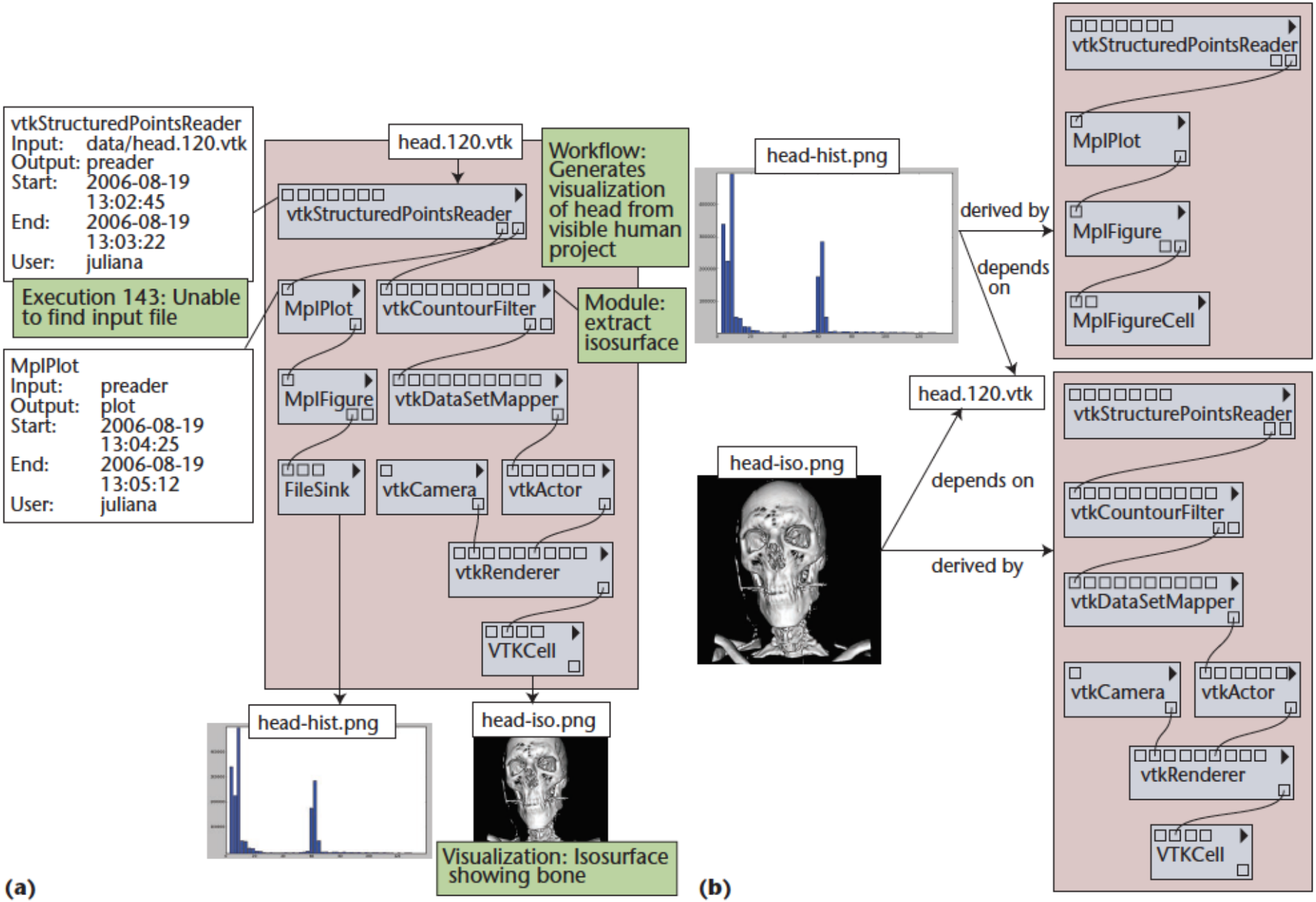
- Workflow-based capture mechanisms are either attached or integrated into a Workflow System

(+) Capturing provenance is straightforward

(+) It is able to capture both prospective and retrospective provenance

(+) They connect prospective and retrospective provenance

(-) Experiment needs to run as a workflow



Source: Freire et al., 2008. Provenance for Computational Tasks: A Survey.

Scripts?

- The classification of workflow-based capture was made in a time where there was very little support for capturing provenance of scripts (2008)
- Today, there are several tools that capture provenance from scripts in a similar way the workflow-based approaches work – transparently and with little to no effort

Process-Based

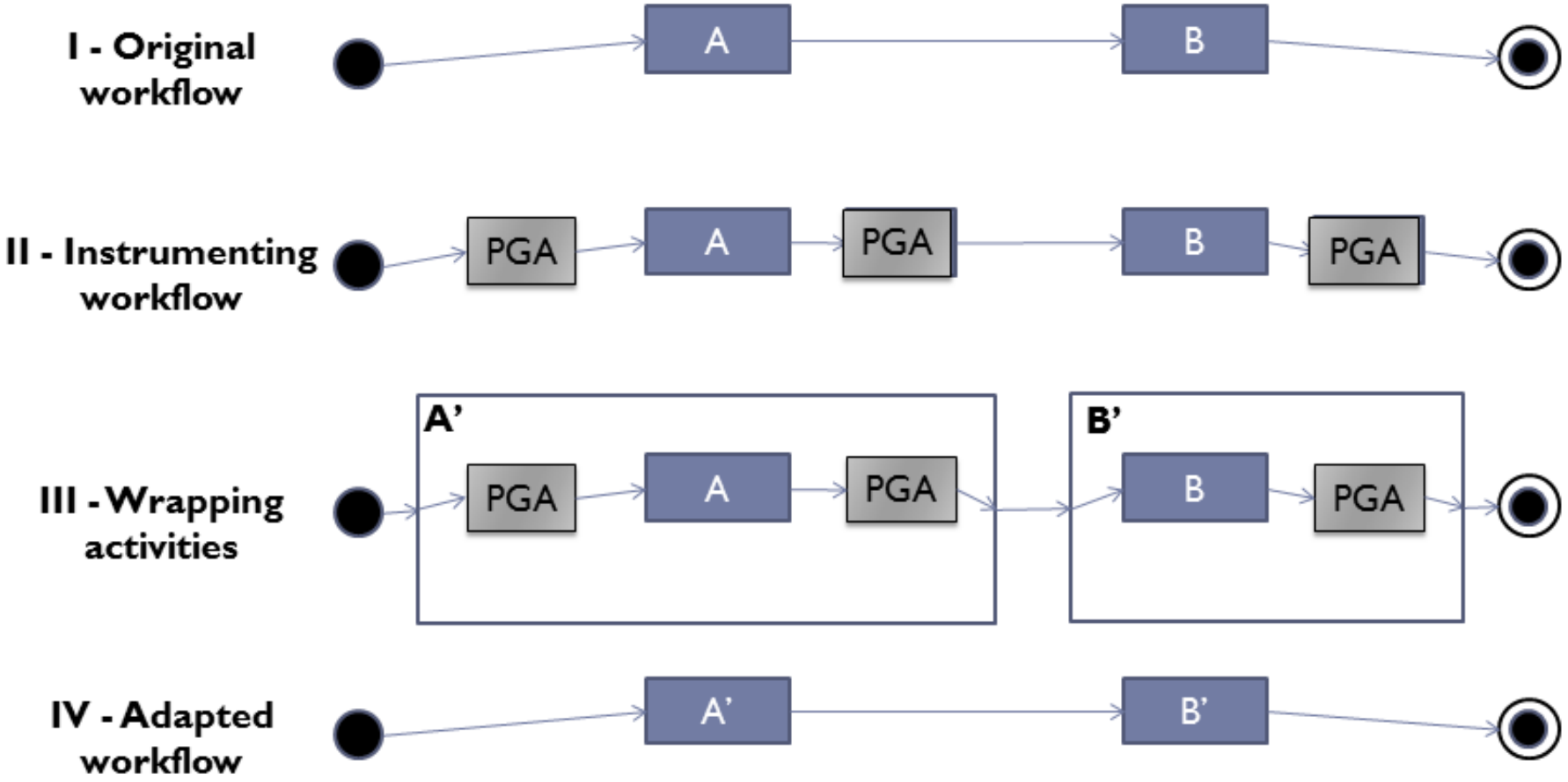
- Process-based mechanisms require each activity to capture its own provenance

(+) It works on any workflow/script system

(-) It requires instrumentation

(-) Only retrospective provenance is captured, unless the prospective provenance is captured during the instrumentation process

Example of Instrumentation

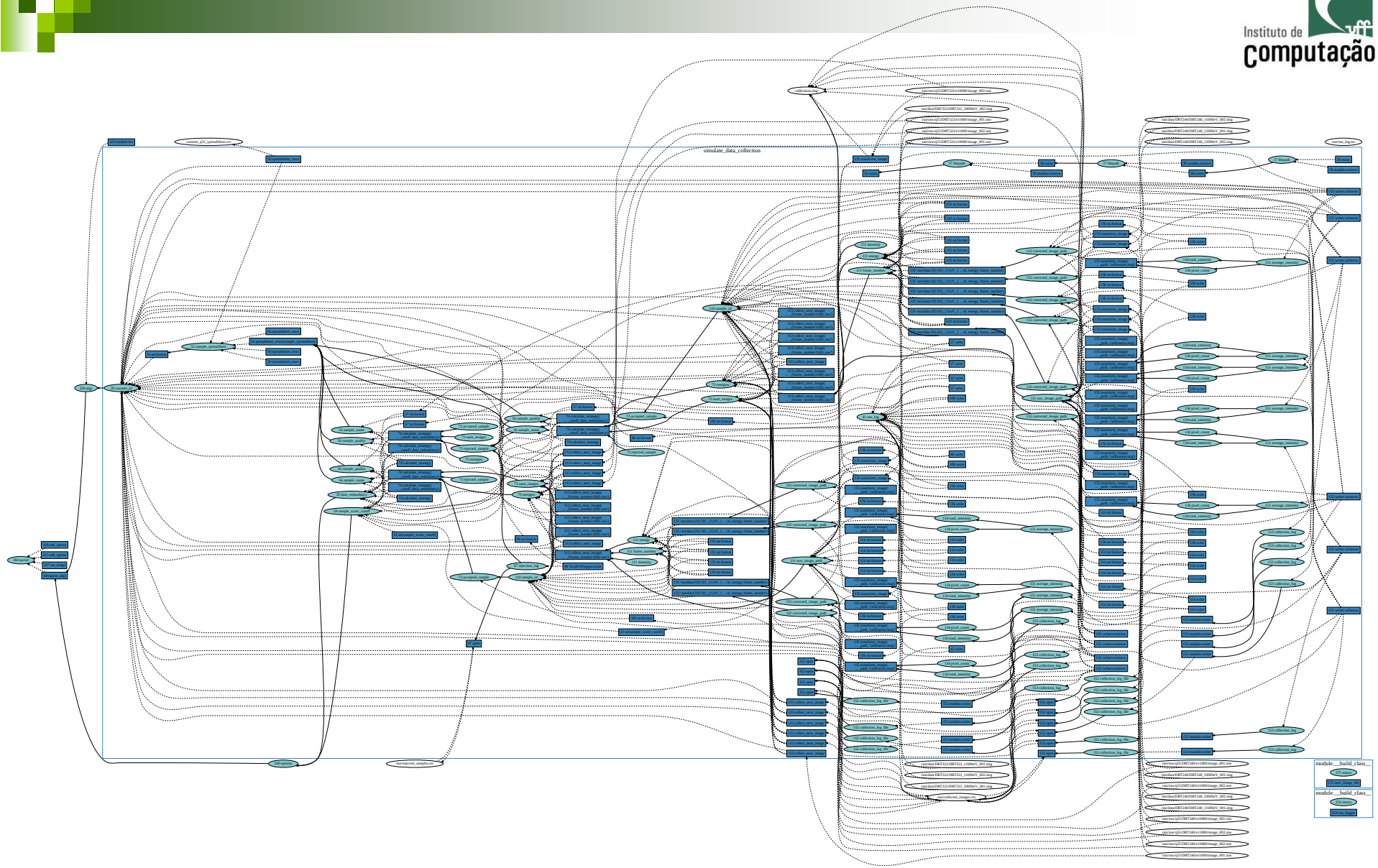


PGA: Provenance Gathering Activity

Source: Marinho et al., 2012. ProvManager: A Provenance Management System for Scientific Workflows.

Granularity

- Different systems capture provenance at different granularity
- There is a trade-off that needs to be taken into account regarding granularity
- **Corse-grain** provenance requires less storage space, but is less detailed
- **Fine-grain** provenance requires lots of storage space, but can be filtered to remove unwanted information during the analysis phase



Source: Pimentel et al., 2016 . Yin & Yang: Demonstrating Complementary Provenance from noWorkflow & YesWorkflow.

Managing Provenance

- A Provenance Management System consists of three main components
  - A capture mechanism
  - A **representation model**
  - An infrastructure (for storage, access and queries)

Provenance Representation

- In 2006, the scientific community started an effort to understand how provenance was being represented and dealt with by different tools
- This was conducted in the form of what they called **Provenance Challenges**

See https://openprovenance.org/provenance-challenge/WebHome.html for details on the Provenance Challenges

1st Provenance Challenge (2006)

- The 1st provenance challenge aimed to establish an **understanding of the capabilities of available provenance-related systems** and, in particular, the following details.
  - The **representations** that systems use to document details of processes that have occurred
  - The **capabilities** of each system **in answering provenance-related queries**
  - What each system considers to be within scope of the topic of provenance (regardless of whether the system can yet achieve all problems in that scope)

2nd Provenance Challenge (2007)

- The first challenge showed that there are **multiple levels of granularity/types of provenance** that may be relevant at different times or in different parts of a process
- Thus, the focus of the 2nd Challenge was **understanding interoperability**

Open Provenance Model

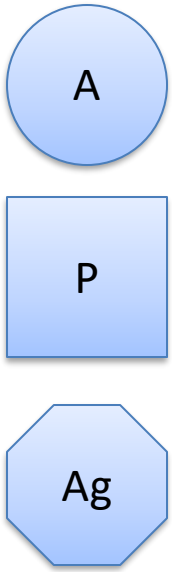
- The result of the first two Provenance Challenges was the **Open Provenance Model** (OPM)

OPM

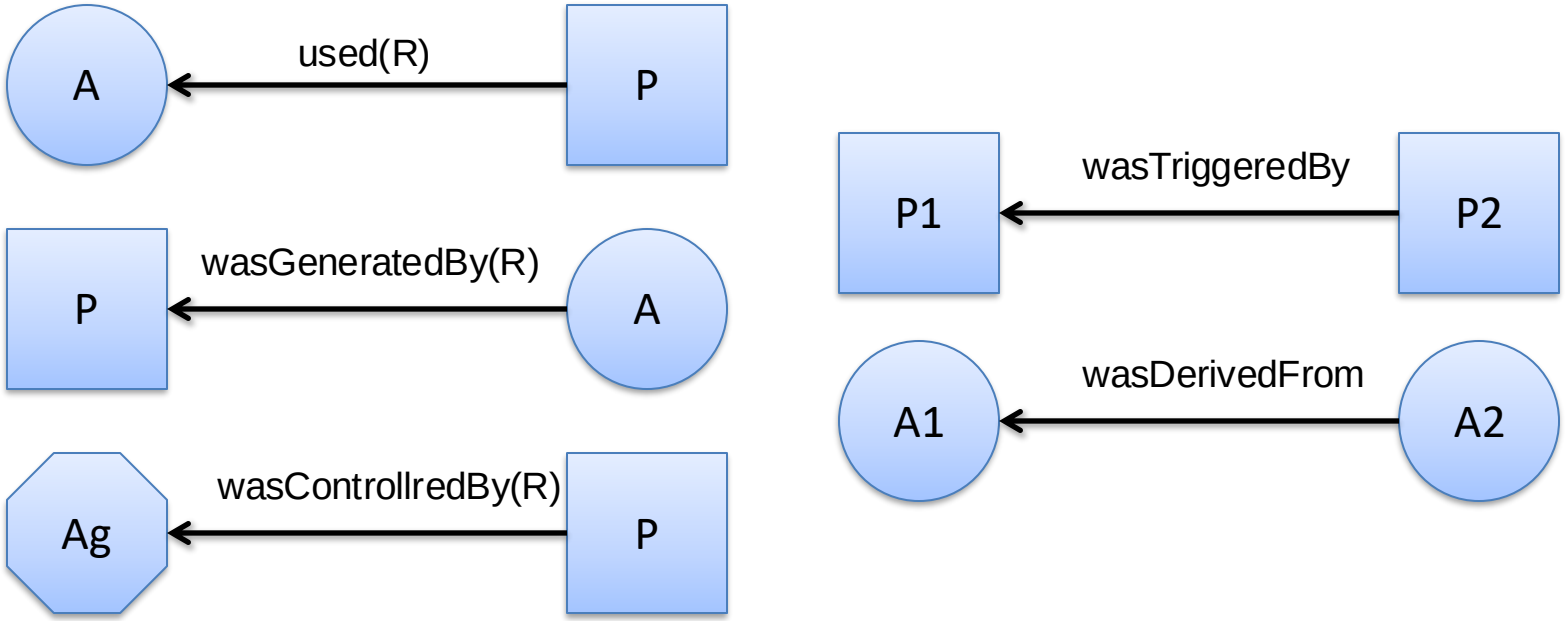
- OPM represents **retrospective provenance**
- It **never** represents things that will happen in the future (prospective provenance)

OPM Basic Concepts

- Provenance is represented by a graph
- Entities
  - **Artifact**
  - **Process**
  - **Agent**



OPM Causality Relations



3rd Provenance Challenge (2009)

- The main goal of the 3rd Provenance Challenge was to **evaluate OPM**, identifying weakness and strengths
- The result of this challenge was a set of proposed changes to the OPM specification

4th Provenance Challenge

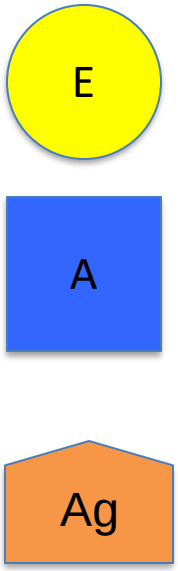
- Interrupted due to the launch of **a new provenance model** – PROV

PROV

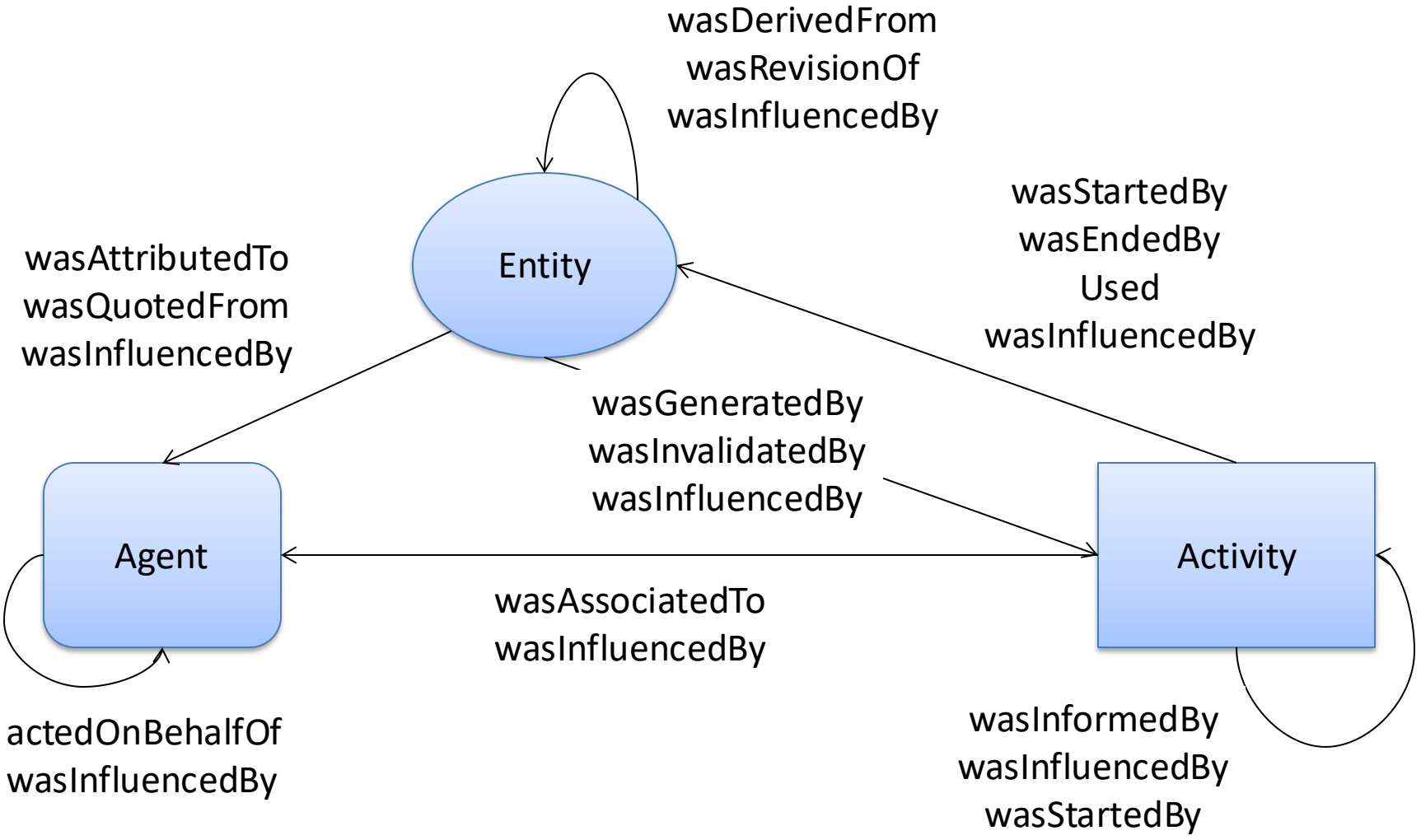
- PROV was developed by the W3C provenance incubator group
- PROV is a data model for **provenance interchange on the Web**
- PROV is a specification to express provenance records, which contain **descriptions of the entities and activities** involved in **producing** and **delivering** or otherwise **influencing** a given object

PROV Basic Concepts

- Provenance is represented as a graph
- Entities
  - ***Entity***
  - ***Activity***
  - ***Agent***

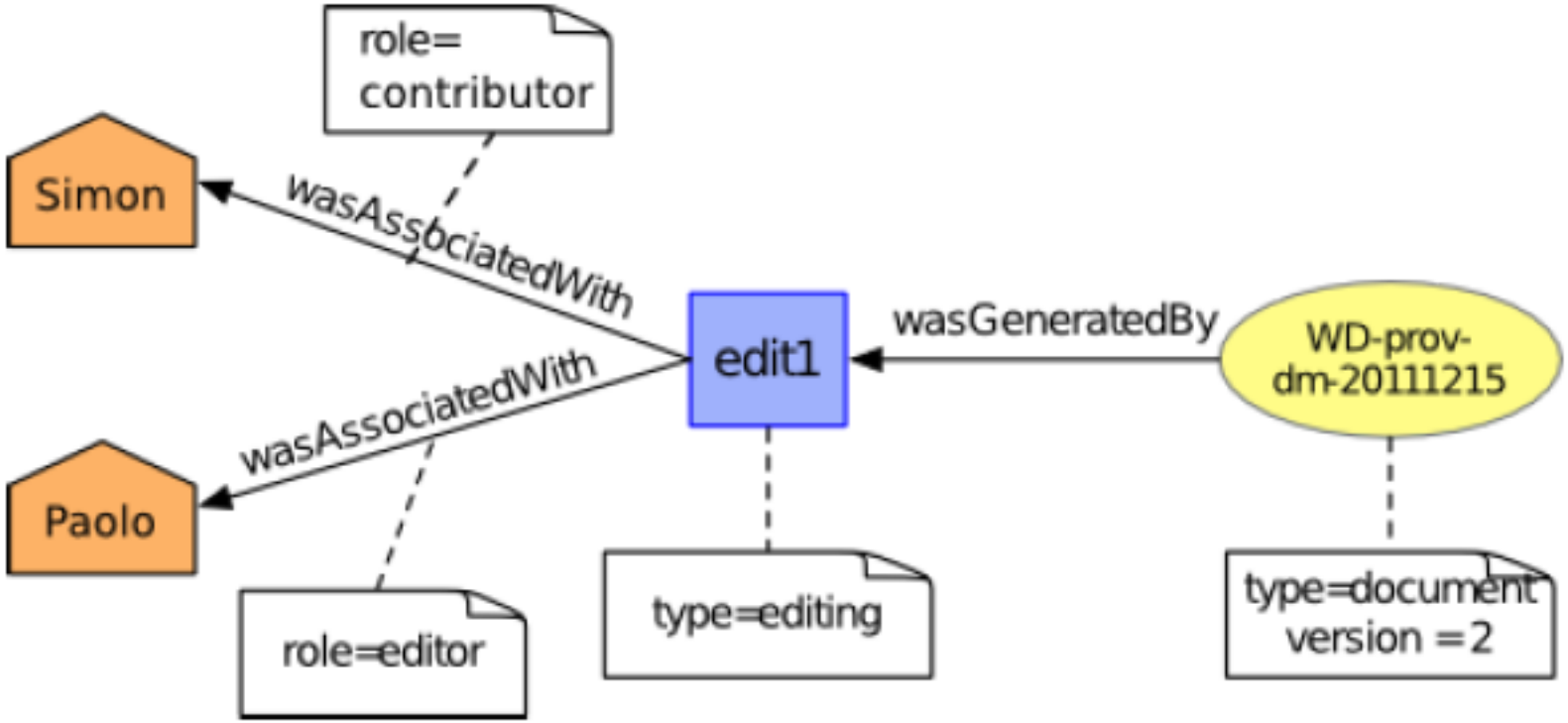


PROV Causality Relations



Example 1

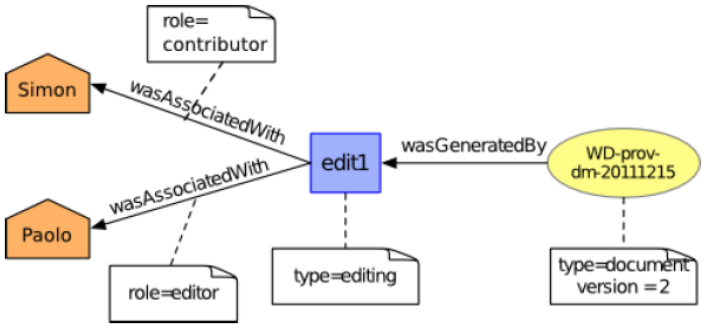
A document is edited by some editor, using contributions from various contributors.



PROV-N

- Provenance in PROV can be represented textually as well
- The representation resembles Datalog facts

PROV-N




```
entity(tr:WD-prov-dm-20111215, [ prov:type="document",
    ex:version="2" ])

activity(ex:edit1, [ prov:type="editing" ])

wasGeneratedBy(tr:WD-prov-dm-20111215, ex:edit1, -)

agent(ex:Paolo, [ prov:type='prov:Person' ])
agent(ex:Simon, [ prov:type='prov:Person' ])

wasAssociatedWith(ex:edit1, ex:Paolo, -, [
    prov:role="editor" ])
wasAssociatedWith(ex:edit1, ex:Simon, -, [
    prov:role="contributor" ])
```

Entity

[3] entityExpression ::= "entity" "(" identifier optionalAttributeValuePairs ")"

[4] optionalAttributeValuePairs ::= ("," "[" attributeValuePairs "]")?

[5] attributeValuePairs ::= (| attributeValuePair ("," attributeValuePair)*)

[6] attributeValuePair ::= attribute "=" literal

Entity	Non-Terminal
id	Identifier
attributes	optionalAttributeValuePairs

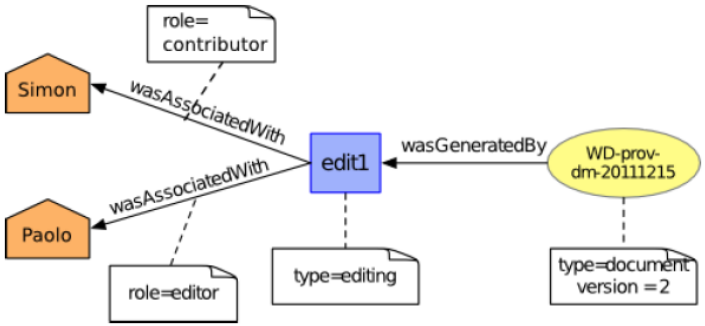
Entity

[3] entityExpression ::= "entity" "(" identifier optionalAttributeValuePairs ")"

[4] optionalAttributeValuePairs ::= ("," "[" attributeValuePairs "]")?

[5] attributeValuePairs ::= (| attributeValuePair ("," attributeValuePair)*)

[6] attributeValuePair ::= attribute "=" literal




```
entity(tr:WD-prov-dm-20111215, [ prov:type="document",
    ex:version="2" ])
```

Activity

[7] activityExpression ::= "activity" "(" identifier ("," timeOrMarker "," timeOrMarker)? optionalAttributeValuePairs ")"

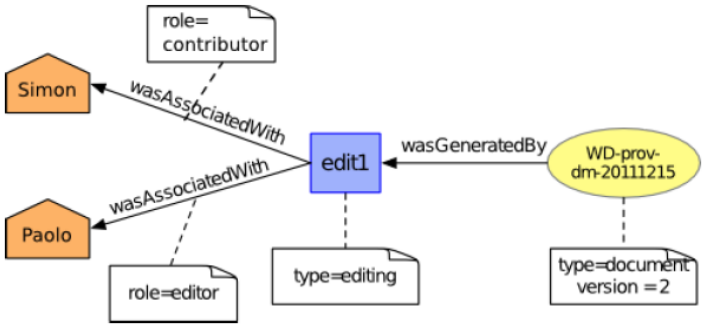
[8] timeOrMarker ::= (time | "-")

Activity	Non-Terminal
id	identifier
startTime	timeOrMarker
endTime	timeOrMarker
attributes	optionalAttributeValuePairs

Activity

[7] activityExpression ::= "activity" "(" identifier ("," timeOrMarker "," timeOrMarker)? optionalAttributeValuePairs ")"

[8] timeOrMarker ::= (time | "-")




```
activity(ex:edit1, [ prov:type="editing" ])
```

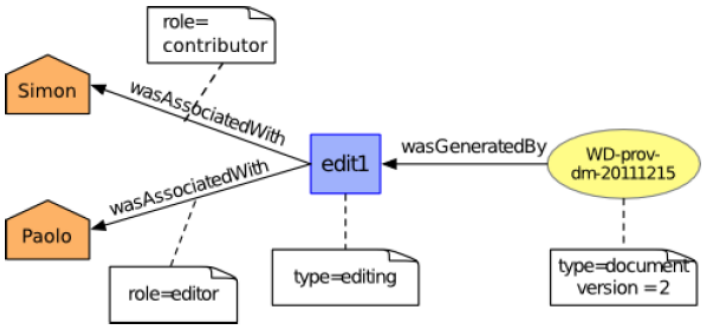
Agent

[18] agentExpression ::= "agent" "(" identifier optionalAttributeValuePairs ")"

Agent	Non-Terminal
id	identifier
attributes	optionalAttributeValuePairs

Agent

[18] agentExpression ::= "agent" "(" identifier optionalAttributeValuePairs ")"




```
agent(ex:Paolo, [ prov:type='prov:Person' ])
agent(ex:Simon, [ prov:type='prov:Person' ])
```

Generation

[9] generationExpression ::= "wasGeneratedBy" "(" optionalIdentifier eIdentifier ("," aIdentifierOrMarker "," timeOrMarker)? optionalAttributeValuePairs ")"

[10] optionalIdentifier ::= (identifierOrMarker ";")?

[11] identifierOrMarker ::= (identifier | "-")

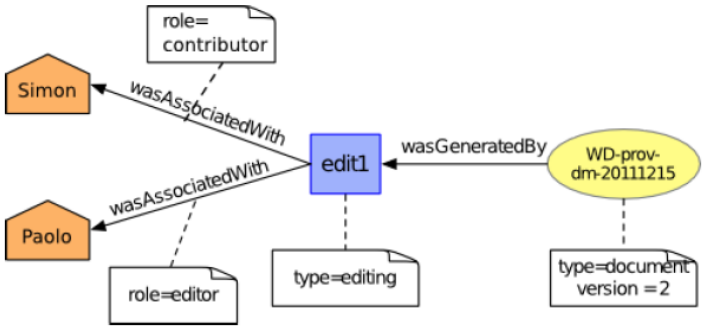
Generation	Non-Terminal
id	optionalIdentifier
entity	eIdentifier
activity	aIdentifierOrMarker
time	timeOrMarker
attributes	optionalAttributeValuePairs

Generation

[9] generationExpression ::= "wasGeneratedBy" "(" optionalIdentifier eIdentifier ("," aIdentifierOrMarker "," timeOrMarker)? optionalAttributeValuePairs ")"

[10] optionalIdentifier ::= (identifierOrMarker ";")?

[11] identifierOrMarker ::= (identifier | "-")




```
wasGeneratedBy(tr:WD-prov-dm-20111215, ex:edit1, -)
```

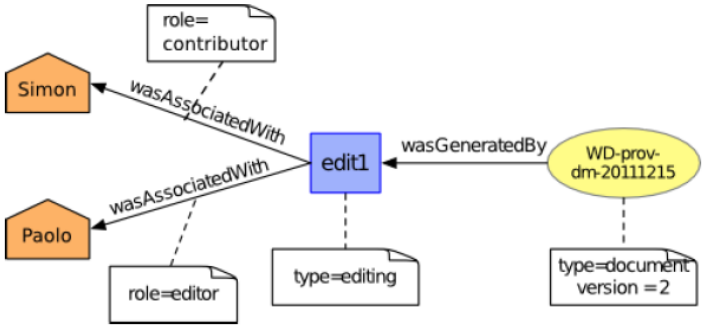
Association

[20] associationExpression::= "wasAssociatedWith" "(" optionalIdentifier aIdentifier ("," agIdentifierOrMarker "," eIdentifierOrMarker)? optionalAttributeValuePairs ")"

Association	Non-Terminal
id	optionalIdentifier
activity	aIdentifier
agent	agIdentifierOrMarker
plan	eIdentifierOrMarker
attributes	optionalAttributeValuePairs

Association

[20] associationExpression::= "wasAssociatedWith" "(" optionalIdentifier aIdentifier ("," agIdentifierOrMarker "," eIdentifierOrMarker)? optionalAttributeValuePairs ")"

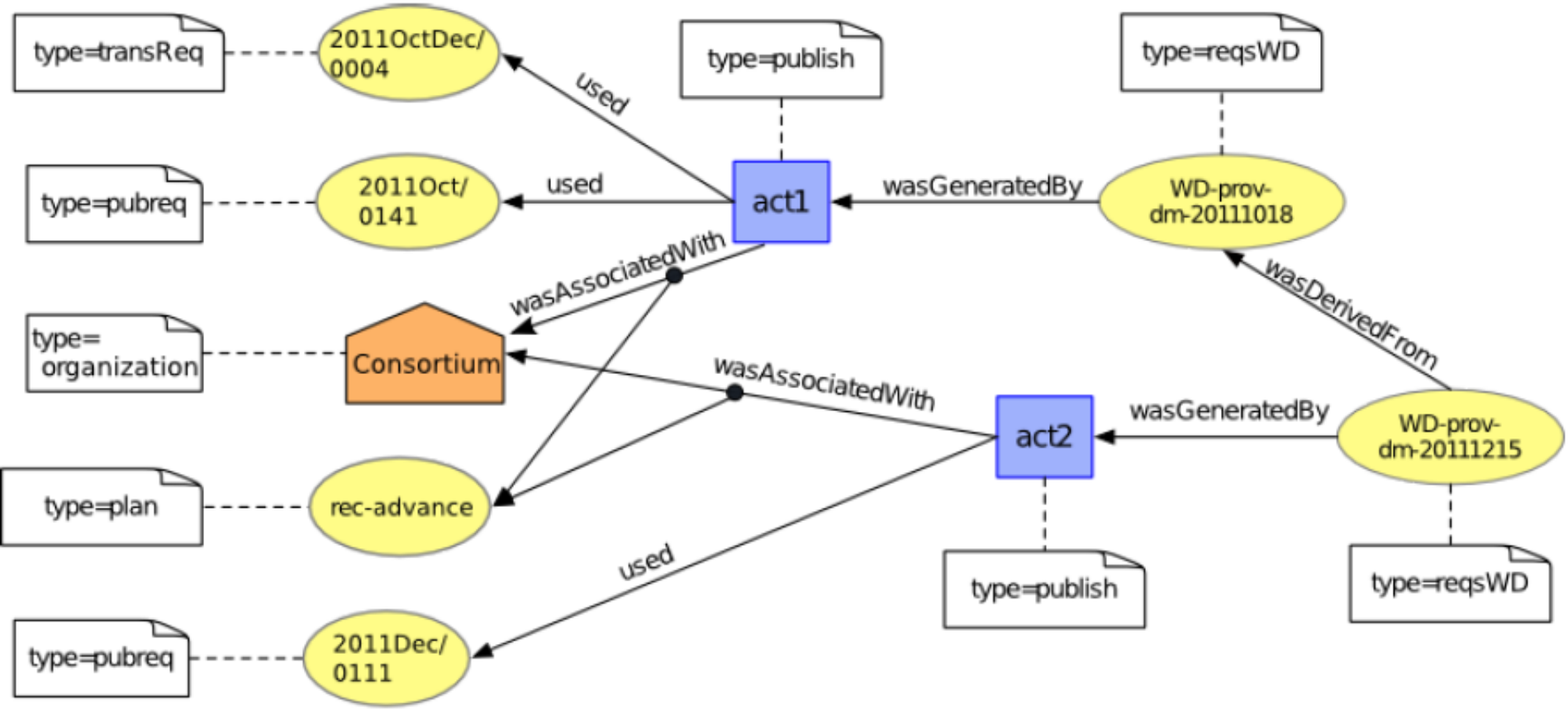



```
wasAssociatedWith(ex:edit1, ex:Paolo, -, [
    prov:role="editor" ])
wasAssociatedWith(ex:edit1, ex:Simon, -, [
    prov:role="contributor" ])
```

Example 2

The World Wide Web Consortium publishes documents according to its publication policy. Working drafts are published regularly to reflect the work accomplished by working groups. Every publication of a working draft must be preceded by a "publication request" to the Webmaster. The very first version of a document must also be preceded by a "transition request" to be approved by the W3C director. All working drafts are made available at a unique IRI. In this scenario, we consider two successive versions of a given document, the policy according to which they were published, and the associated requests.

Example 2 (cont.)



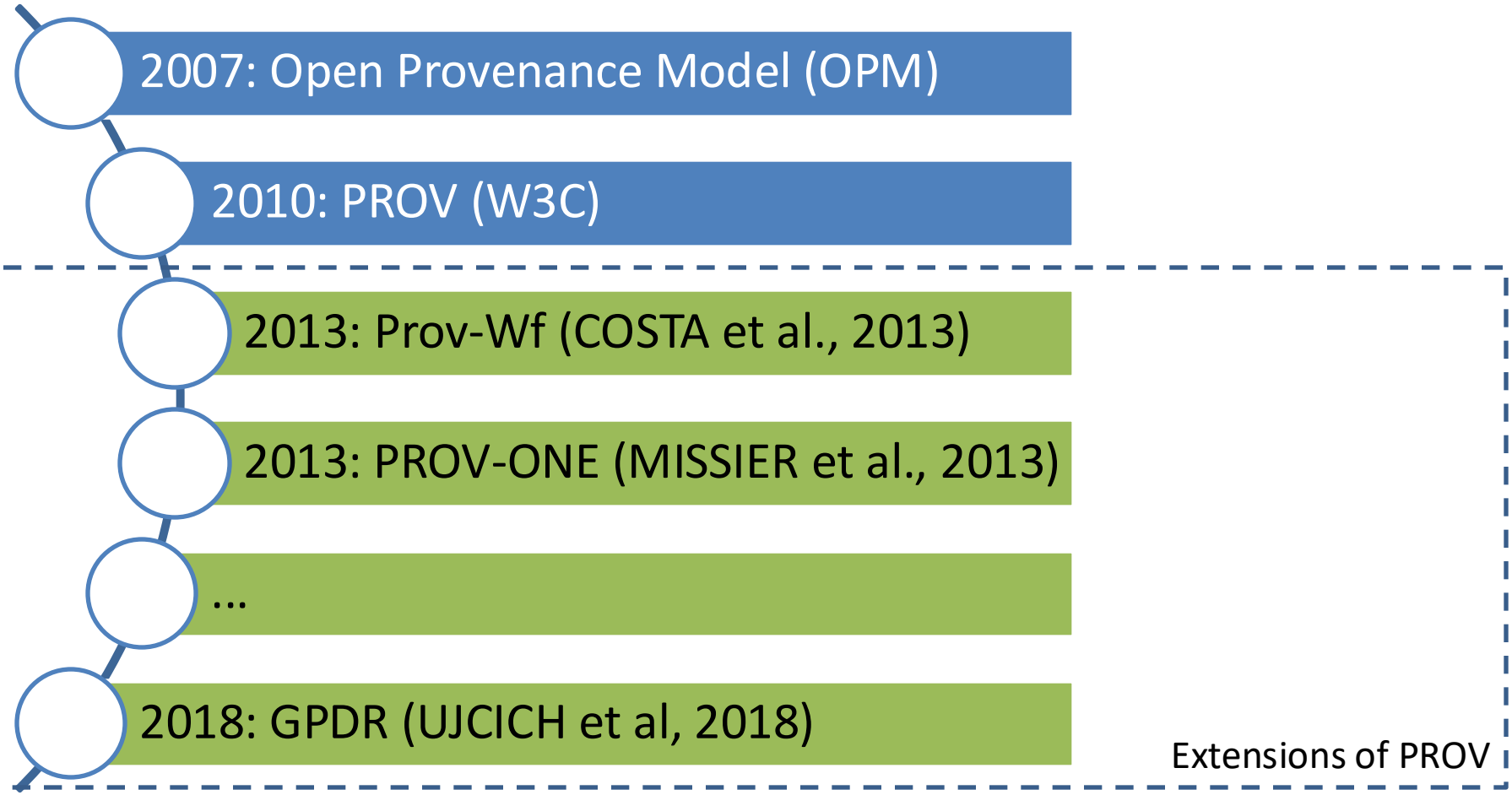
And much more...

- For a complete list of PROV relationships, and how to represent them, please check the W3C website

PROV is extensible

- New properties can be added to agents, processes, entities and relationships as needed

Timeline of Provenance Models



Managing Provenance

- A Provenance Management System consists of three main components
  - A capture mechanism
  - A representation model
  - An **infrastructure** (for storage, access and queries)

Repositories

- Dataverse (http://dataverse.org/)
- Zenodo (https://zenodo.org)
- MyExperiment (https://www.myexperiment.org/)
- GenBank (https://www.ncbi.nlm.nih.gov/genbank/)
- …

Infrastructure

- During this course we will discuss several tools that capture, manage and/or store provenance somehow
  - VisTrails
  - Taverna
  - noWorkflow
  - YESWorkflow
  - Reprozip
  - CDE

Infrastructure

- During this course we will discuss several tools that capture, manage and/or store provenance somehow
  - VisTrails
  - Taverna
  - noWorkflow
  - YESWorkflow
  - Reprozip
  - CDE

This is **only a subset** of the available tools, but serve to give an overview of the types of tools available to capture and manage provenance

Workflow Provenance x Data Provenance

- Literature distinguishes **Workflow Provenance** (what we saw today until this point) from **Data Provenance**
- **Data Provenance** allows to track the processing of individual data items (e.g., tuples) at the "highest resolution," i.e., the provenance itself is at the level of individual data items (and the operations they undergo).

Source: Melanie Herschel, Ralf Diestelkämper, Houssem Ben Lahmar: **A survey on provenance: What for? What form? What from?** VLDB J. 26(6): 881-906 (2017)

Data Provenance

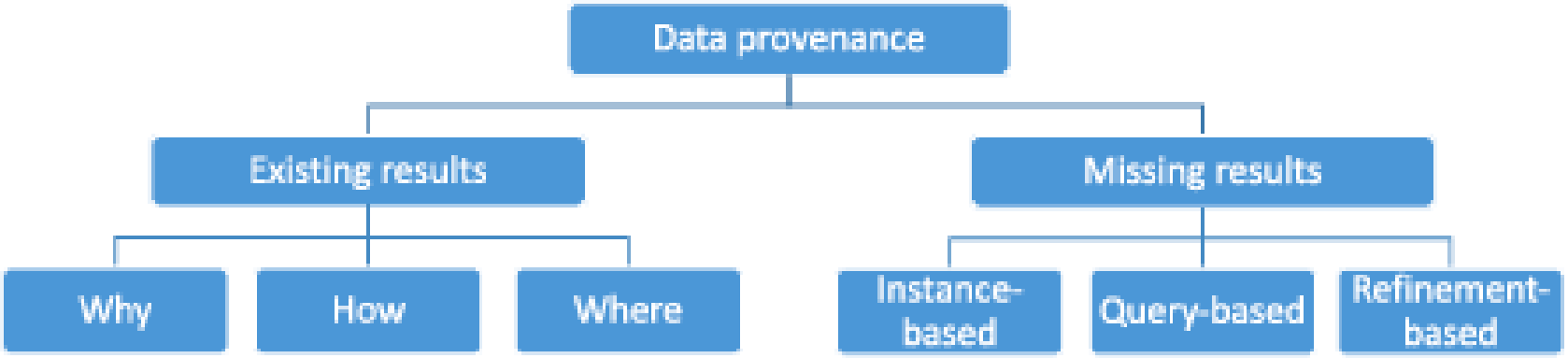


Fig. 4 Classification of data provenance research

Source: Melanie Herschel, Ralf Diestelkämper, Houssem Ben Lahmar: **A survey on provenance: What for? What form? What from?** VLDB J. 26(6): 881-906 (2017)

Types of Data Provenance

- **Why Provenance**: this tuple was in the result because some other tuple was in the input
- **How Provenance**: this tuple was formed by joining tuple t1 from R1 to tuple t2 from R2
- **Where Provenance**: this value was derived from the value x in tuple t1 from R1

Source: Peter Buneman, Wang-Chiew Tan: **Data Provenance: What next?** SIGMOD Record 47(3): 5-16 (2018)

Types of Data Provenance

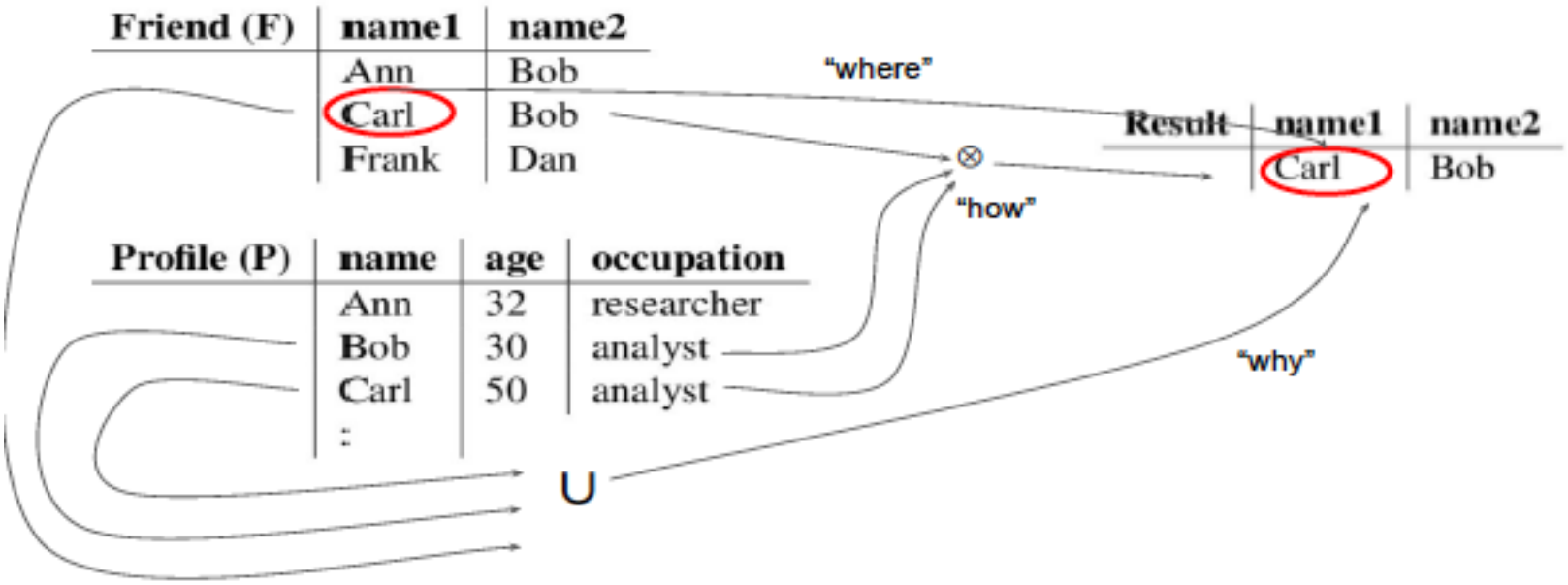


Figure 1: An illustration of where, how, and why-provenance.

Source: Peter Buneman, Wang-Chiew Tan: **Data Provenance: What next?** SIGMOD Record 47(3): 5-16 (2018)

Our focus

- In the remaining of this course, we will focus on Workflow Provenance

Exercise

- Assume that you want to re-execute an experiment that one of your students run 30 years ago. You have the source code (a Python script), the input data, and also all the results described in a paper that was published years ago.
- What would you need to do in order to re-execute that experiment?
- What could go wrong?
- How to prevent this from happening again in the future?

Provenance of these slides...

- Some of these slides were authored by Fernando Chirigati (NYU), João Felipe Nicolaci Pimentel (UFF), Leonardo Murta (UFF) and Troy Kohwalter (UFF)
- Benjamin E. Ujcich, Adam Bates, William H. Sanders: **A Provenance Model for the European Union General Data Protection Regulation**. IPAW 2018: 45-57
- Costa, F., Silva, V., de Oliveira, D., Ocaña, K., Ogasawara, E., Dias, J., Mattoso, M.: **Capturing and querying workflow runtime provenance with PROV: a practical approach**. In: EDBT/ICDT Workshops. (2013).
- Freire, J., Koop, D., Santos, E., Silva, C. **Provenance for Computational Tasks: A Survey**. Computing in Science & Engineering, 2008.
- Frew, J., Metzger, D., Slaughter, P. Automatic capture and reconstruction of computational provenance. Concurrency and Computation: Practice and Experience, 2007.
- Gil, Y., Miles, S., 2010. **PROV Model Primer**. W3C. URL http://www.w3.org/TR/prov-primer/
- Marinho, A. ; Murta, L. ; Werner, C. ; Braganholo, V. ; Cruz, S. ; Ogasawara, E. ; Mattoso, M. **ProvManager: a provenance management system for scientific workflows**. Concurrency and Computation, v. 24, p. 1513-1530, 2012.

Provenance of these slides...

- Melanie Herschel, Ralf Diestelkämper, Houssem Ben Lahmar: **A survey on provenance: What for? What form? What from?** VLDB J. 26(6): 881-906 (2017)
- Missier, P., Dey, S., Belhajjame, K., Cuevas-Vicenttín, V., Ludäscher, B.: **D-PROV: Extending the PROV Provenance Model with Workflow Structure**. In: TaPP (2013).
- Moreau, L., Freire, J., Futrelle, J., McGrath, R.E., Myers, J., Paulson, P.: **The Open Provenance Model: An Overview**. In: IPAW. (2008).
- Moreau, L., Clifford, B., Freire, J., Futrelle, J., Gil, Y., Groth, P., Kwasnikowska, N., Miles, S., Missier, P., Myers, J., Plale, B., Simmhan, Y., Stephan, E., Den Bussche, J.V., 2011. **The Open Provenance Model core specification (v1.1).** In: Future Generation Computer Systems 27, 743–756.
- Murta, L., Braganholo, V., Chirigati, F., Koop, D., Freire, J. **noWorkflow: Capturing and Analyzing Provenance of Scripts**. In: IPAW, 2014.
- Peter Buneman, Wang-Chiew Tan: **Data Provenance: What next?** SIGMOD Record 47(3): 5-16 (2018)
- Pimentel, J. ; Dey, S. ; McPhillips, T. ; Belhajjme, K. ; Koop, D. ; Murta, L. ; Braganholo, V. ; Ludascher, B. . **Yin & Yang: Demonstrating Complementary Provenance from noWorkflow & YesWorkflow**. In: IPAW 2016, Washington D.C. , v. 9672. p. 161-165.
- Susan B. Davidson, Juliana Freire: **Provenance and scientific workflows: challenges and opportunities**. SIGMOD Conference 2008: 1345-1350