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DFRWS
DIGITAL FORENSIC RESEARCH WORKSHOP

August 5, 2014

A Complete Formalized Knowledge Representation Model for Advanced Digital Forensics Timeline Analysis

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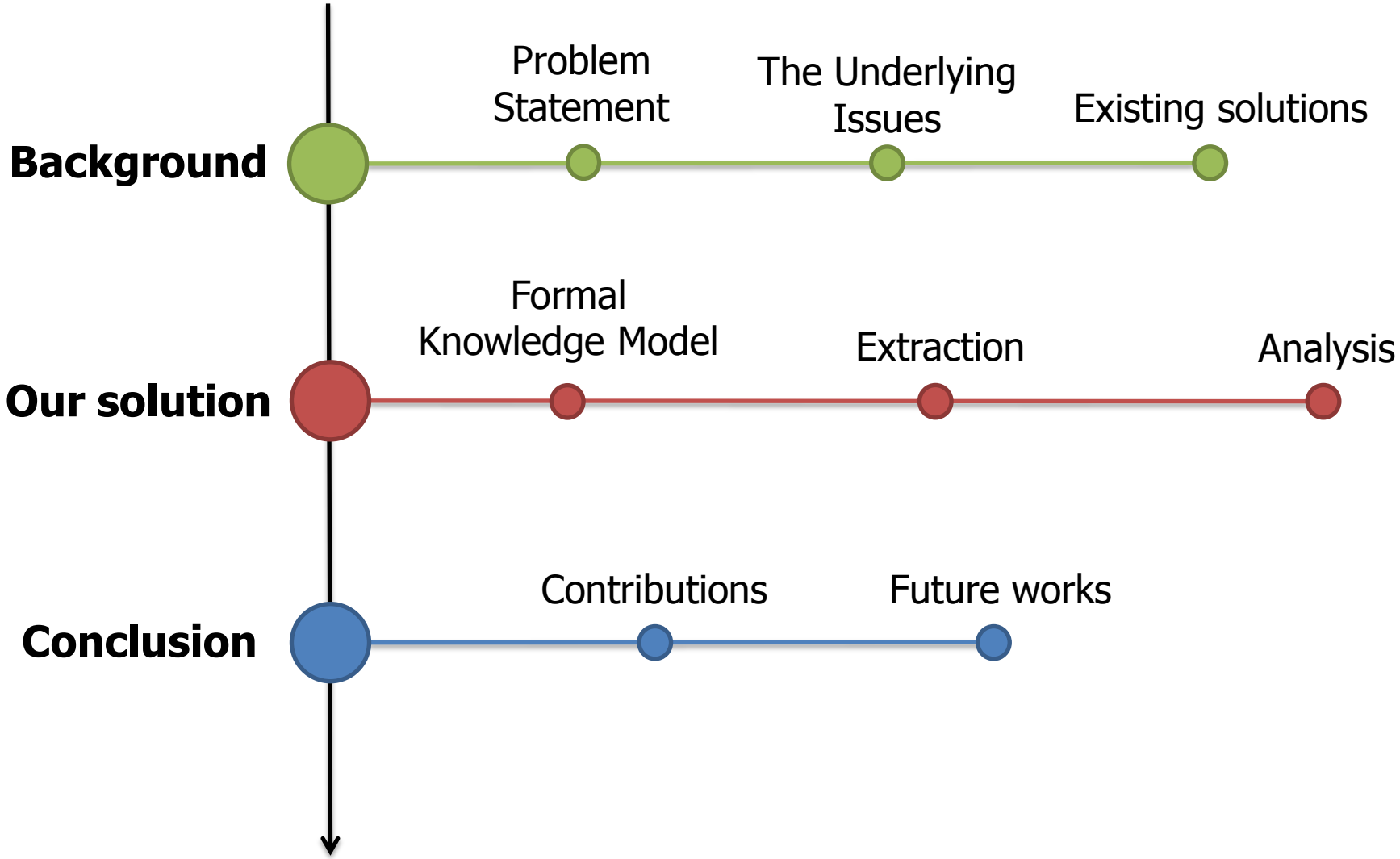
Outline



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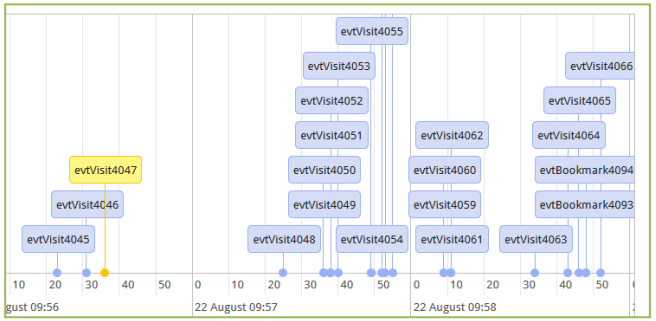
Event Reconstruction

Footprints



Timeline

Conclusions of the investigation

GOAL: Determine the circumstances of the incident

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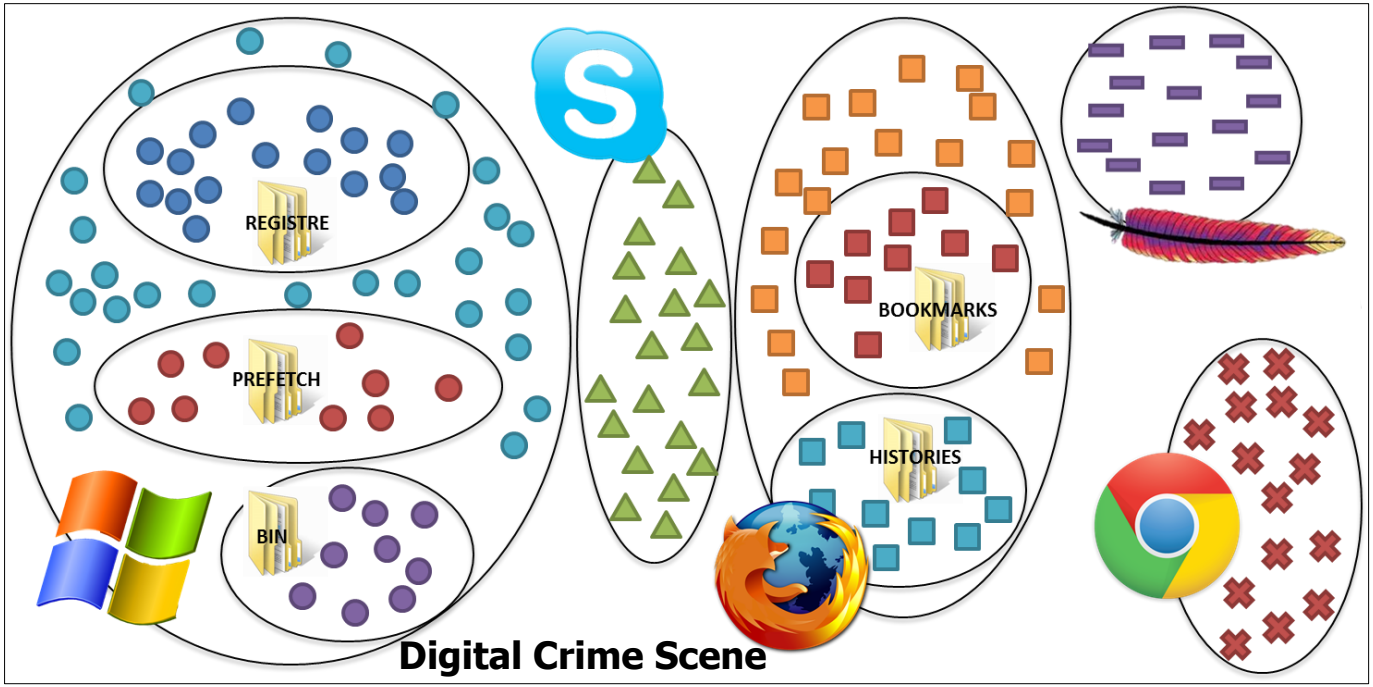
The Underlying Issues

Technical gaps

- Large amount of data
- Heterogeneity (Semantic, Format, Time)



Legal requirements

- Credibility
- Veracity
- Precision
- Reproducibility

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Existing Solutions

ECF, FORE, Finite state machine approach, Zeitline, Neural networks appraoch, CyberForensic TimeLab, etc.

log2timeline by Kristinn Gudjonsson

Super-timelines using a large number of sources

- Windows Event Logs
- Web Browsers Histories
- Apache logs
- PDF document metadata
- Firewall logs
- etc.

```
Yoan@Checksem-PC /cygdrive/j/Local Workspace/plaso
$ ./log2timeline ../output.dump ../Scenarios/scenario1/EnCase/scenario1.E01 > log.txt

Yoan@Checksem-PC /cygdrive/j/Local Workspace/plaso
$ ./psort -w ../timeline.txt ../output.dump > log.txt
```

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Knowledge Model

How to analyze this large amount of data?

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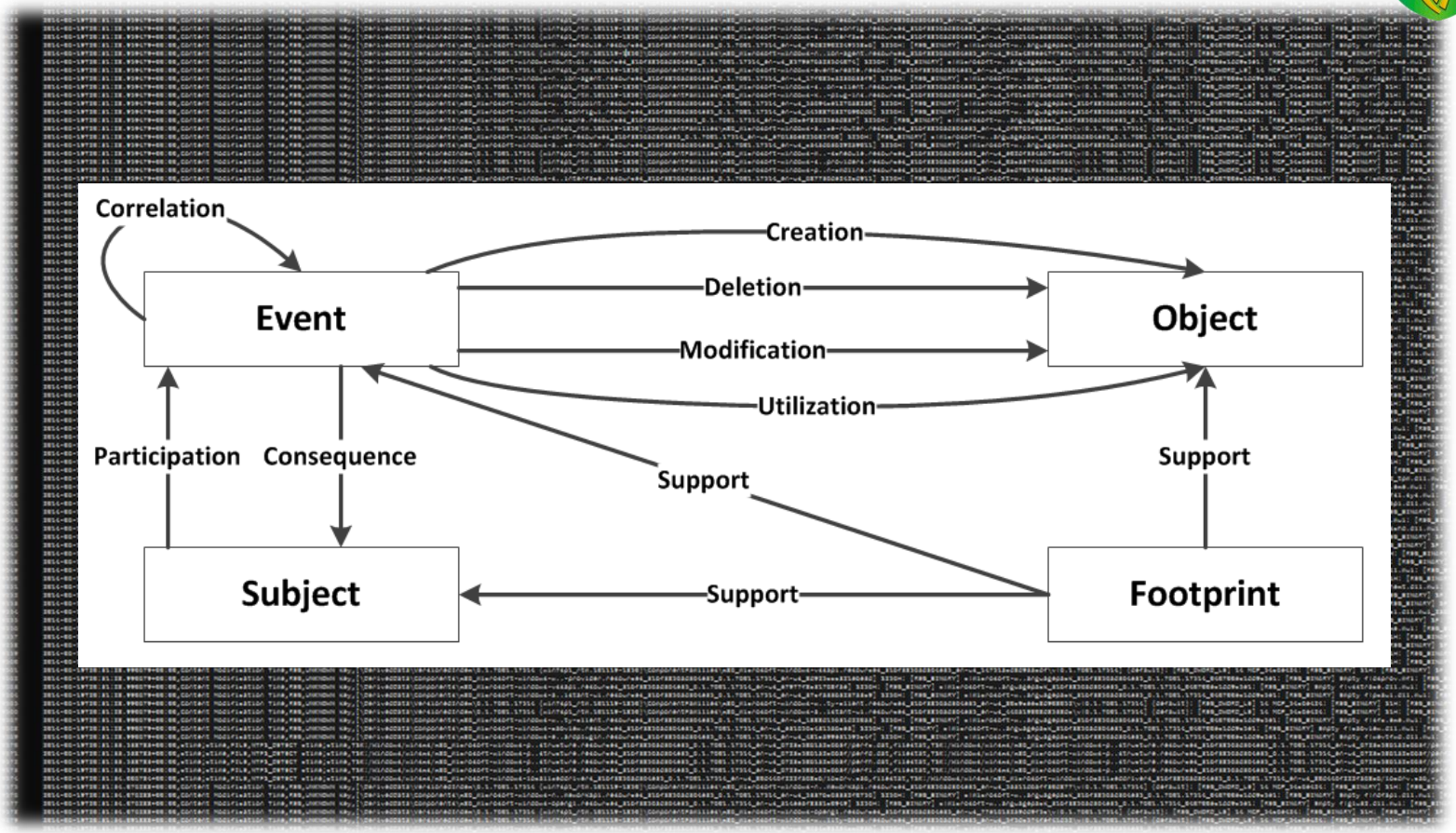
Knowledge Model



Introduce a semantically rich knowledge representation of events to enhance analysis capabilities

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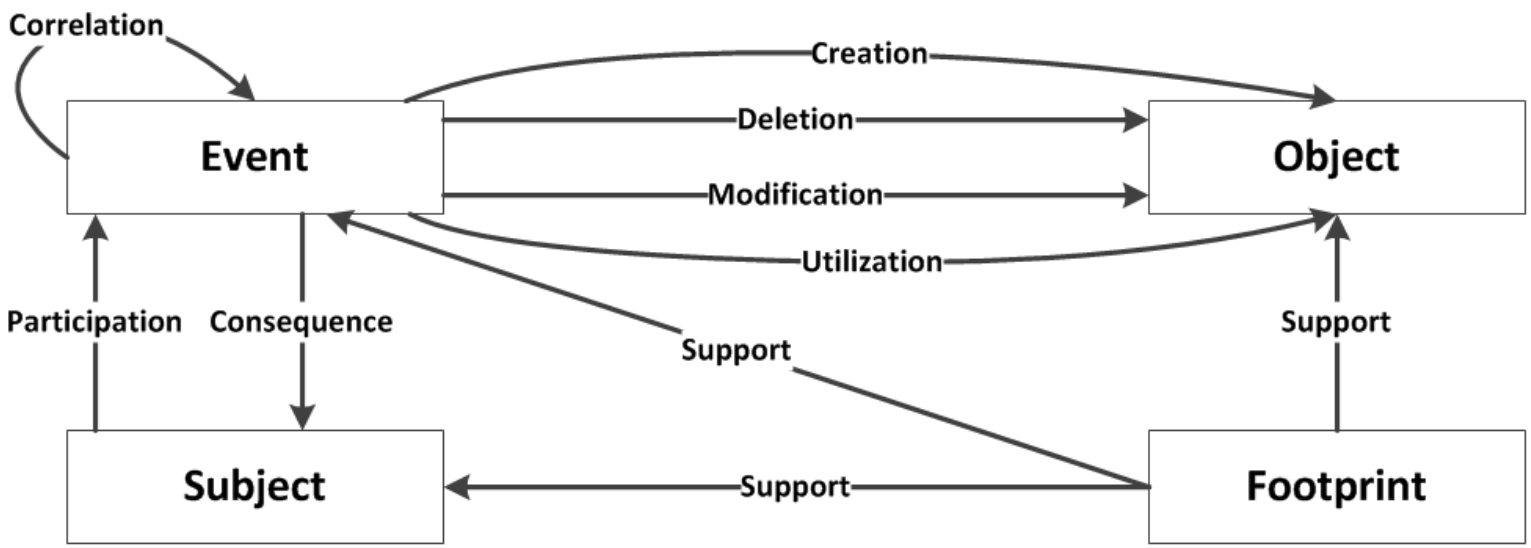
Knowledge Model



Entities

- $s \in S = \{a \in A_s \mid s\ \alpha_s\ a\}$
- $o \in O = \{a \in A_o \mid x\ \alpha_o\ a\}$
- $O \subseteq \wp(A_o)$
- $f \in F = \{f \in A_f \mid x\ \alpha_f\ a\}$
- $e \in E = \{t_{start}, t_{end}, l, S_e, O_e, E_e\}$
- $S_e = \{s \in S \mid e \in E, s\ \sigma_s\ e\}$
- $O_e = \{o \in O \mid e \in E, e\ \sigma_o\ o\}$
- $E_e = \{x \in E \mid e \in E, e\ \sigma_e\ x\}$

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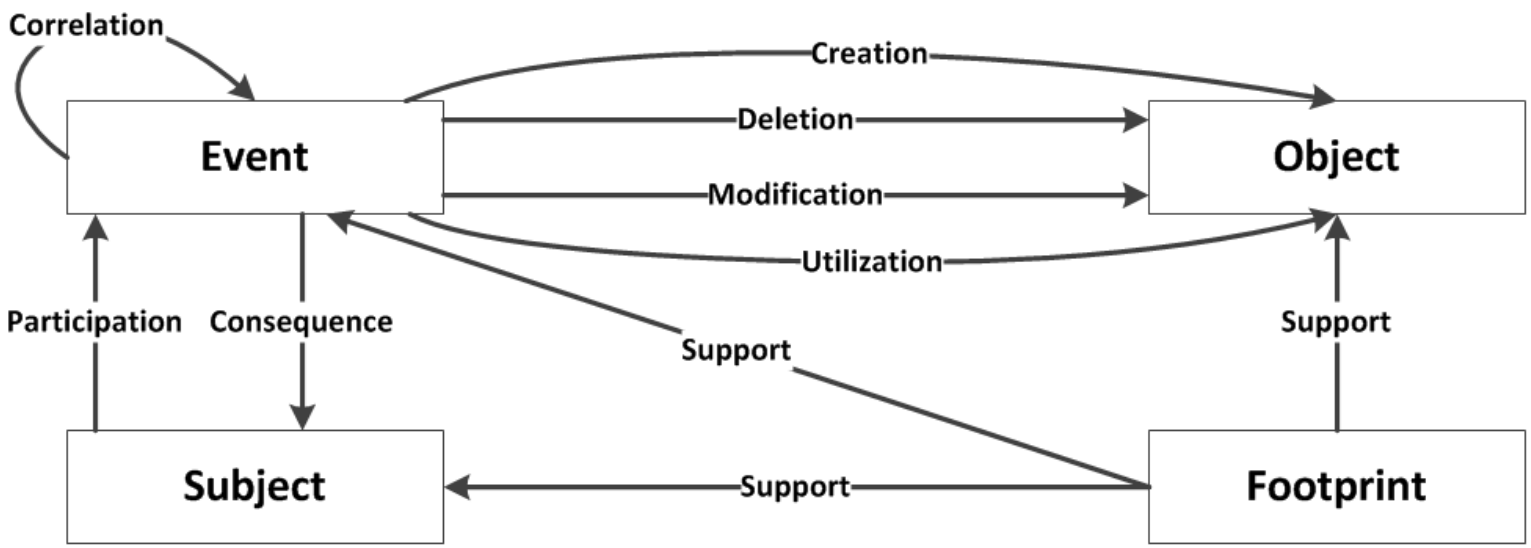
Knowledge Model



Relationships

- $\sigma_s = \{participation, repercussion\}$
- $\sigma_o = \{creation, suppression, modification, utilization\}$
- $\sigma_e = \{correlation\}$
- $\sigma_f = \{support\}$
- $support(en \in \{E \times O \times S\}) = \{f \in F \mid f\ \sigma_f\ en\}$

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Operators

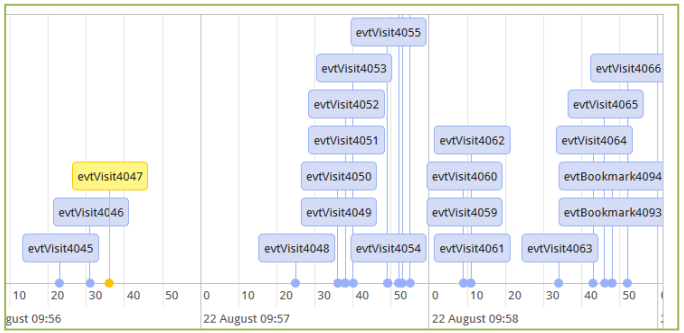
Footprints left on the crime scene

Extraction and Mapping Operators

Knowledge Base

Inference Operators

Analysis Operators



Enhanced Timeline

Conclusions

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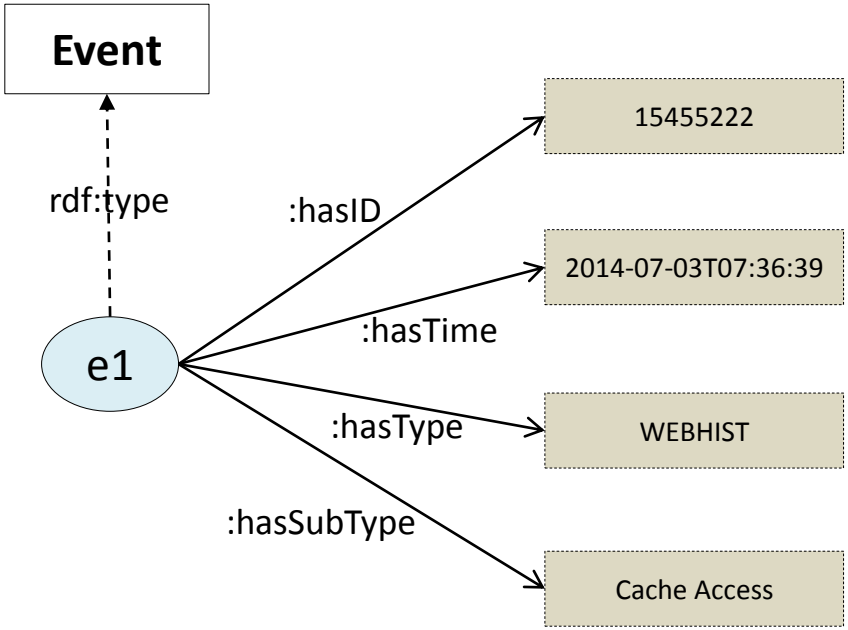
From Raw Data To Giant Graphs

2014-07-03T07:36:39.408000+00:00,Last Visited Time,WEBHIST,MSIE Cache File URL record,Location: Visited: Yoan@file:///C:/Users/Yoan/Pictures/dfrws12-039.jpg Number of hits: 2 Cached file size: 0,msiecf,TSK:/Users/Yoan/AppData/Local/Microsoft/Windows/History/History.IE5/index.dat,-,3,378480



Mapping: 1st Example

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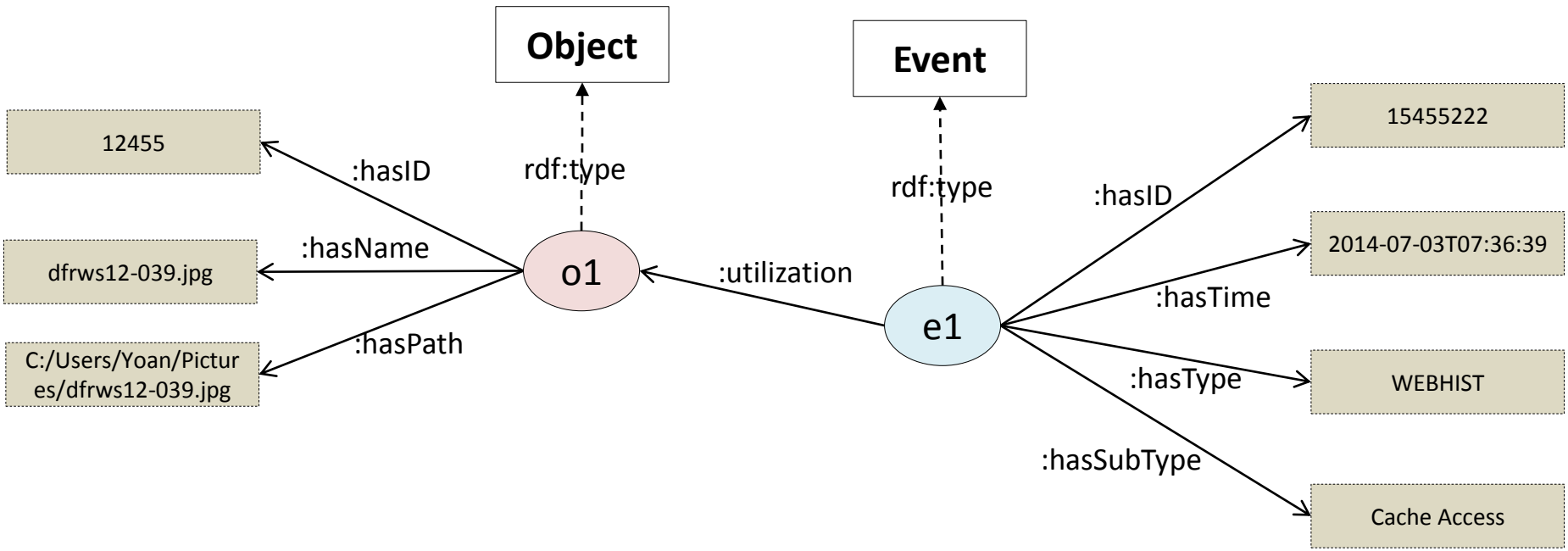

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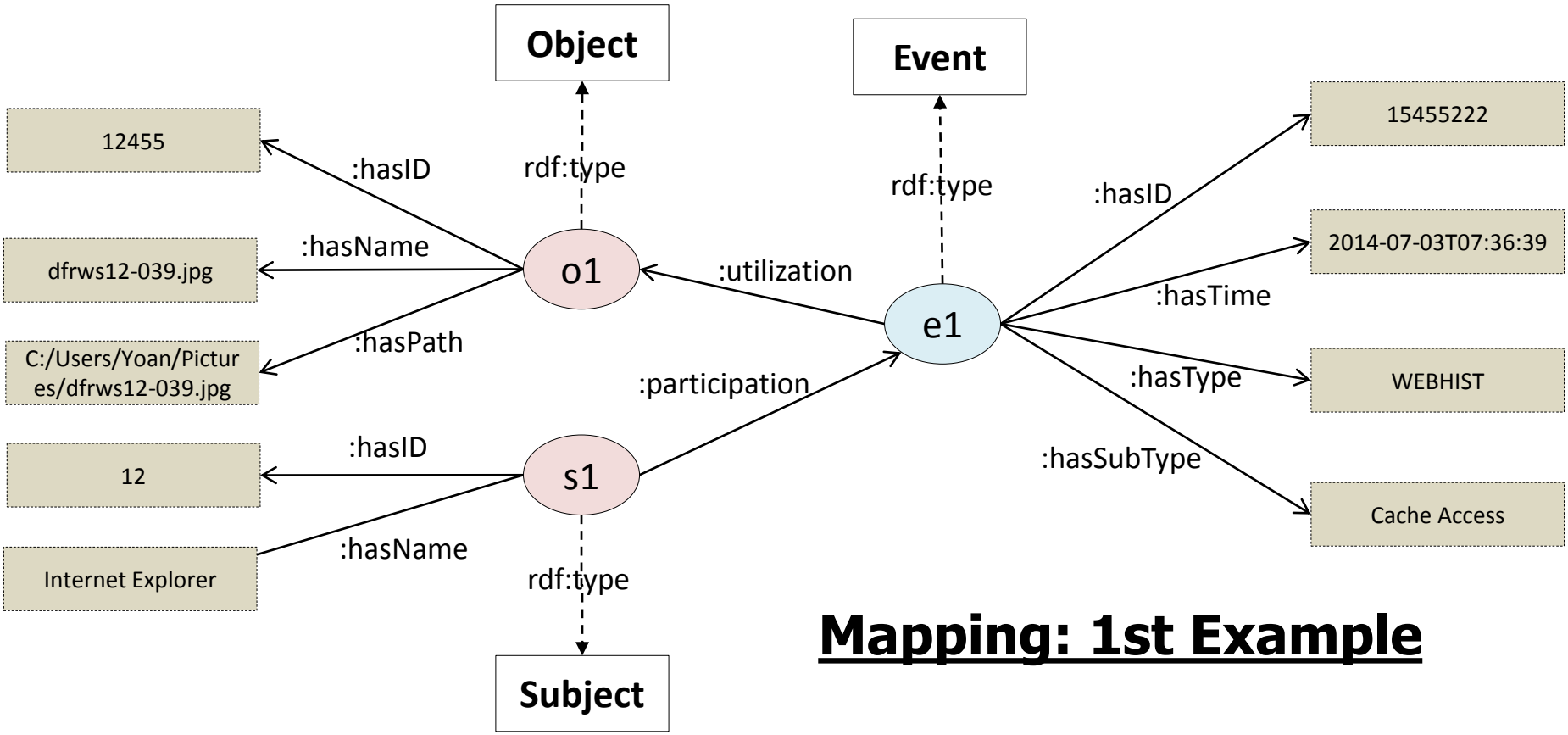

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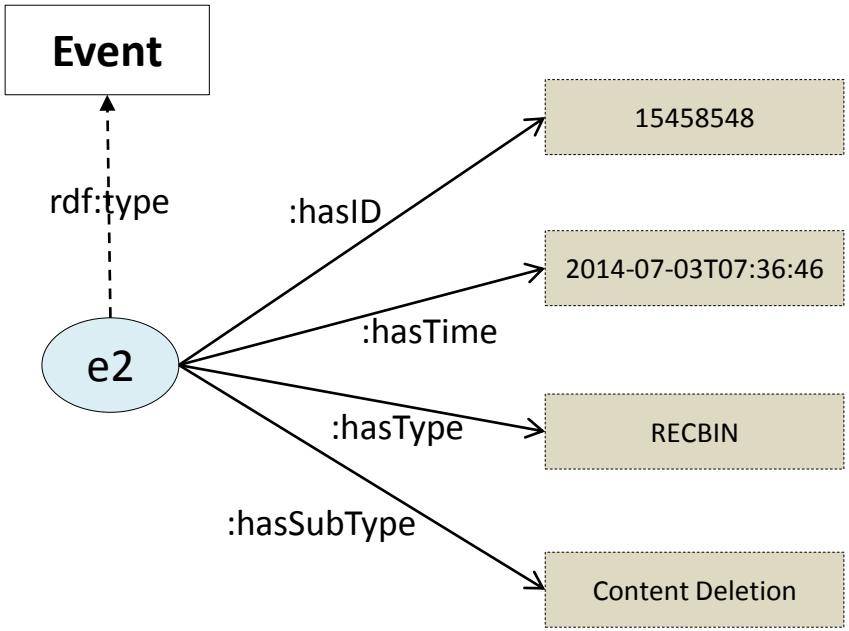

Mapping: 2nd Example

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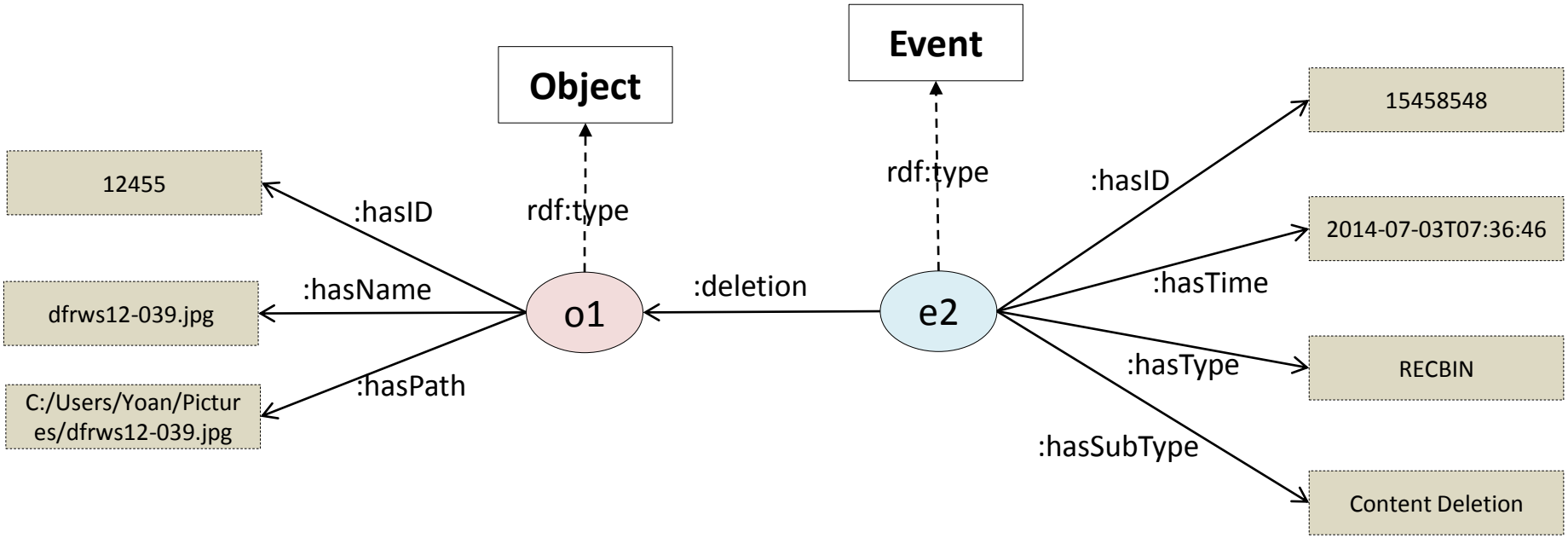

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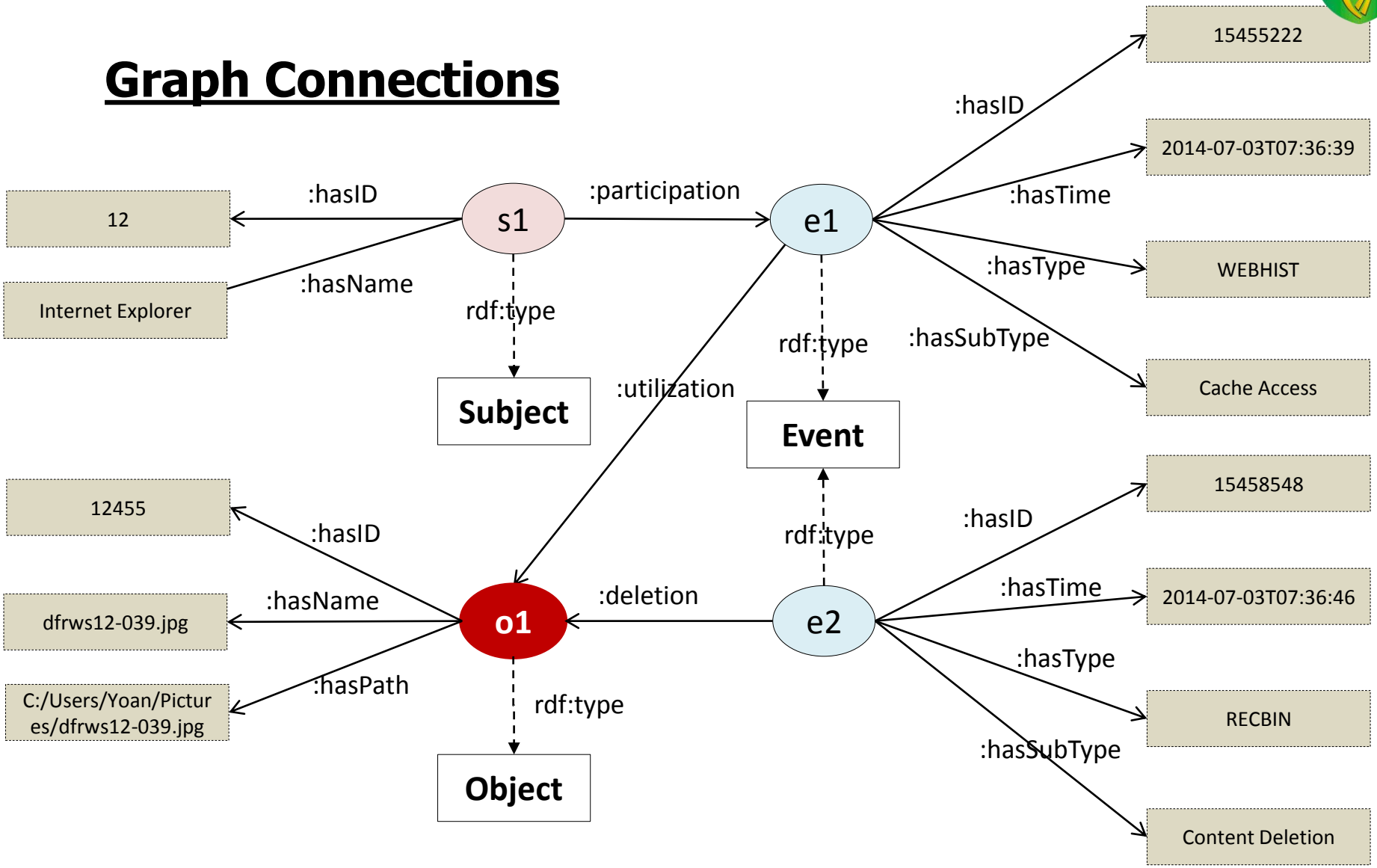
Graph Connections



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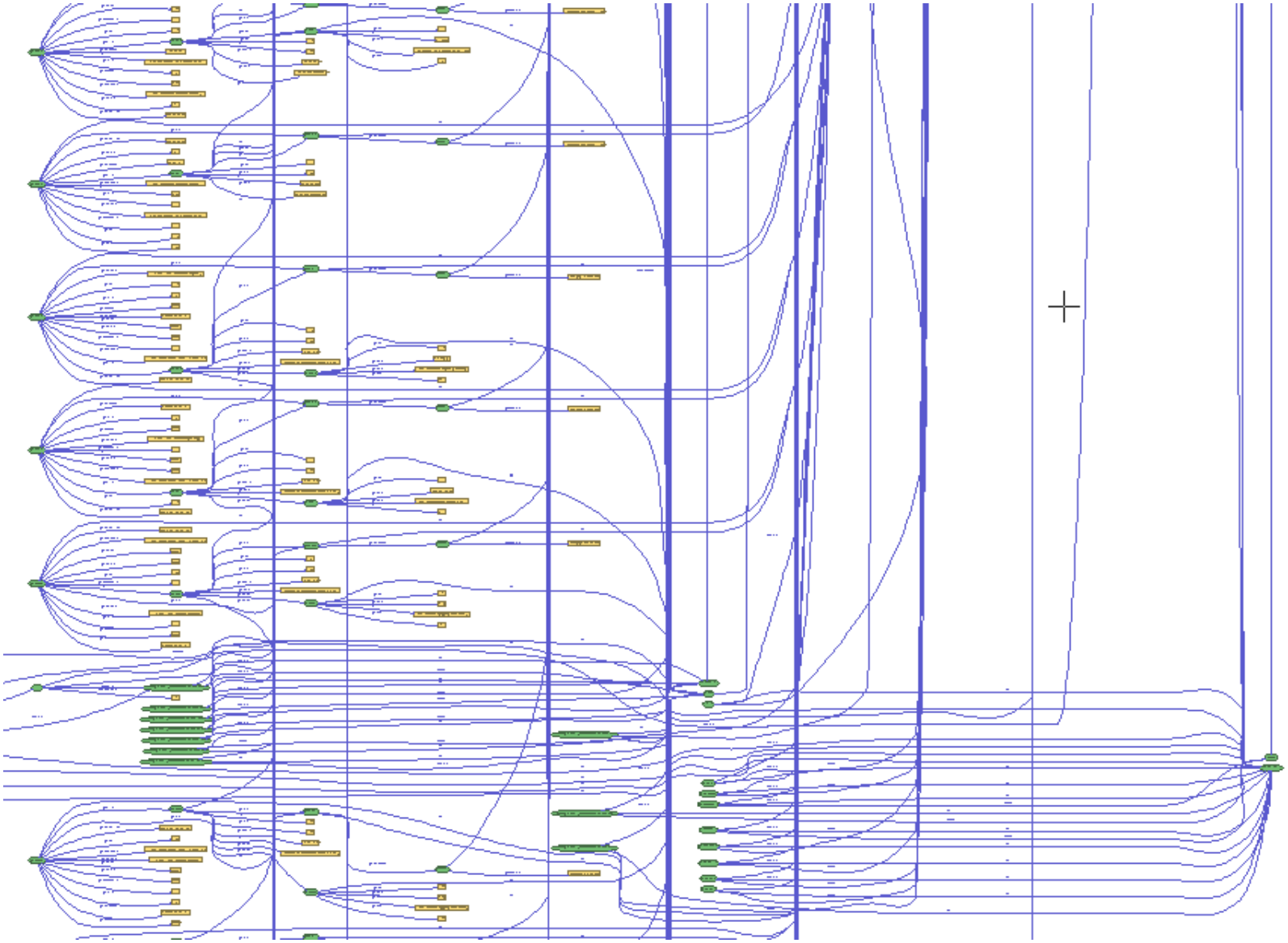

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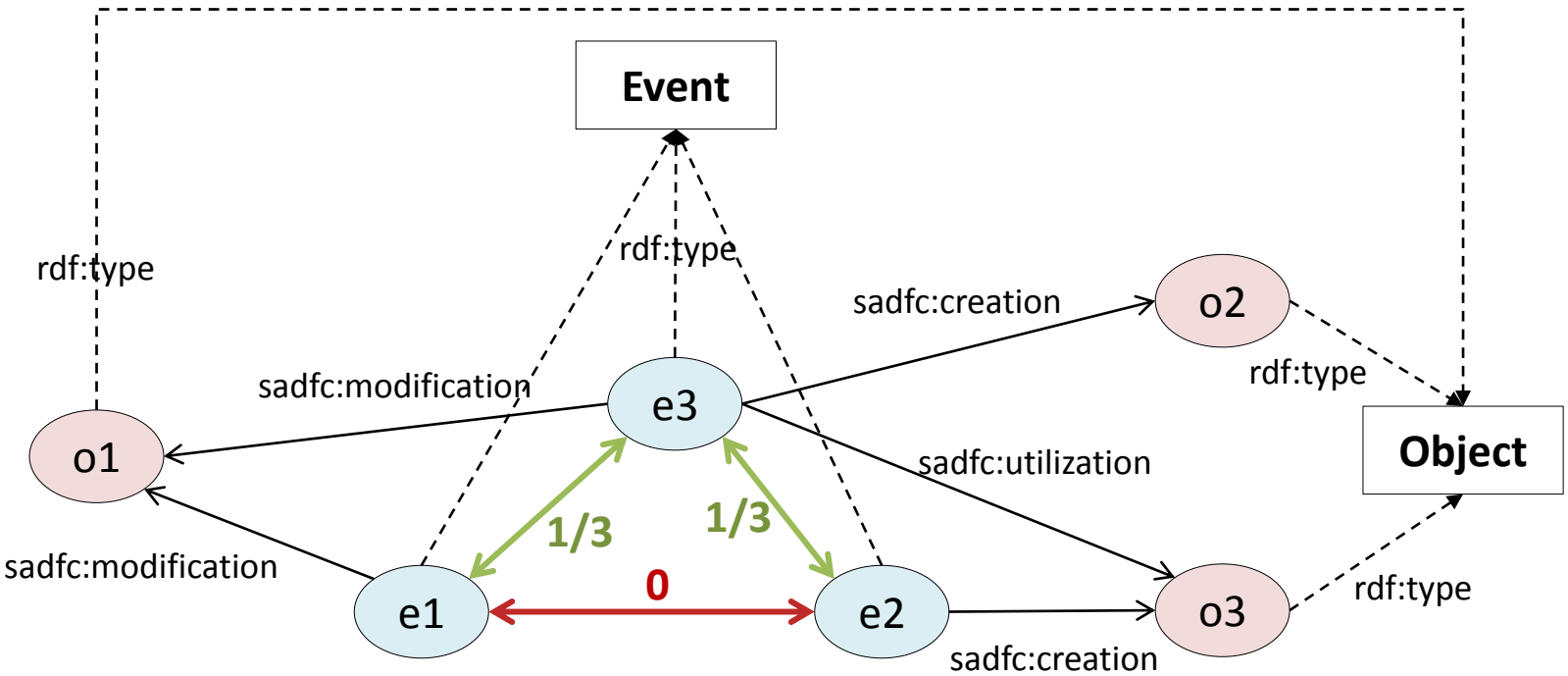
Automatic Analysis Operators



$$Correlation_O(e,x) = |O_e \cap O_x| / \max(|O_e|, |O_x|)$$

Object Correlation	Subject Correlation
Event Correlation	
Temporal Correlation	Knowledge-Based Correlation

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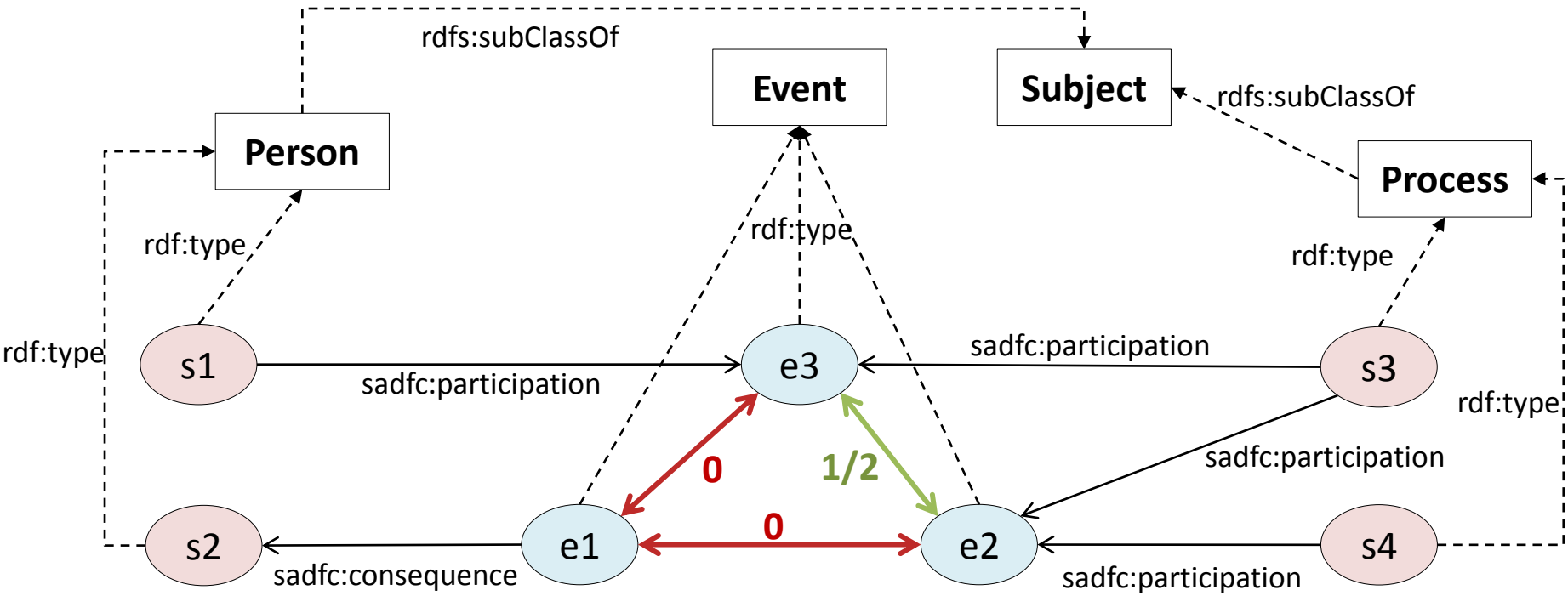
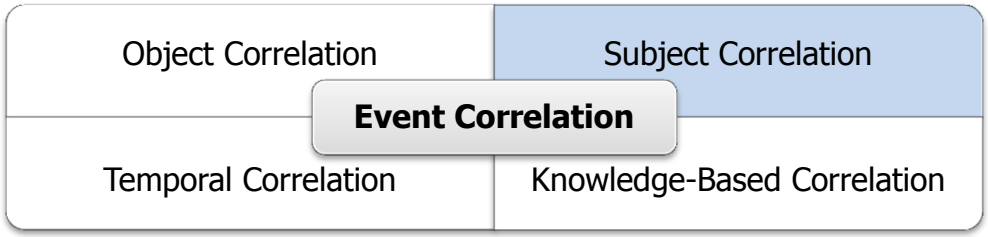


$$Correlation_S(e,x) = |S_e \cap S_x| / \max(|S_e|, |S_x|)$$



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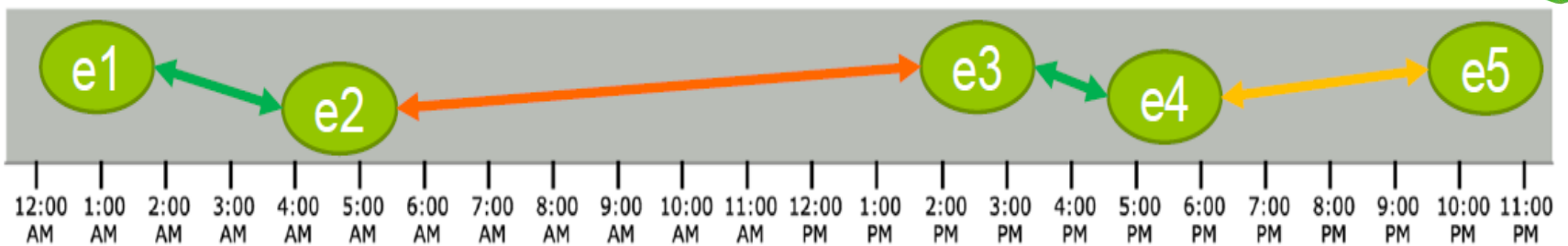
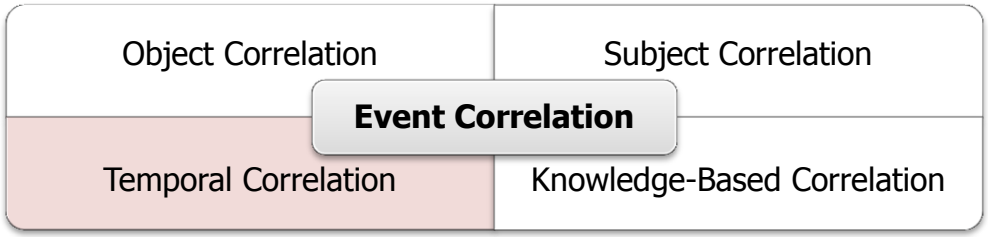
Automatic Analysis Operators



$$Correlation_T(e,x) = \alpha \times starts(e,x) + \alpha \times equals(e,x) + meets(e,x) + overlaps(e,x) + during(e,x) + finishes(e,x) + before(e,x)$$

Functions	Constraints	Example
before(X,Y)	$x_{t_{end}} < y_{t_{start}}$	X Y
equal(X,Y)	$x_{t_{start}} = y_{t_{start}}$ && $x_{t_{end}} = y_{t_{end}}$	X Y
meets(X,Y)	$x_{t_{end}} = y_{t_{start}}$	X Y
overlaps(X,Y)	$x_{t_{start}} < y_{t_{start}}$ && $x_{t_{end}} > y_{t_{start}}$	X Y
during(X,Y)	$x_{t_{start}} > y_{t_{start}}$ && $x_{t_{end}} < y_{t_{end}}$	X Y
starts(X,Y)	$x_{t_{start}} = y_{t_{start}}$	X Y
finishes(X,Y)	$x_{t_{end}} = y_{t_{end}}$	X Y



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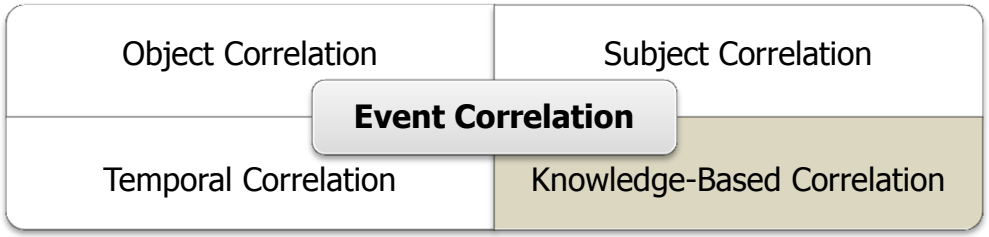
Automatic Analysis Operators

2014-06-20T13:57:16.544000+00:00 | Creation Time | WEBHIST | Firefox History | Bookmark URL CheckSem - Semantic Intelligence Research (http://checksem.u-bourgogne.fr/www/)| sqlite | TSK:/Users/Yoan/AppData/Roaming/Mozilla/Firefox/Profiles/94zxtt2a.default/places.sqlite | - | 3 | 373176 |

2014-06-20T13:57:21.474000+00:00 | Page Visited | WEBHIST | Firefox History | http://checksem.u-bourgogne.fr/www/ (CheckSem - Semantic Intelligence Research Host: checksem.u-bourgogne.fr visited from: http://checksem.u-bourgogne.fr/www/ (checksem.u-bourgogne.fr) Transition: BOOKMARK | sqlite | TSK:/Users/Yoan/AppData/Roaming/Mozilla/Firefox/Profiles/94zxtt2a.default/places.sqlite | - | 3 | 373182 |

$$Correlation_{KBR}(e,x) = \sum_{r=1}^{n} rule_r(e,x)$$

With $rule_r(e,x) = 1$ if the rule is satisfied and 0 otherwise



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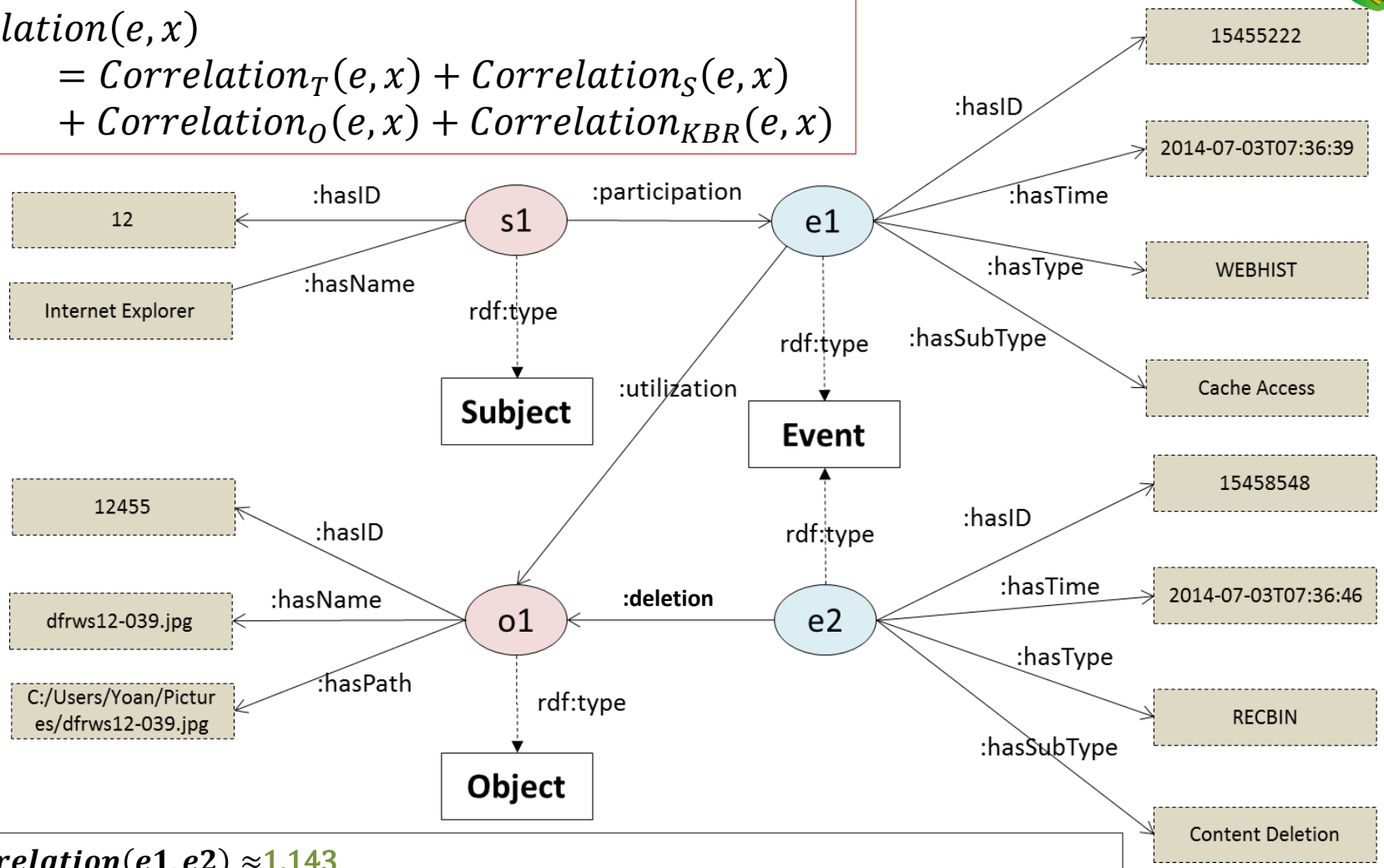
Automatic Analysis Operators

$$Correlation(e,x) = Correlation_T(e,x) + Correlation_S(e,x) + Correlation_O(e,x) + Correlation_{KBR}(e,x)$$



$\boldsymbol{Correlation(e1,e2)} \approx$ 1,143

- $Correlation_O(e1,e2)$: *o1* ➔ ***1/1 = 1***
- $Correlation_S(e1,e2)$: $\emptyset$ ➔ **0/1 = 0**
- $Correlation_T(e1,e2)$: 2014-07-03T07:36:39 <-> 2014-07-03T07:36:46 ➔ ≈**0,143**
- $Correlation_{KBR}(e1,e2)$: **0**

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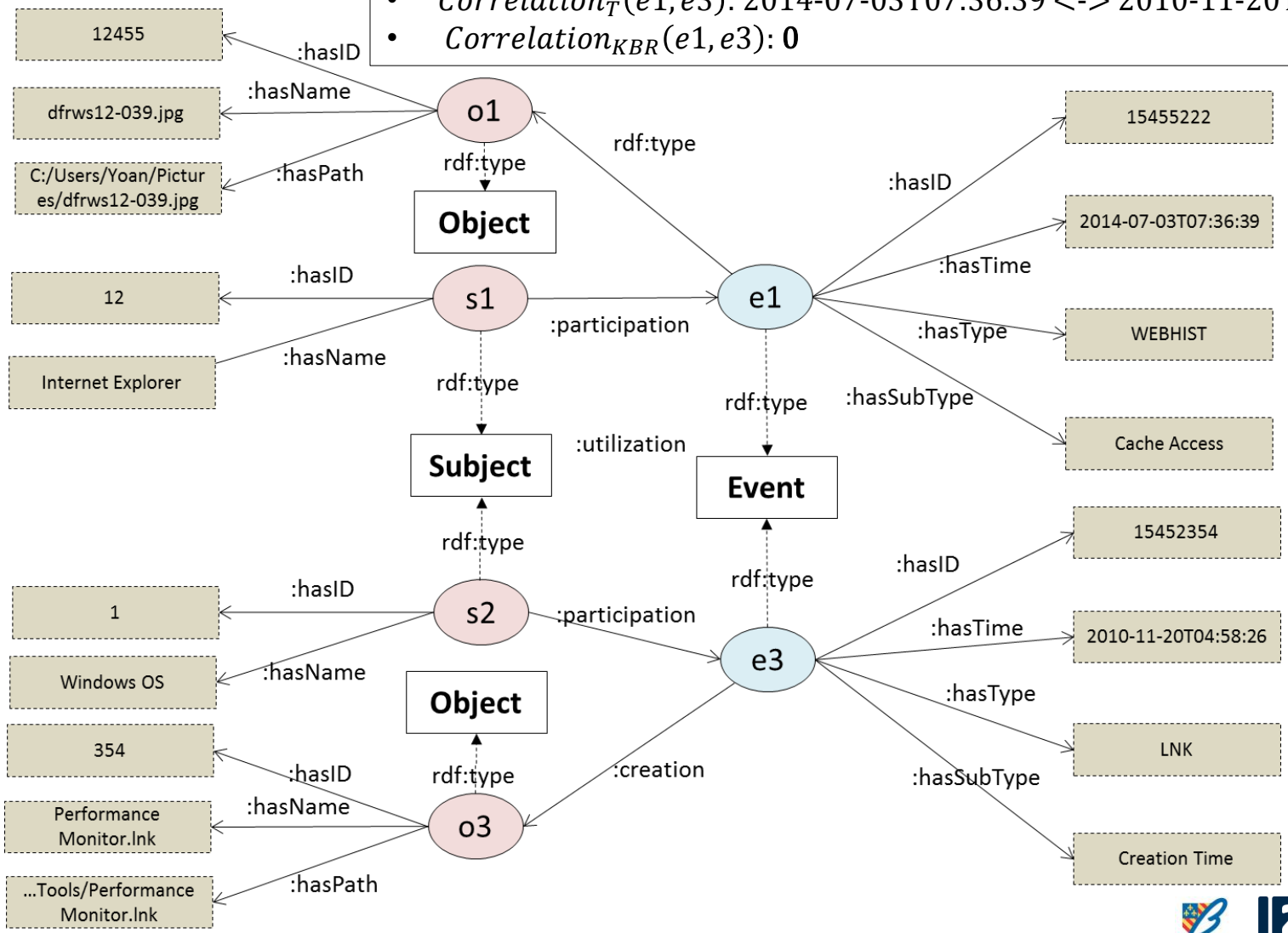
Automatic Analysis Operators

$\boldsymbol{Correlation(e1, e3)} \approx \mathbf{0}$

- $Correlation_O(e1, e3)$: $\emptyset$ ➔ $\mathbf{0/1 = 0}$
- $Correlation_S(e1, e3)$: $\emptyset$ ➔ $\mathbf{0/1 = 0}$
- $Correlation_T(e1, e3)$: 2014-07-03T07:36:39 <-> 2010-11-20T04:58:26 ➔ $\approx \mathbf{0}$
- $Correlation_{KBR}(e1, e3)$: $\mathbf{0}$



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Contributions

Data volume

- Automatic Operators
- Scalable Technologies

Heterogeneity

- Unified model of knowledge representation
- Extractors dedicated to each source

Credibility

- Based on a formal knowledge representation

Reproducibility

- Storing information about provenance

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Future Works

New Analysis operators

New Semantic dimensions

Mechanisms for knowledge checking and reproducibility

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