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

By

Yoan Chabot, Aurelie Bertaux, Christophe Nicolle and Tahar Kechadi

Presented At

The Digital Forensic Research Conference

DFRWS 2014 USA Denver, CO (Aug 3rd - 6th)

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DIGITAL FORENSIC RESEARCH WORKSHOP

August 5, 2014

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

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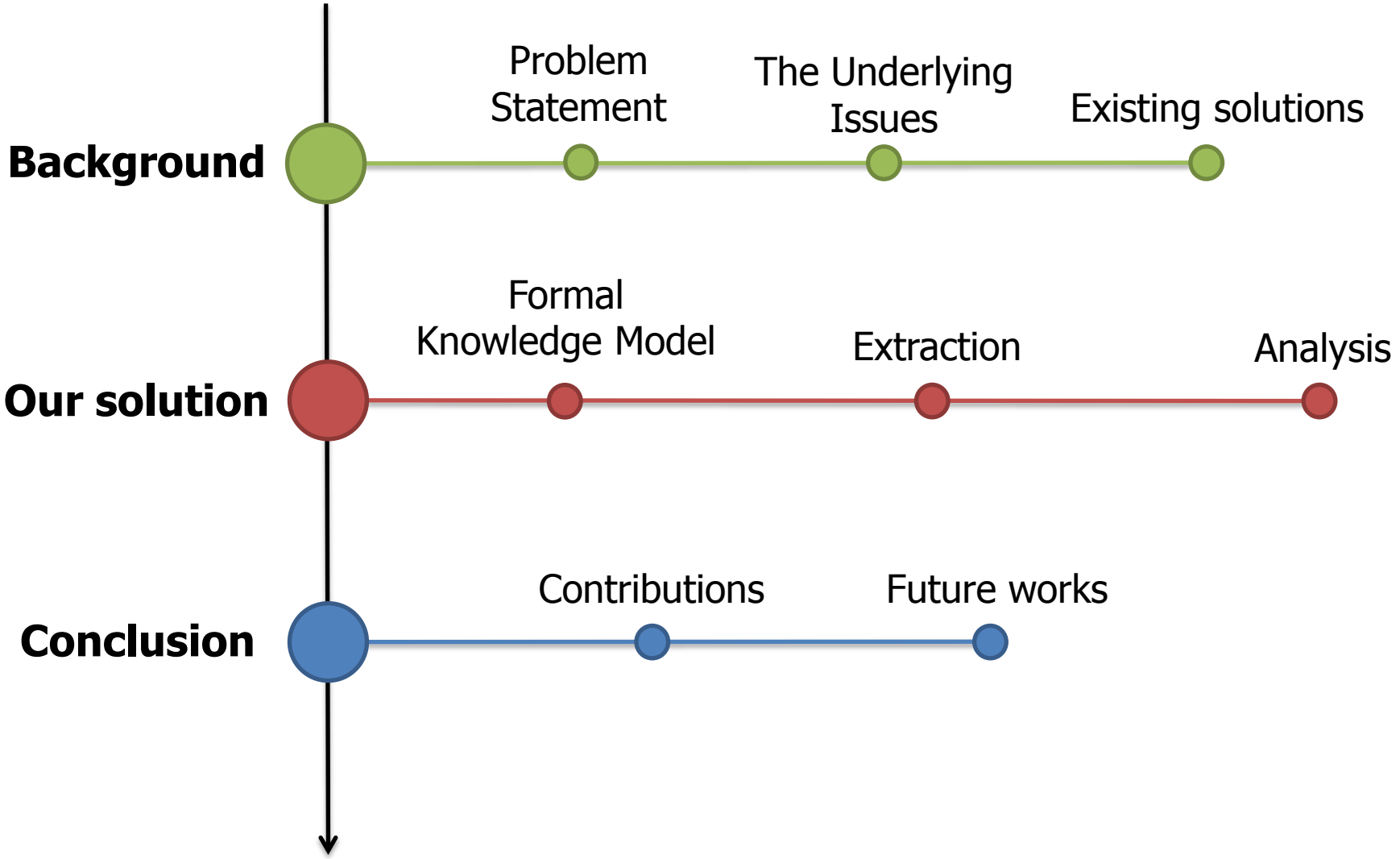
Outline



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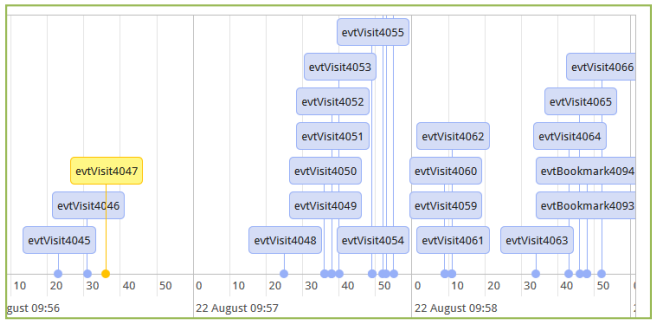
Problem Statement

Event Reconstruction

Footprints

Conclusions of the investigation



Timeline

GOAL: Determine the circumstances of the incident

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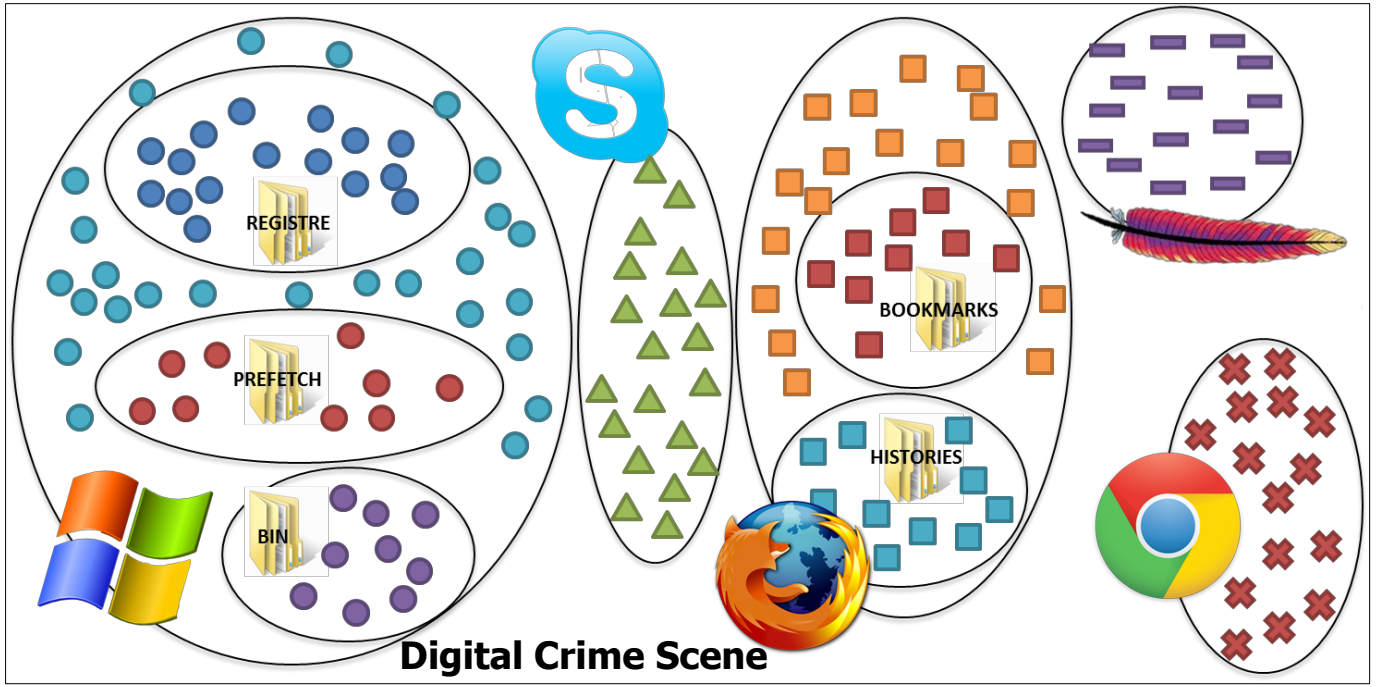
The Underlying Issues

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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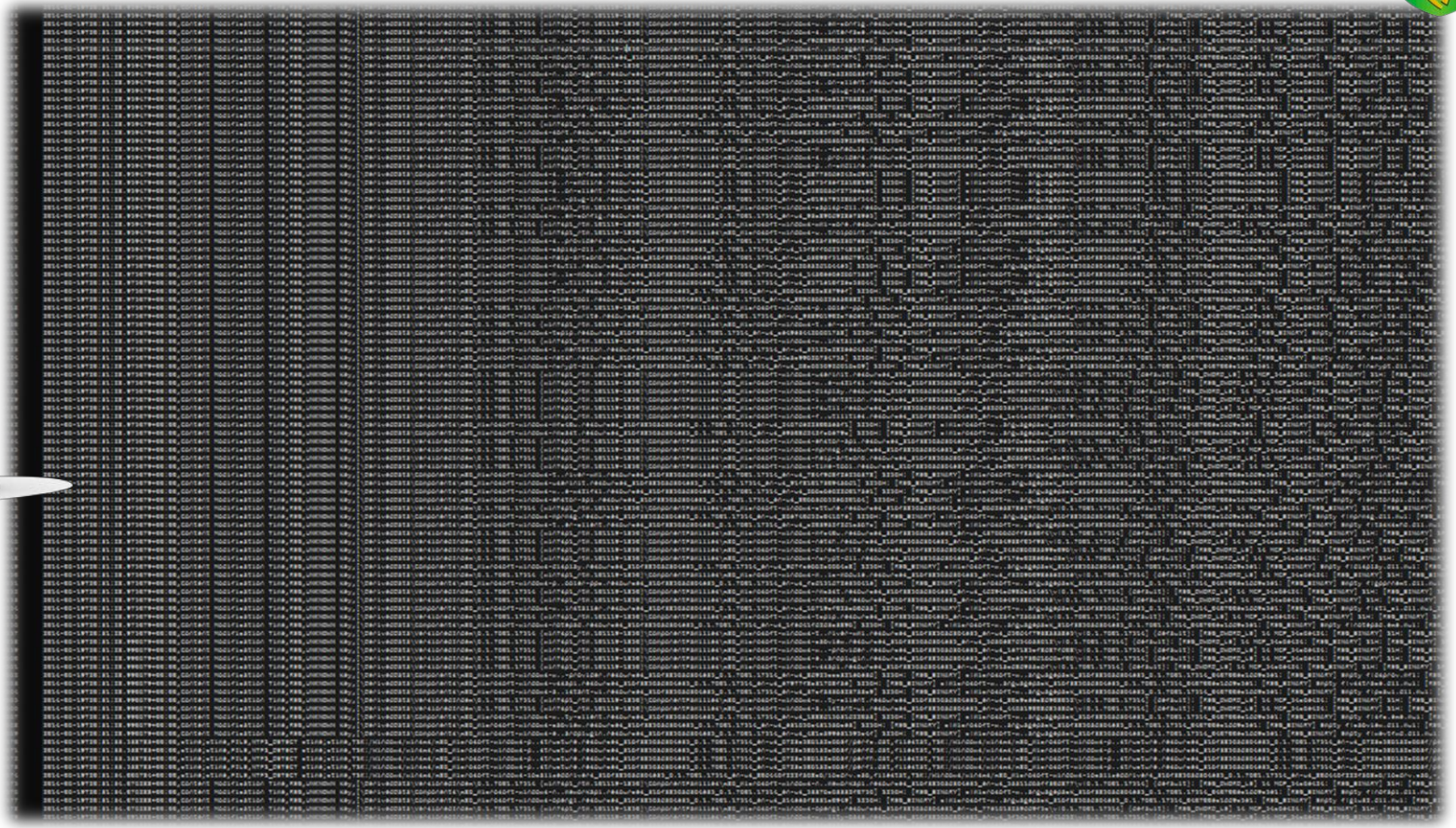
Knowledge Model



How to analyze this large amount of data?

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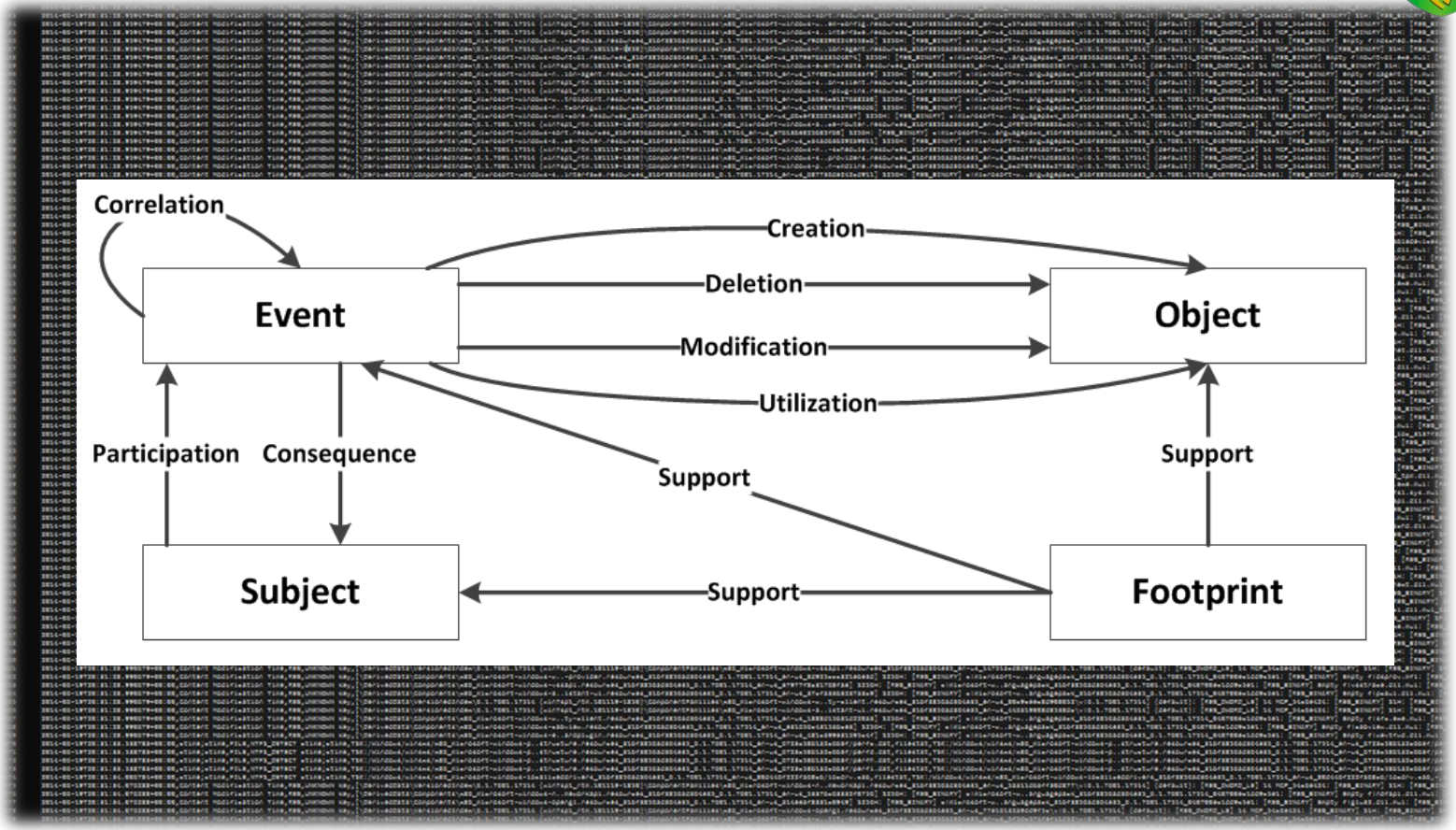
Knowledge Model



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

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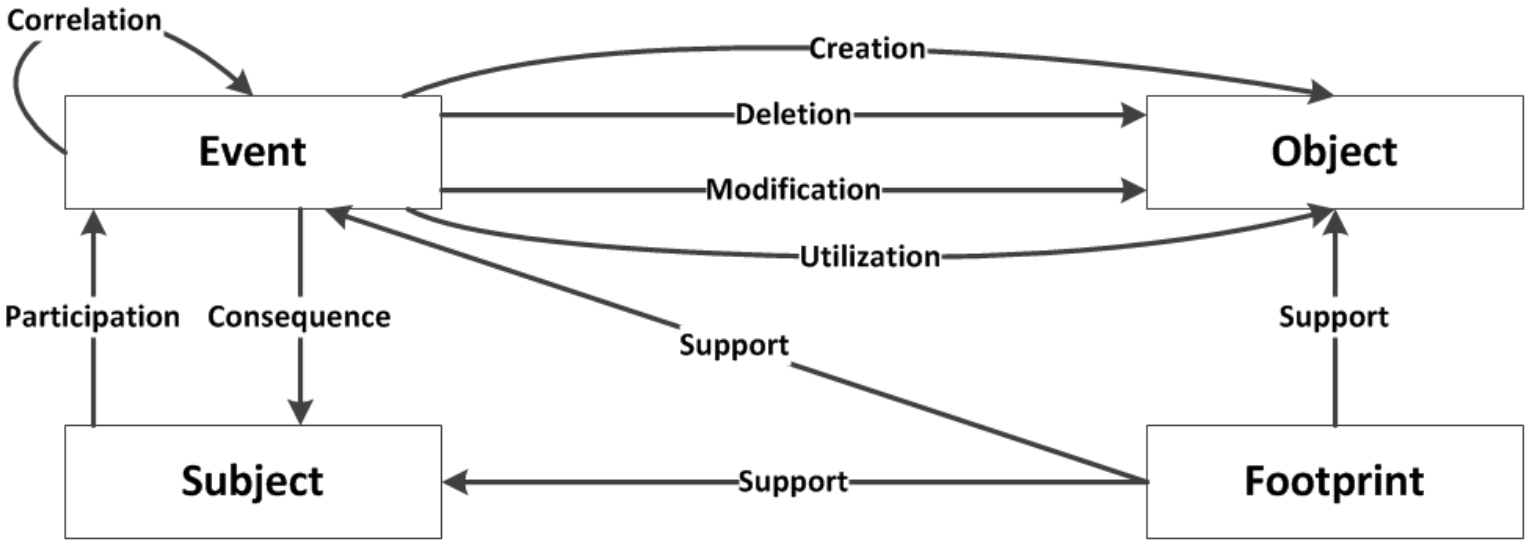
Knowledge Model



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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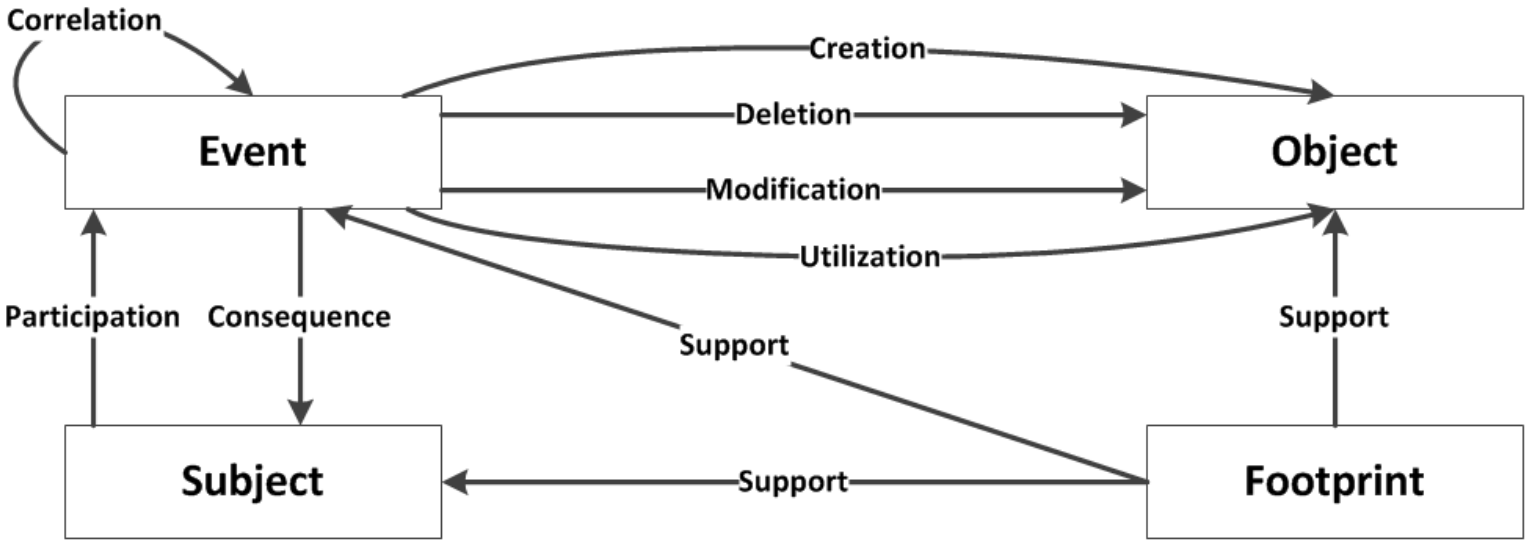
Knowledge Model



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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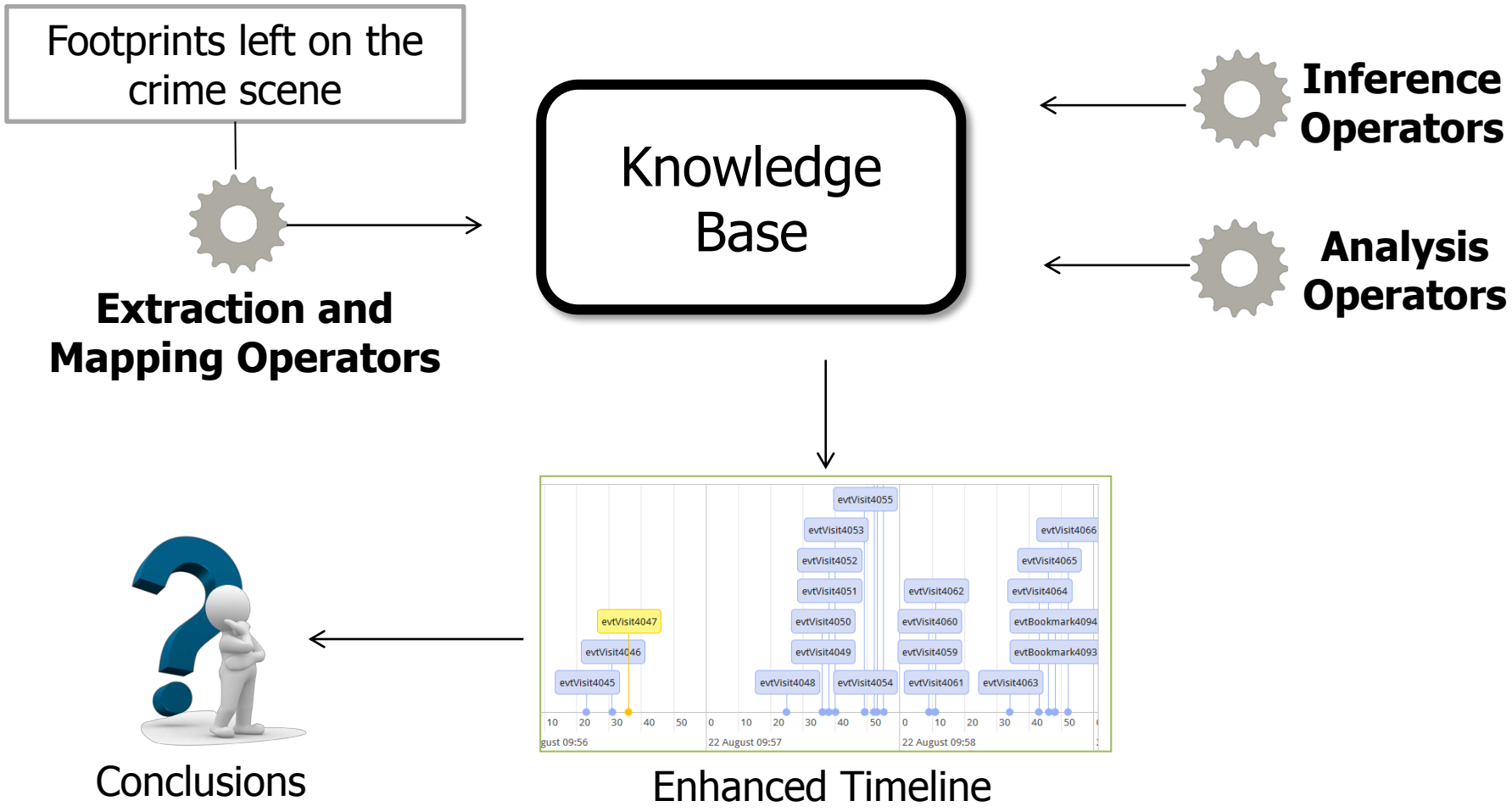
Operators



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From Raw Data To Giant Graphs

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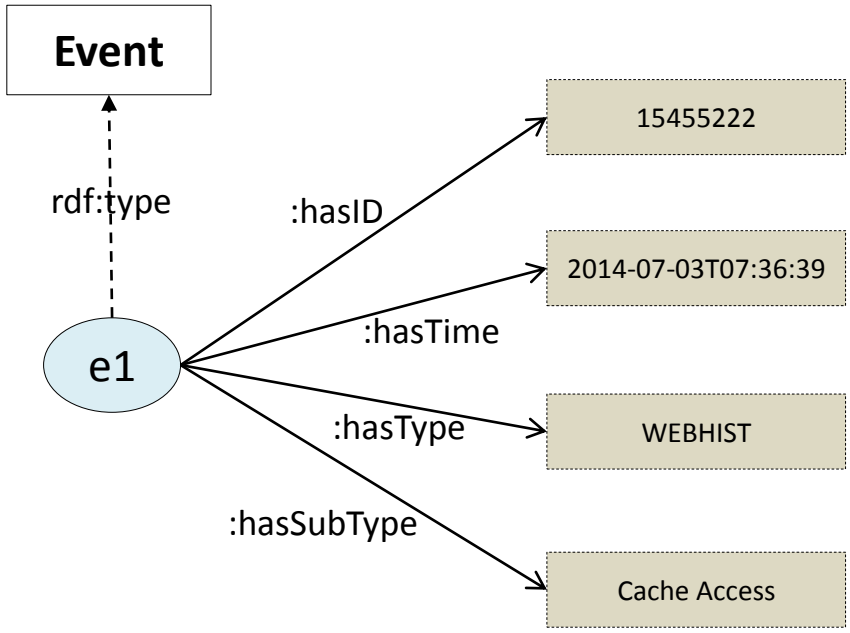

Mapping: 1st Example

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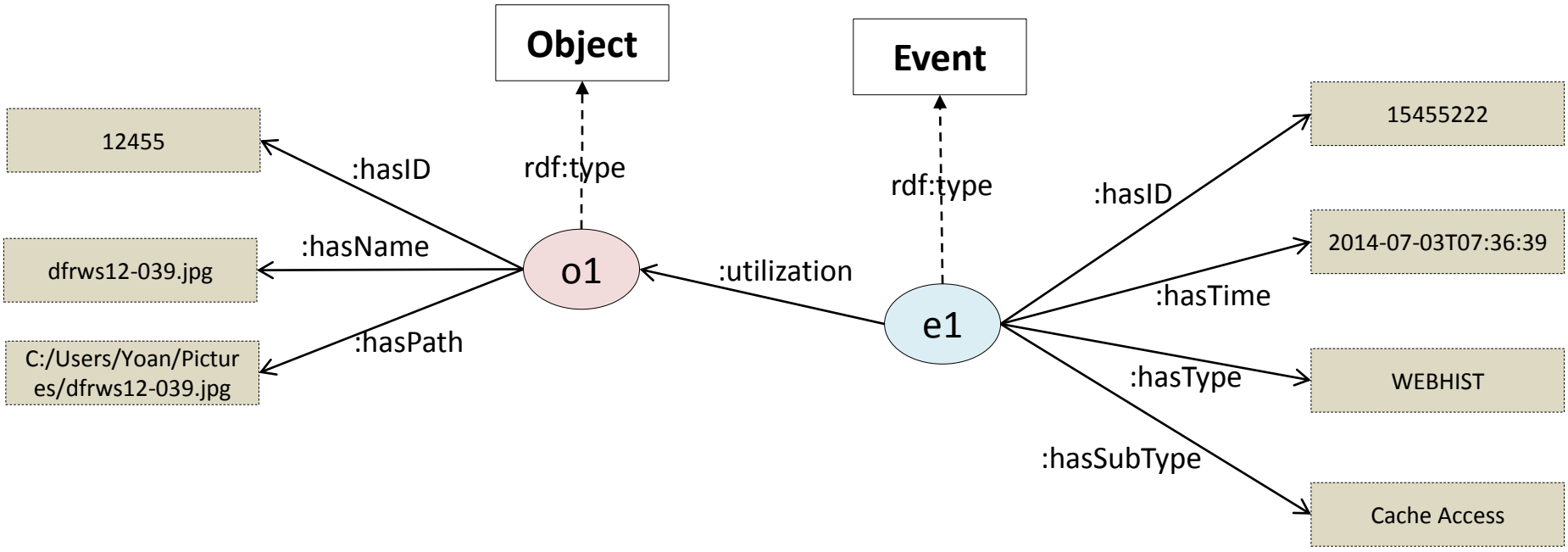

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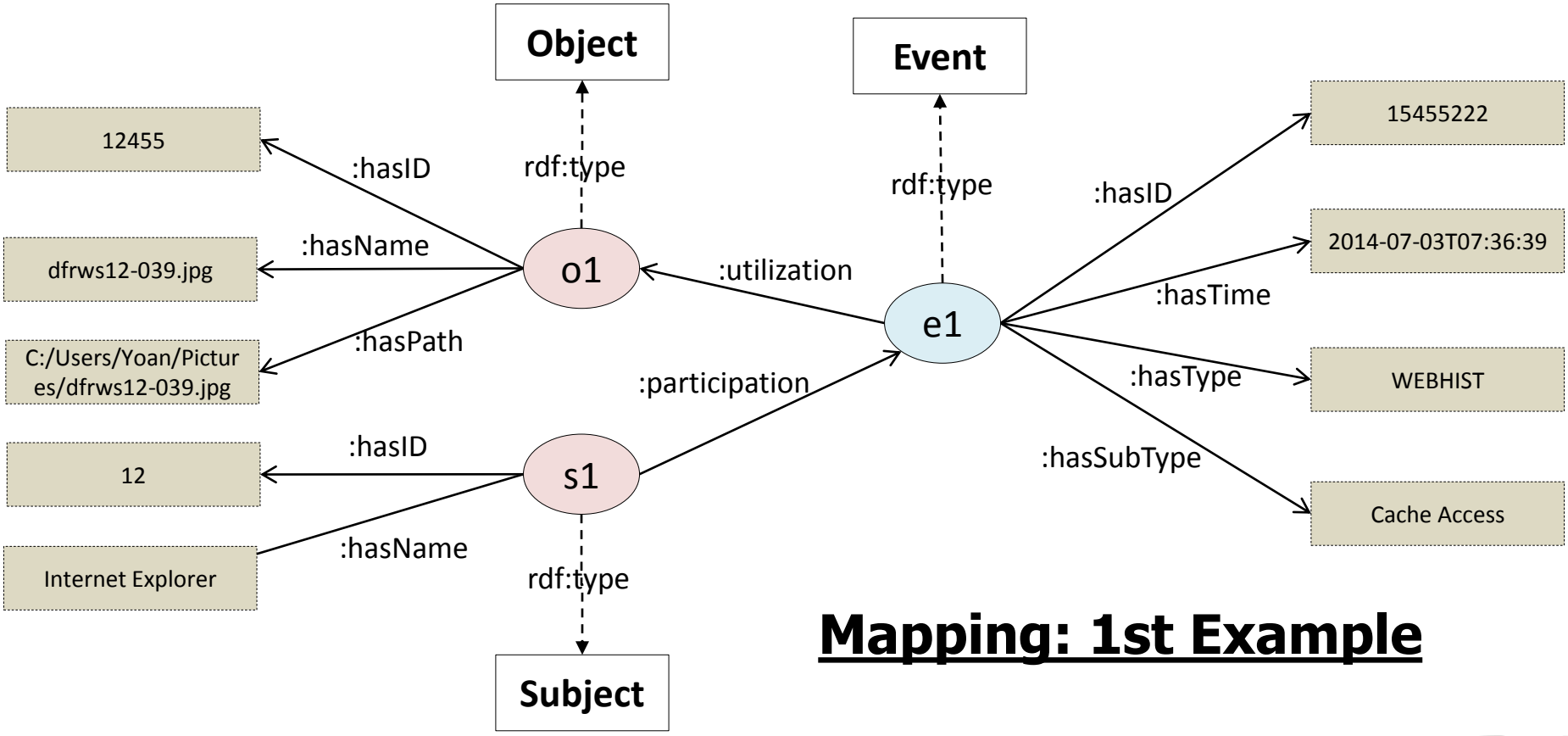

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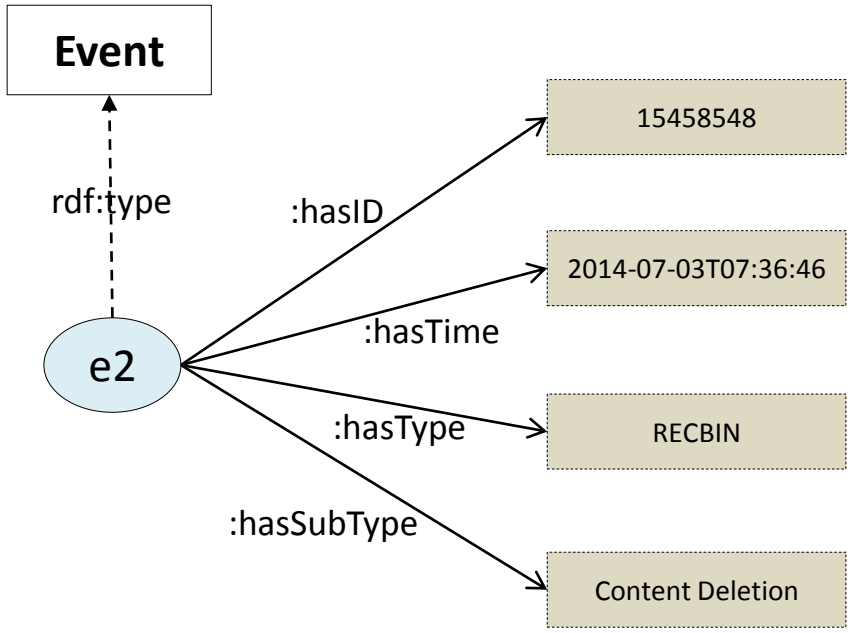

Mapping: 2nd Example

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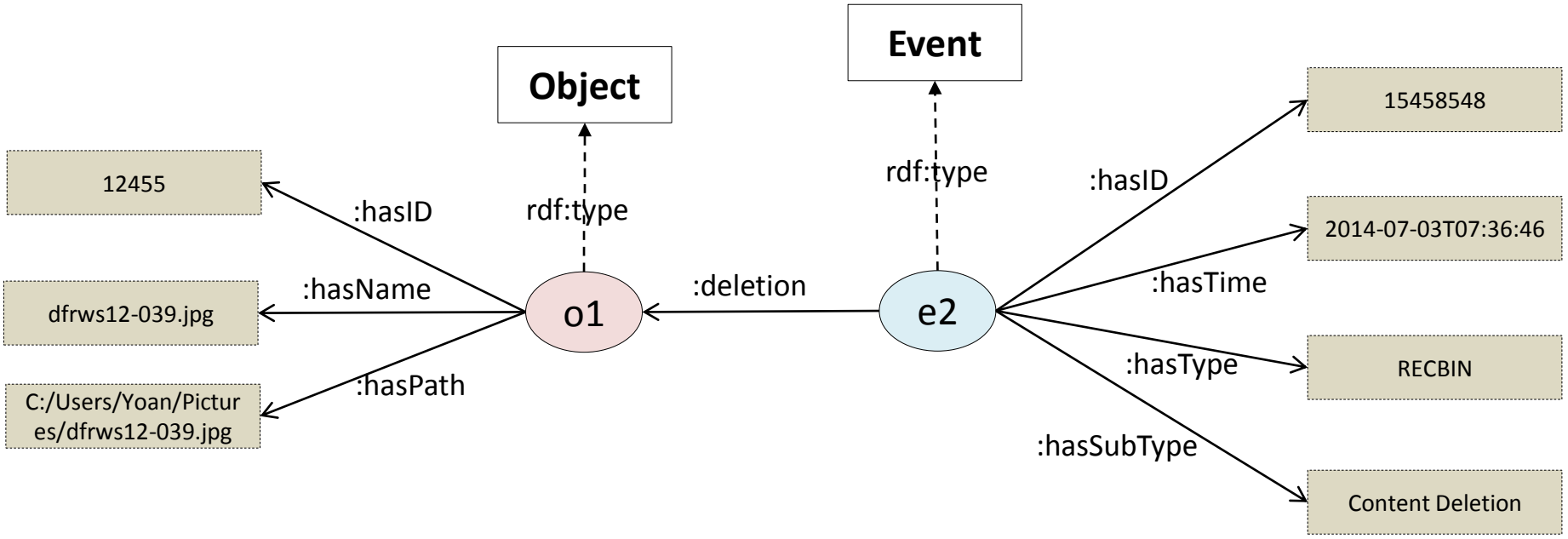

Mapping: 2nd Example

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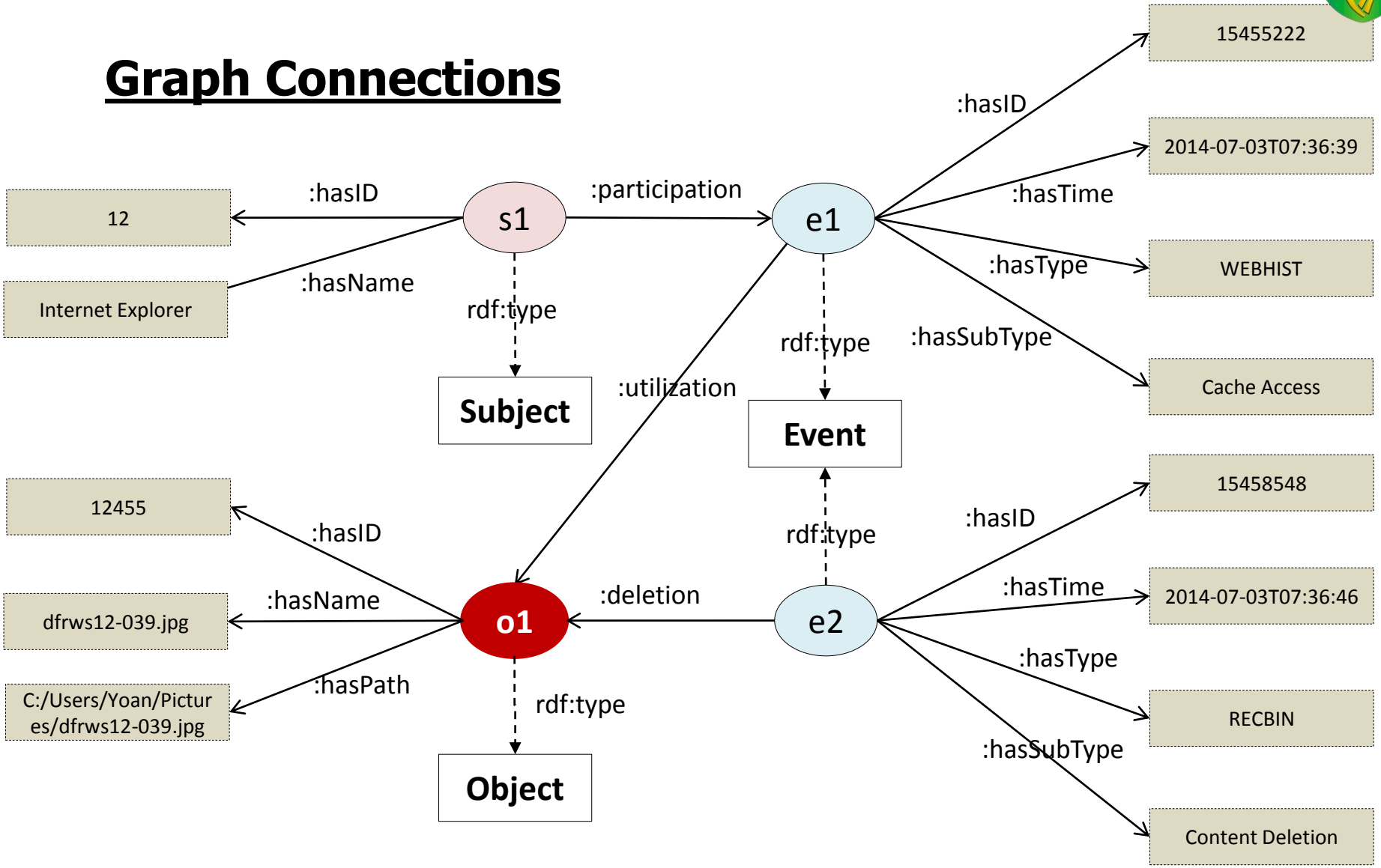
Graph Connections



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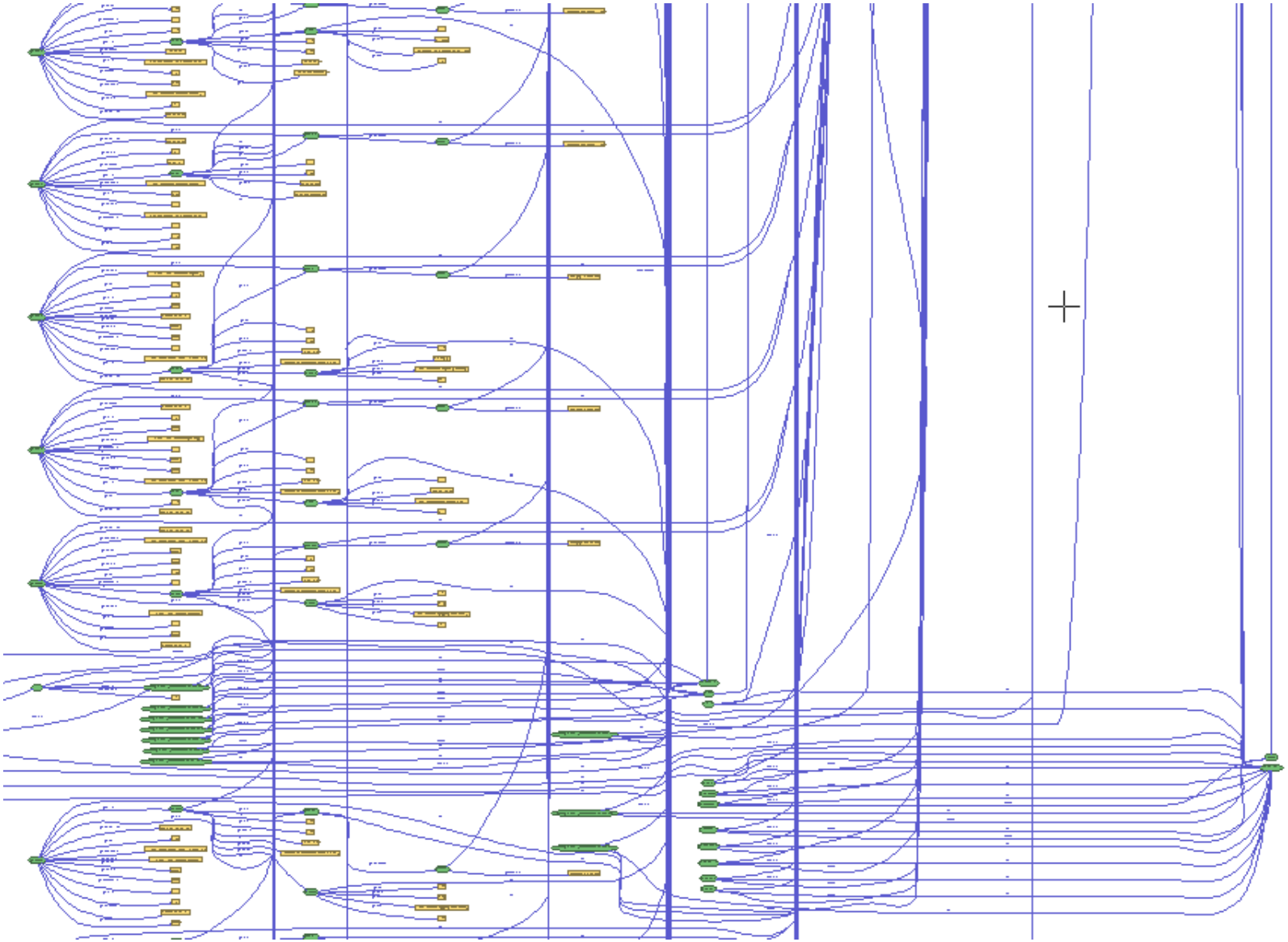

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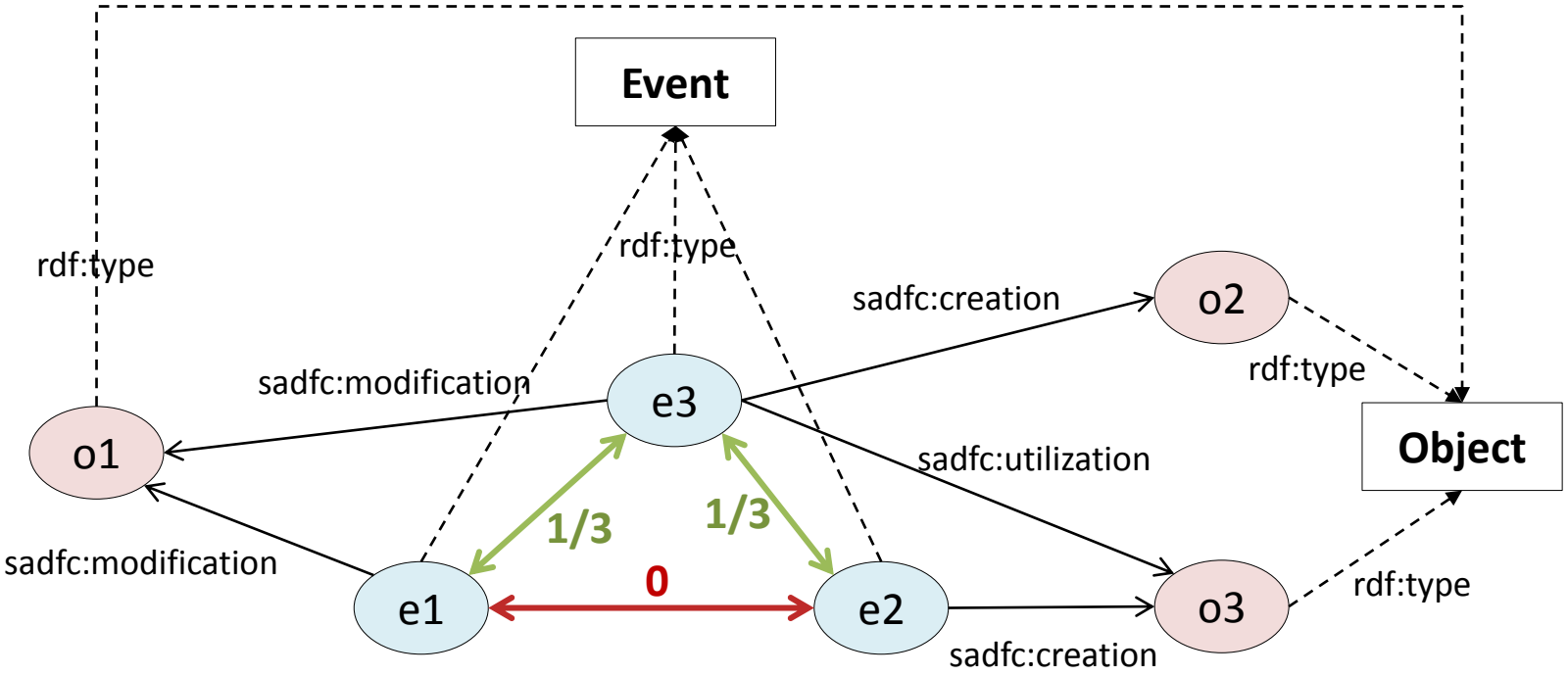
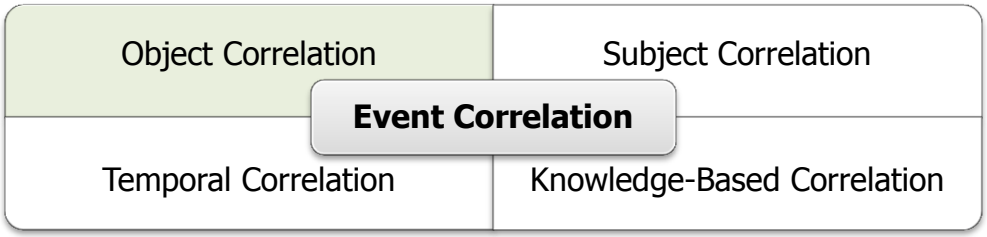
Automatic Analysis Operators



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



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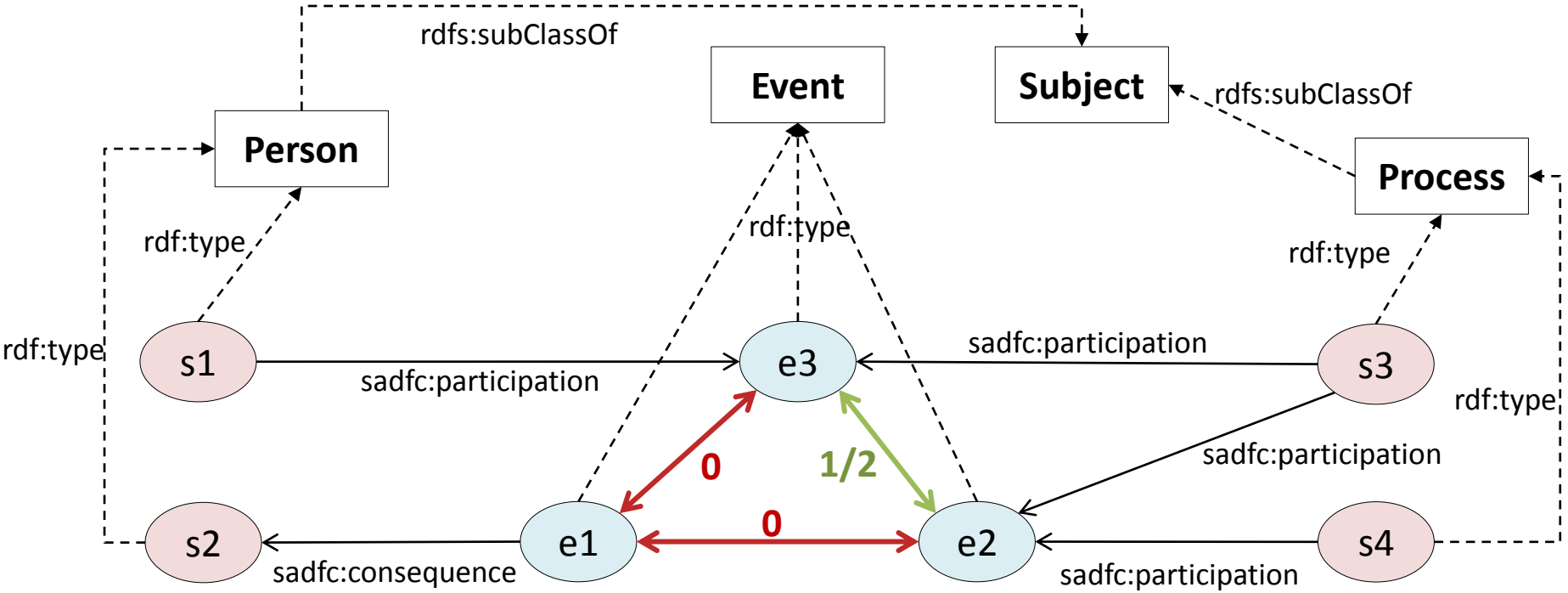
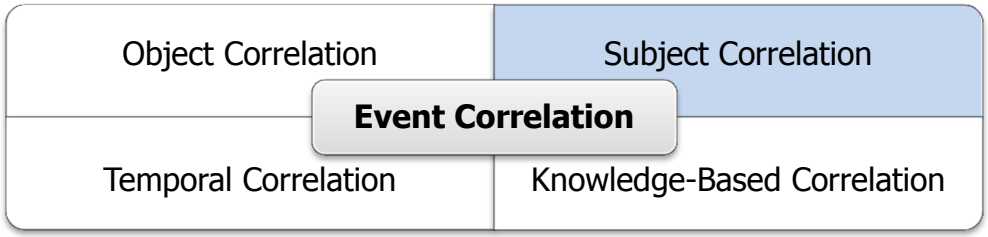
Automatic Analysis Operators



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



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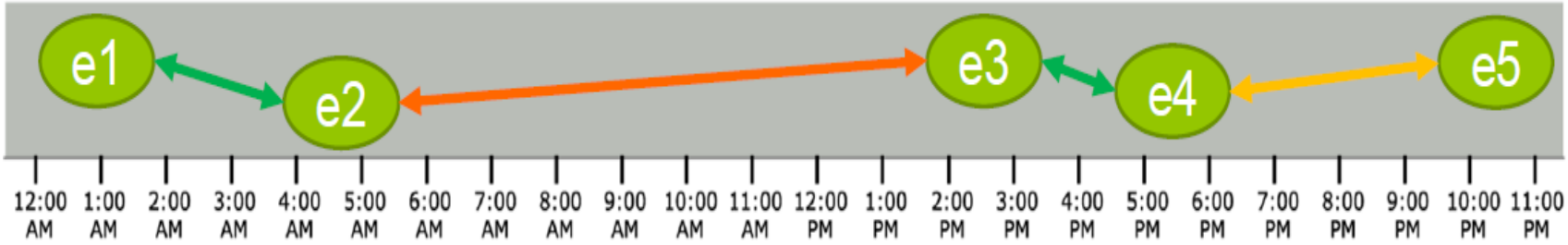
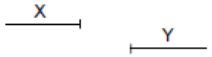
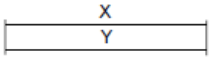
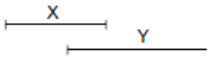
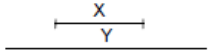
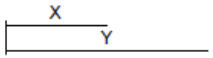
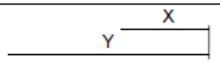
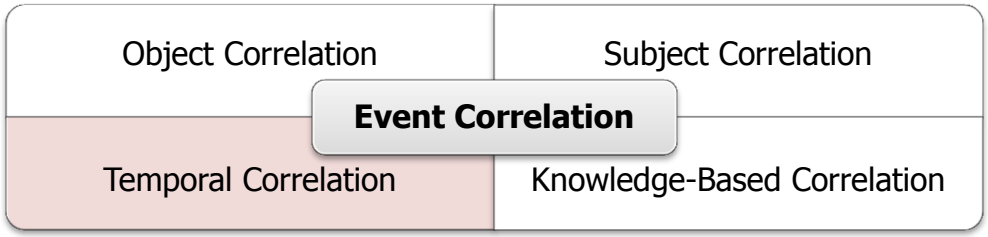


$$Correlation_T(e,x) = \alpha \times starts(e,x) + \alpha \times equals(e,x) + meets(e,x) + overlaps(e,x) + during(e,x) + finishes(e,x) + before(e,x)$$

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



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Automatic Analysis Operators

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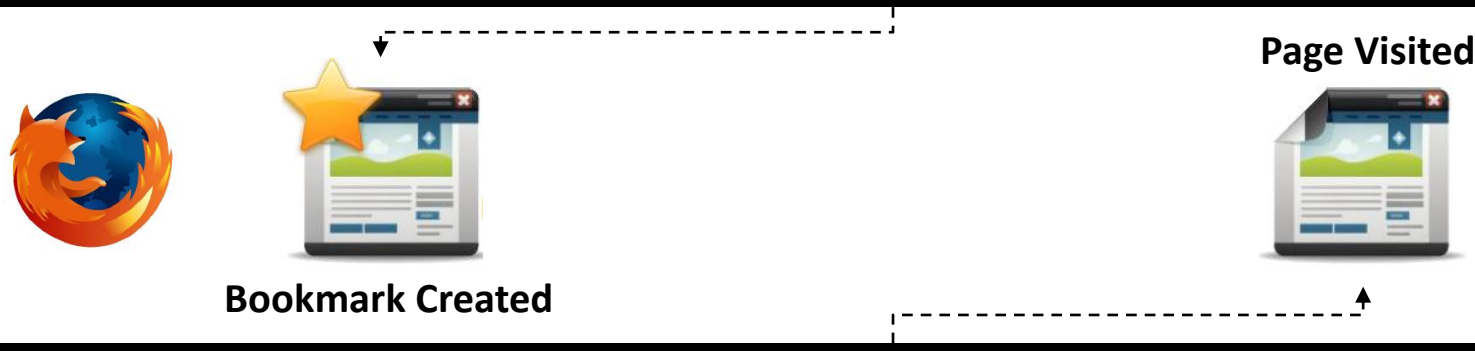

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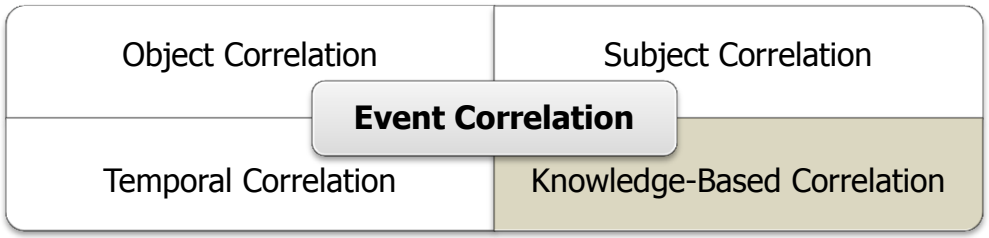
$$Correlation_{KBR}(e,x) = \sum_{r=1}^{n} rule_r(e,x)$$

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



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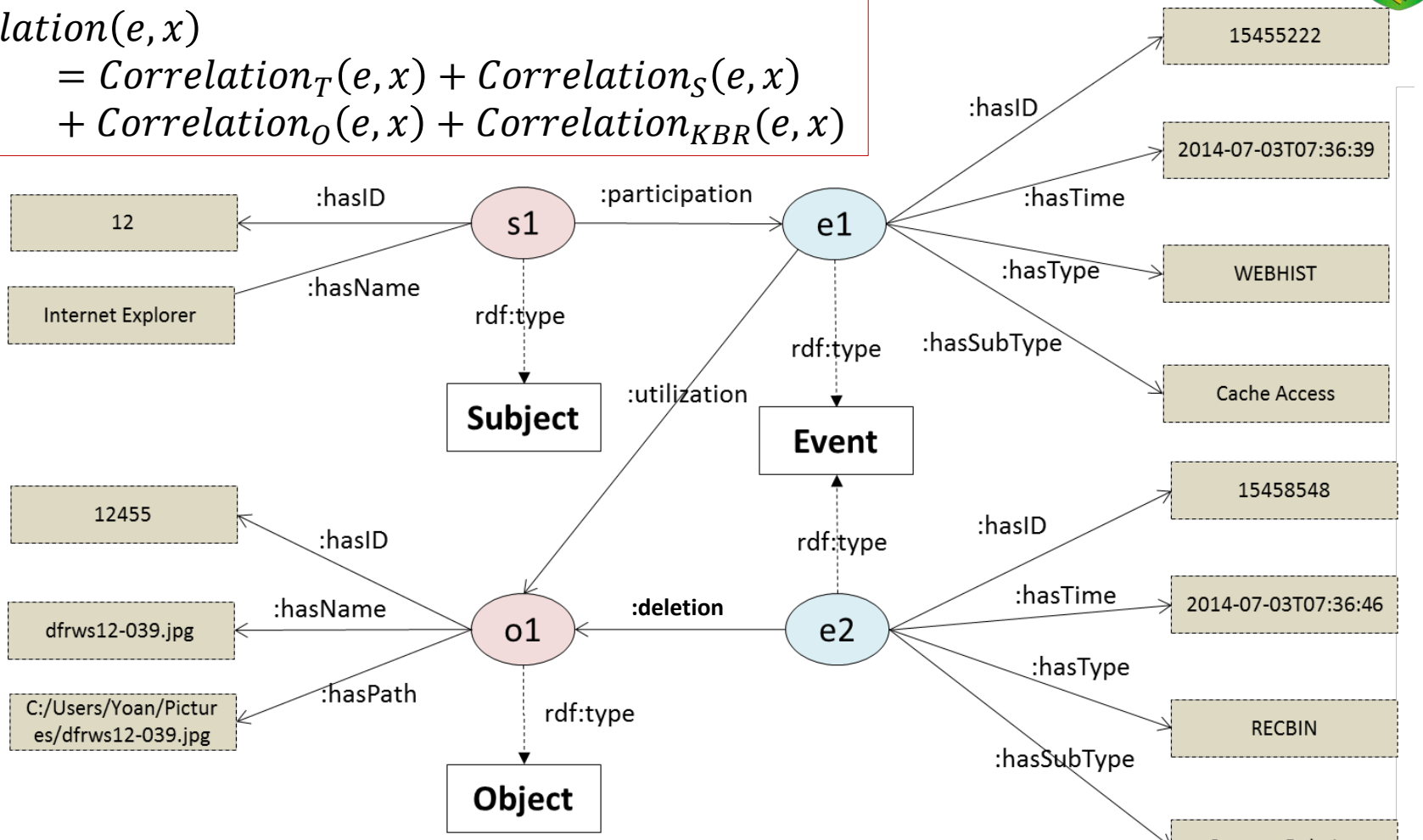
Automatic Analysis Operators

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



$Correlation(e1, e2)$ ≈1,143

- $Correlation_O(e1, e2)$: *o1* ➔ ***1/1 = 1***
- $Correlation_S(e1, e2)$: ∅ ➔ **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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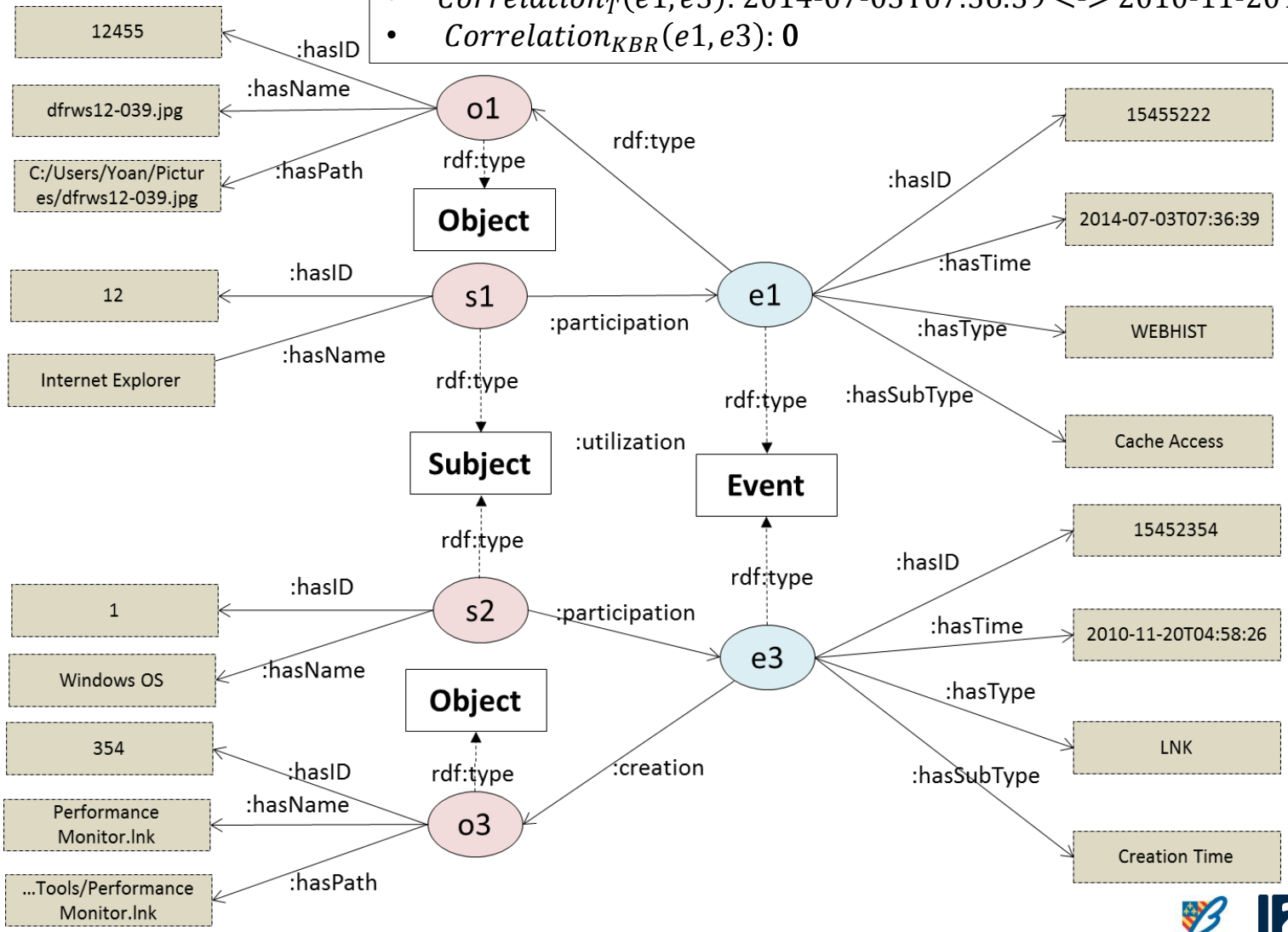
Automatic Analysis Operators

$Correlation(e1, e3) \approx 0$

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

August 5, 2014

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

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