Overview of Provenance on the Web
by the
W3C Provenance Incubator Group

Semantic Web Activity
World Wide Web Consortium

http://www.w3.org/2005/Incubator/prov/wiki

Special thanks to contributing group members: Chris Bizer, James Cheney, Sam Coppens, Kai Eckert, Andre Freitas, Irini Fundulaki, Daniel Garijo, Yolanda Gil, Jose Manuel Gomez Perez, Paul Groth, Olaf Hartig, Deborah McGuinness, Simon Miles, Paolo Missier, Luc Moreau, James Myers, Michael Panzer, Paulo Pinheiro da Silva, Christine Runnegar, Satya Sahoo, Yogesh Simmhan, Raphaël Troncy, Jun Zhao

“The US Constitution was written by space aliens from the future.”
Outline

- Need for provenance on the web
- W3C Provenance Group: What is known about provenance in the community
  - Definition of provenance
  - Key dimensions of provenance
  - Use cases: Requirements for provenance
  - State-of-the-art and existing provenance vocabularies
  - Situating provenance on the Web architecture
- Towards a standard for provenance
Provenance is Key in Open Information Systems (such as the Web)

- Provenance questions useful for information integration:
  - Who created that content (author/attribution)?
  - Was the content ever manipulated, if so by what processes/entities?
  - Who is providing that content (repository)?
  - What is the timeliness of that content?
  - Can any of the answers to these questions be verified (eg e-signatures)?
Broad Need for Provenance in Many Areas

- **Open information systems (such as the Web)**
  - Making trust judgments on what web content to trust

- **Business practices**
  - Manufacturing processes and providers of a given product

- **Science applications**
  - How new results were obtained: from assumptions to conclusions and everything in between

- **News-spheres**
  - Blogosphere, twittosphere

- **Laws for IP and privacy protection**
  - Licensing and attribution of a document/software that combines permissions and rights of text, images, etc.
  - Privacy of information as well as of its provenance
"At the toolbar (menu, whatever) associated with a document there is a button marked "Oh, yeah?". You press it when you lose that feeling of trust. It says to the Web, 'so how do I know I can trust this information?'. The software then goes directly or indirectly back to metainformation about the document, which suggests a number of reasons."

Provenance in Web Documents, Blogosphere

“The problem is - and this is true of books and every other medium - we don't know whether the information we find [on the Web] is accurate or not. We don't necessarily know what its provenance is.” – Vint Cerf

“In content, as creation becomes overabundant and as value shifts from creator to curator, it becomes all the more vital to properly cite and link to sources [...]. Good curation demands good provenance. [...] Provenance is no longer merely the nicety of artists, academics, and wine makers. It is an ethic we expect.” – Jeff Jarvis

- Illustrates the need for provenance for attribution, licensing, making trust judgments
Provenance in Open Government

“Provenance is the number one issue that we face when publishing government data in data.gov.uk” -- John Sheridan, UK National Archives, data.gov.uk

- Illustrates the need for provenance for data integration and reuse
  - Sources of data are very diverse
  - Varying quality
  - Different scope
  - Different assumptions
Provenance in Science

"We need a paradigm that makes it simple [...] to perform and publish reproducible computational research. [...] A Reproducible Research Environment (RRE) [...] provides computational tools together with the ability to automatically track the provenance of data, analyses, and results and to package them (or pointers to persistent versions of them) for redistribution."

- Jill Mesirov, Chief Informatics Officer of the MIT/Harvard Broad Institute, in Science, January 2010

Illustrates the need for provenance for reproducibility and verification of processes
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W3C Chartered a New Provenance Group in Sept’09 (Chair: Y. Gil)

- Provenance is a pressing issue in many areas for W3C
  - Linked Data and the semantic web (linkedopendata.org)
  - Open government (data.gov, data.gov.uk)
  - HCLS

- Most people do not know how to approach provenance
  - Many are asking for a standard and methodology that they can use immediately

- Existing work scattered in many areas of computer science and library sciences research
  - “The number of publications on provenance is [...] a total of 425 [...] with about half the papers published in the last two years.” – Luc Moreau
W3C Provenance Group: Original Charter

Provide **state-of-the-art** understanding and develop a **roadmap** for development and possible standardization

- Articulate requirements for accessing and reasoning about provenance information on an open system like the Web
  - Develop use cases

- Relate issues in provenance to Web architecture
  - Semantic Web, security, identity, etc.

- Report on state-of-the-art work on provenance

- Propose on a roadmap for provenance in the Semantic Web
  - Identify starting points for provenance representations
  - Identifying elements of a provenance architecture that would benefit from standardization
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Products of the W3C Provenance Group to Date

- Shared working **definition** of provenance (10/10)
- Developed a set of **key dimensions** for provenance (11/09)
  - Grouped into three major categories: content, management, use
- Collected **use cases** for provenance (12/09)
  - More than 30 use cases, most were improved and curated
- Designed 3 **flagship scenarios** from the use cases (4/10)
- Developed **provenance requirements** from the scenarios (6/10)
  - User requirements: what is the purpose/use of the provenance information
  - Technical requirements: derived from the user requirements
- Created **mappings** for existing provenance vocabularies (7/10)
- **State-of-the-art** report (9/10)
  - Need standards for publishing and accessing provenance
- Provenance in Web architecture (expected 11/15)
- Currently preparing recommendations and final report (expected 11/30)
  - Preparing a proposal charter for a working group on provenance
Our Working Definition of Provenance

Provenance of a resource is **a record that describes entities and processes involved in producing and delivering or otherwise influencing that resource.**

Provenance provides a critical foundation for assessing authenticity, enabling trust, and allowing reproducibility.

- Is provenance = metadata? Or = trust? Or = authentication?
  - Provenance can be seen as **metadata**, but not all metadata is provenance
  - Provenance provides a substrate for deriving different **trust** metrics
  - Provenance records can be used to **verify** and authenticate among other uses

- Notice:
  - Provenance assertions can have **their own provenance**
  - **Inference** is useful if provenance records are incomplete/erroneous
  - There may be alternative **accounts** of provenance of the same resource

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http://www.w3.org/2005/Incubator/prov/wiki/What_Is_Provenance
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W3C Provenance Group: Major Dimensions of Provenance

1) Content
- Attribution - provenance as the sources or entities that were used to create a new result
  - Responsibility - knowing who endorses a particular piece of information or result
  - Origin - recorded vs reconstructed, verified vs non-verified, asserted vs inferred
- Process - provenance as the process that yielded an artifact
  - Reproducibility (eg workflows, mashups, text extraction)
  - Data Access (e.g. access time, accessed server, party responsible for accessed server)
- Evolution and versioning
  - Republishing (e.g. retweeting, reblogging, republishing)
  - Updates (e.g. a document with content from various sources and that changes over time)
- Justification for decisions – Includes argumentation, hypotheses, why-not questions
- Entailment - given the results to a particular query, what axioms or tuples led to those results

2) Management
- Publication - Making provenance information available (expose, distribute)
- Access - Finding and querying provenance information
- Dissemination control – Track policies specified by creator for when/how an artifact can be used
  - Access Control - incorporate access control policies to access provenance information
  - Licensing - stating what rights the object creators and users have based on provenance
  - Law enforcement (eg enforcing privacy policies on the use of personal information)
- Scale - how to operate with large amounts of provenance information
W3C Provenance Group: Major Dimensions of Provenance (Cont’d)

3) Use

- Understanding - End user consumption of provenance.
  - abstraction, multiple levels of description, summary
  - presentation, visualization
- Interoperability - combining provenance produced by multiple different systems
- Comparison - finding what’s in common in the provenance of two or more entities (e.g., two experimental results)
- Accountability - the ability to check the provenance of an object with respect to some expectation
  - Verification - of a set of requirements
  - Compliance - with a set of policies
- Trust - making trust judgments based on provenance
  - Information quality - choosing among competing evidence from diverse sources (e.g., linked data use cases)
  - Incorporating reputation and reliability ratings with attribution information
- Imperfections - reasoning about provenance information that is not complete or correct
  - Incomplete provenance
  - Uncertain/probabilistic provenance
  - Erroneous provenance
  - Fraudulent provenance
- Debugging
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W3C Provenance Group:
30+ Use Cases Contributed by the Community

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<tr>
<th>1. Result Differences</th>
<th>17. Provenance at different levels in Cultural Heritage</th>
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<td>2. Anonymous Information</td>
<td>18. Identifying attribution and associations</td>
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<td>3. Information Quality Assessment for Linked Data</td>
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<td>4. Timeliness</td>
<td>20. Documenting axiom formulation</td>
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<td>6. Ignoring Unreliable Data</td>
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</tr>
</tbody>
</table>
Structure of the Use Cases

Owner
Chris Bizer
(Curator: Satya Sahoo)

Provenance Dimensions
Primary: Attribution (Content), Evolution and versioning (Content)
Secondary: Scale (Management), Law Enforcement (Management), Understanding (Use), Trust (Use), Incomplete provenance (Use)

Background and Current Practice
Within the Blogosphere, topics are discussed across blogs that refer to each other, for example on personal blogs, project weblogs, and on company blogs. The cross references are in the form of links at the bottom of a blog post, hyperlinks within a blog post, and quotation of text from other blogs. Blog posts are also aggregated and republished by services like Technorati, BlogPulse, Tailrank, and BlogScope, that track the interconnections between bloggers. Correct attribution of blogs, as they are processed, aggregated and republished on the Web, is an important requirement in the blogosphere.

Goal
Enable applications on the Web to attribute content from different sources to a specific individual or an organization. In this use case, blogs are an example of content flow between websites, and it is important to trace back republished posts to their original source.

Use Case Scenario
A website X collates Web content from multiple sites on a particular topic that is processed and aggregated for use by its customers. It is imperative for website X to present only credible and trusted content on its site to satisfy its customer, attract new business, and avoid legal issues. In the context of this blogosphere use case, a blog aggregator service or an user wants to identify the author of a blog without violating privacy laws. In some scenarios, the aggregator service or user may have only incomplete attribution information. In case the author of a blog is listed by name (first name, last name), disambiguation of an author is difficult with multiple blog authors sharing the same name and this may require use of additional user information (for example, email address) without violation of user privacy or privacy laws.

Problems and Limitations
The provenance of Web content in general and blog posts in particular are necessary to users for correct attribution and to aggregating services. Aggregating services require provenance information to not only attribute content but also offer additional services such as ranking of popular blog posts.

Technical Challenges:
Enable Trace back and correct attribution without violating user privacy and privacy laws
Disambiguating content authors with incomplete provenance information
Extend existing vocabulary for representing posts, such as SIOC, to model finer granularity provenance information.

Existing Work
The SIOC project has developed a vocabulary for representing posts. This vocabulary is often used together with FOAF (that represent information about the physical person related to a sioc:User, e.g. its name, lastname, phone, social network, etc.) and SKOS, used mainly to represent topics and taxonomy relationships between these topics.
Three Flagship Scenarios for Provenance

1. **News Aggregator**
   - Theme: blog aggregator wishes to check the veracity of information published by other sources
   - Focus: web information, attribution, licensing

2. **Disease Outbreak**
   - Theme: government sources, scientific sources, and open web data are integrated and analyzed to create policies
   - Focus: e-Government, e-Science, linked open data
   - Issues: provenance for heterogeneous data integration, reproducibility through provenance

3. **Business Contracts**
   - Theme: Customer wishes to check that business delivered according to pre-defined contract
   - Focus: e-Business
   - Issues: provenance as proof, partial release of provenance records to respect IP
1) News Aggregator Scenario

BLOGAGG : CONTENT

1) News Aggregator Scenario

W3C Provenance XG  http://www.w3.org/2005/Incubator/prov/wiki  October 28, 2010
News Aggregator Scenario: Provenance Management
News Aggregator Scenario: Provenance Use

Click to go to provenance info at the original source

Click to see how the provenance was used in the trust calculation

Common Representations for Trust based on Provenance

Subscribe to Changes in Provenance

Click to Display Sources
2) Disease Outbreak Scenario

- Data released by various sources (government, NGOs, news, blogs, etc)
- Social scientists integrate and analyze data, release new data about the spread of the disease
- Biologists analyze data as well, reuse data from social scientists, generate new results
- Analytical results are used by government to define policies to manage the dissemination of the disease
- Processes need to be repeated as new data becomes available over time
3) Business Contract Scenario

Expert A  
Bob’s Website Factory  
Expert B

5  
Existing website design

6  
New design version 1

7  
New design version 2

8  
Verification of quality

9  
Implemented Website

8  
Verification of quality
Business Contract Scenario: Provenance Management

10
Access: Confidential
Existing website design

11
Recorded Documentation
Development process

12
Access: Immutability
Tampering of records by BWF

13
Semantics
Verifications of quality before implementation

14
Semantics
Post-hoc sign-off after implementation

BWF’s Claim
Customer Inc.’s Claim

Implemented Website
Business Contract Scenario: Provenance Use

15 Generate proof of claim

16 Generate proof of claim

Recorded Documentation Development process

17 Two independent verifications of quality

New design

Implemented Website

Customer Inc.'s Claim

BWF's Claim

Poor summary

Non-independent
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State of the Art Report

- Created tagged bibliography collection
- Compilation of survey articles on provenance
- Invited presentations from people outside the group and in various communities
- Mapped 10 well-known provenance vocabularies
- Analysis of 3 flagship scenarios regarding state of the art
- Created gap analysis on what is missing to address the three flagship scenarios
Existing Provenance Vocabularies

- Many provenance vocabularies exist
  - Originated in scientific data management, workflows, library sciences, semantic web, etc.

- Provenance group mapped ten well-known vocabularies:
  1. Open Provenance Model (OPM)
  2. Dublin Core
  3. PREMIS
  4. WOT Schema
  5. Provenance Vocabulary
  6. Provenir ontology
  7. Proof Markup Language
  8. SWAN Provenance Ontology
  9. Semantic Web Publishing Vocabulary
  10. Changeset Vocabulary

- Used OPM as a reference model for the mappings
- Used SKOS when appropriate to express mappings
Provenance Spans Many Areas of Research

- **Web**
  - Tracking content dissemination on the web

- **Workflow Systems**
  - Computations leading to new data products, reproducibility
  - Reproducibility

- **Databases**
  - Query derivation, aggregations of data, streaming

- **Knowledge representation and reasoning**
  - Justification and explanation of reasoning

- **Argumentation**
  - What is taken into account to make a judgment

- **Information retrieval**
  - Question answering when documents are contradictory
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Provenance and Web Architecture: Provenance Situations to Consider

1. SIMPLE OH YEAH SITUATION
   • User retrieves a document, then clicks on “oh yeah” button, then site returns a provenance record

2. LICENSING SITUATION
   • User retrieves a document (eg an image), then wants to check permission to use

3. REFERRAL SITUATION
   • Site refers queries about provenance in terms of pointers to other site’s provenance facilities

4. REPEATED QUERIES SITUATION
   • Service repeatedly queries a site, wants provenance for all the answers

5. VERSIONING SITUATION
   • User retrieves a document, then wants to see its provenance, but the document has been updated in the original site (its provenance as well)

6. DYNAMIC RESOURCE SITUATION
   • User retrieves a resource that is dynamically created
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Towards a Standard for Provenance

- Currently discussing the charter of a Provenance Working Group
- Agreement on the following objectives:
  - Define a provenance exchange language and protocol to publish and access provenance
  - The scope of this language will be any resource, not just semantic web objects
  - The exchange language should have a low entry point to facilitate widespread adoption, therefore it should be easy to do simple things
  - It should have a small core model and allow for extensions (ie, species/profiles, integration of other more expressive/complementary vocabularies/frameworks)
  - Some deliverables should be released early, WG should end in 18 months or 2 years
THANK YOU

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