

To trust, or not to trust: Highlighting the need for data provenance in mobile apps for smart cities

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Introduction

Related work

Semantic representation of provenance

Provenance-based trust model

Conclusions and future work

What is a *Smart City*?

A city that makes available all the services and applications **enabled by ICT** to citizens, companies and authorities that are part of a city's system.

It aims to increase all citizens' **quality of life** and improve the **efficiency and quality of the services** provided by governing entities and businesses.

Smartphones in Smart Cities

Smartphones are an essential part of Smart Cities

- Enable a way to **access** smart cities' services
- Enable the **participation** of the citizens in city governance
- Ease the way users share they own opinion, data...



biased information

uncompleteness

incorrect
data

contradictions

outdated
information

conflicts



partial data

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partial data

Solution? Trust!

We need **trust mechanisms** to...

- Measure if submitted data is reliable.
- Identify a given user and measure his/her reputation.

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Build user-centric smartphone apps for smart cities that **keep provenance information**

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Build user-centric smartphone apps for smart cities that **keep provenance information**

Provide **trust** mechanisms that help authorities and users deciding if the data is reliable or not

IES Cities: Internet Enabled Services for cities across Europe

Motivations:

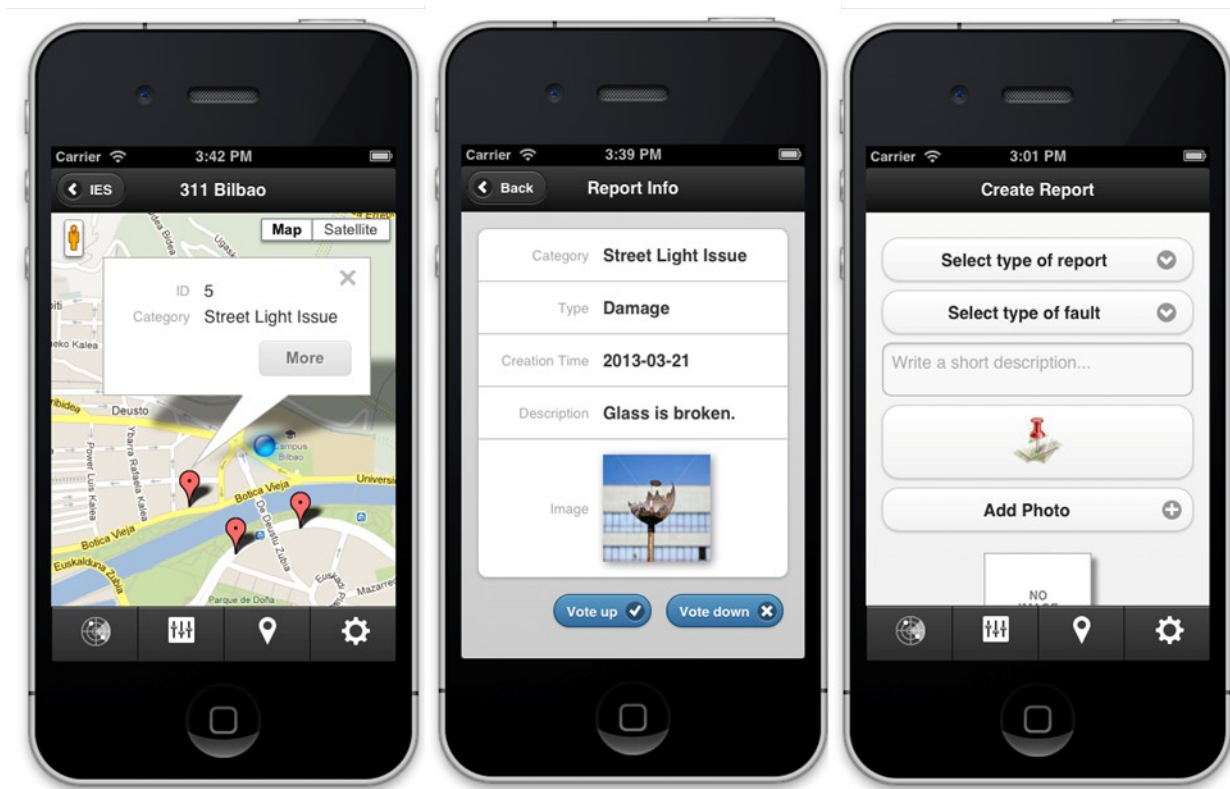
- Citizens must be **heard & empowered**
- The information gathered and provided by both cities and citizens must be **linked and processed**

Goals:

- Create a multi-device dataset and application marketplace based on standard and accessible web technologies, **exploiting data** shared between citizens and councils, and providing an enhanced experience to municipalities

Use case: 311 Bilbao

Consuming & reporting of complaints concerning public infrastructures





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Apps for Smart Cities

Urbanopoly

- Human Computation + Linked Data + Gamification to verify and correct data about POIs

Urban Match

- User compares photos to link smart-cities' datasets

csxPOI

- Collaborative creation, edition and share of semantic POIs



Apps for Smart Cities

Different ways to “trust” user data:

- Popularity (Urbanopoly)
- User historical reputation (Urbanopoly)
- Clustering of properties of reports (csxPOI)
- Combine known real and false data (Urban Match)

Apps for Smart Cities

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Our proposal: Keep provenance information and use it in trust algorithms



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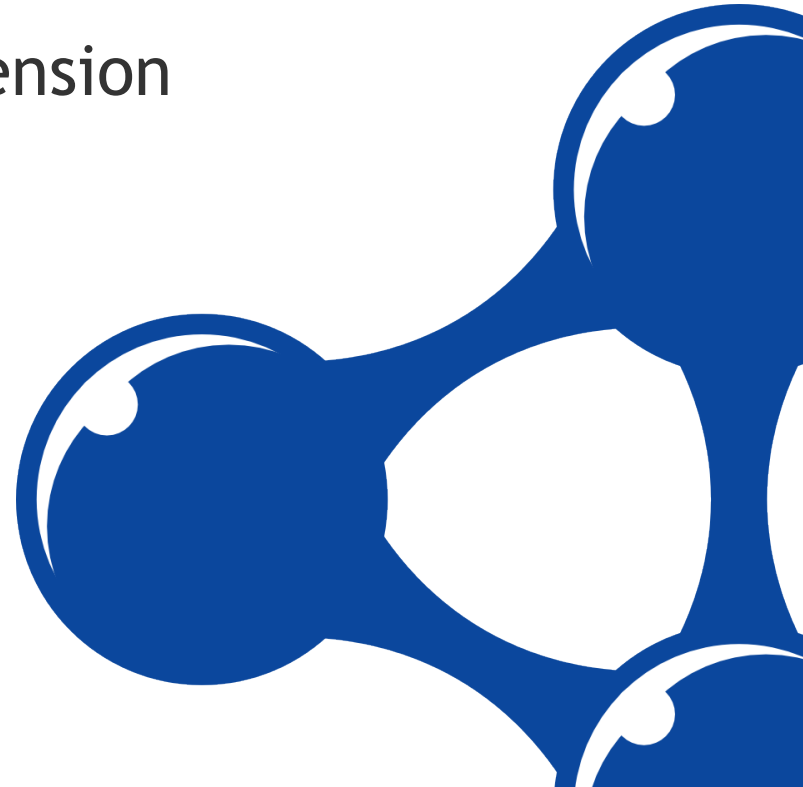
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Representation of provenance

W3C PROV Data Model

- RDF model for provenance representation
- PROV-O ontology
- Extensible: Uncertainty extension



Representation of a report

User John Doe sends
a report

```
entity(:report_23456, [prov:value="The  
paper bin is broken"])  
  
wasAttributedTo(:report_23456, :jdoe)  
  
agent(:jdoe,  
[ prov:type='prov:Person',  
  foaf:name="John Doe",  
  foaf:mbox='<mailto:jdoe@example.org>'  
])  
  
wasGeneratedBy(:report_23456,  
:reportActivity_23456)  
  
activity(:reportActivity_23456,  
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Representation of a revision report

A worker of the
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wasInvalidatedBy(:report_23456, :invActivity_639,  
2013-07-22T03:05:03)  
  
activity(:invActivity_639, 2013-07-22T02:58:01,  
2013-07-22T03:04:47)  
  
wasAssociatedWith(:invActivity_639, :jane)  
  
entity(:report_23457, [ prov:value="It is incorrect,  
another paper bin has replaced the old one, but 2  
meters beyond" ])  
  
wasDerivedFrom(:report_23457, :report_23456,  
:invActivity_639, -, -,  
[ prov:type='prov:Revision' ])  
  
wasAttributedTo(:report_23457, :jane)  
  
agent(:jane, [ prov:type='prov:Person',  
foaf:name="Jane",  
foaf:mbox='<mailto:jane@bilbao.iescities.org>' ])  
  
actedOnBehalfOf(:jane, :bilbao_city_council)  
  
agent(:bilbao_city_concil,  
[ prov:type='prov:Organization', foaf:name="Bilbao  
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Trust measure function for a given property [0,1]

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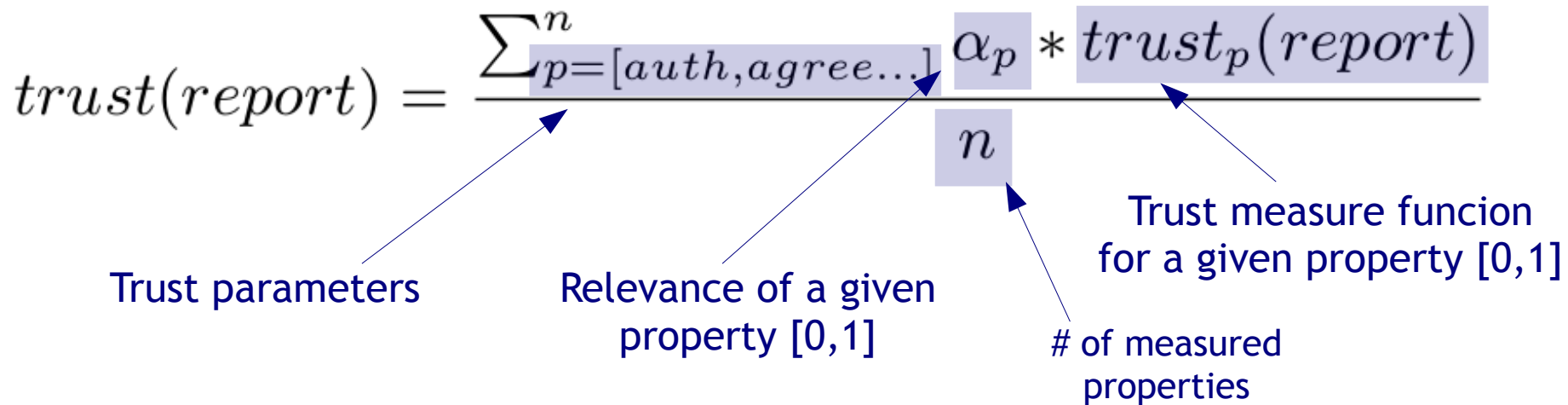
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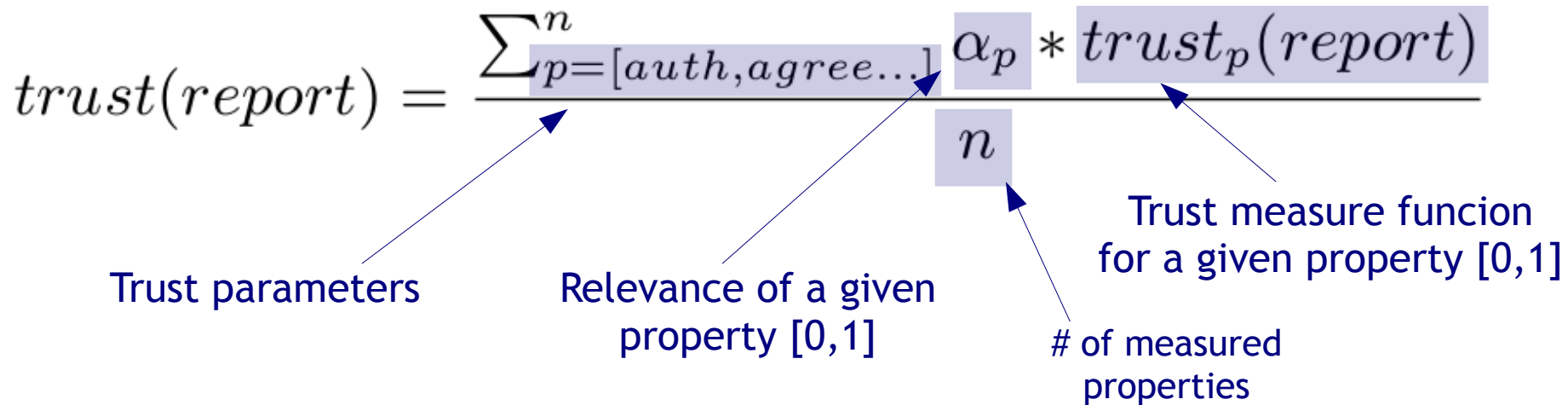
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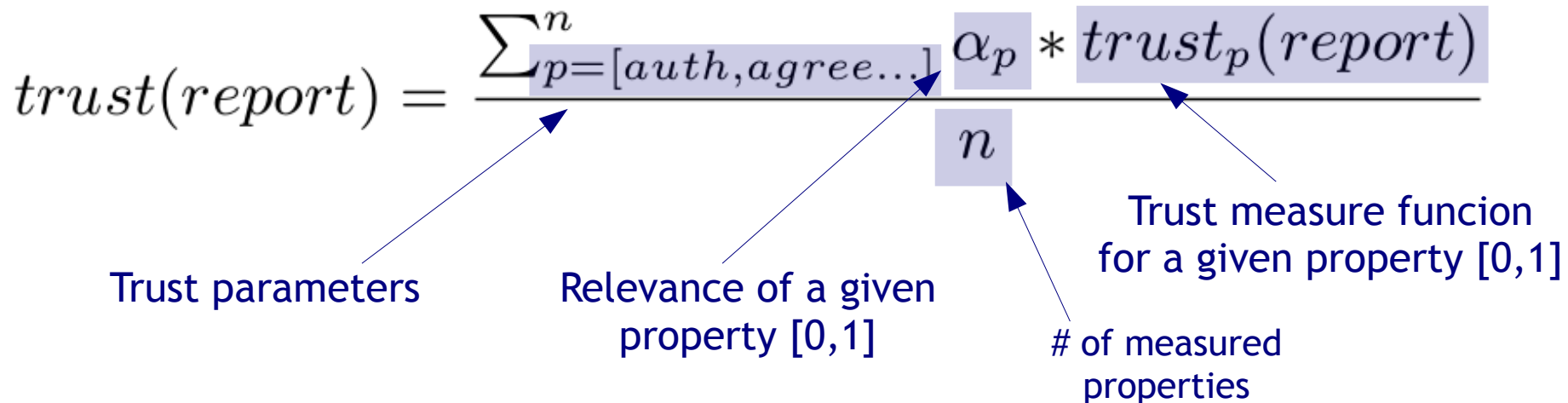
The diagram shows the equation for calculating trust in a report. The equation is: $trust(report) = \frac{\sum_{p=[auth, agree...]}^n \alpha_p * trust_p(report)}{n}$. Annotations with arrows point to specific parts of the equation:

- An arrow points from the text "Trust parameters" to the list of properties $p=[auth, agree...]$ in the summation index.
- An arrow points from the text "Relevance of a given property [0,1]" to the weight α_p .
- An arrow points from the text "Trust measure function for a given property [0,1]" to the function $trust_p(report)$.
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- Generic and flexible model
- α_p and trust_p defined by developers or councils

Authority

Was the data **created by an authority** in a given context?

Authority

Was the data **created by an authority** in a given context?

$$trust_{authority} = \begin{cases} 0 & \text{if } user \neq authority \\ 1 & \text{if } user = authority \end{cases}$$

In Bilbao 311 and for John Doe, an SPARQL query like...

```
ASK { :jdoe prov:actedOnBehalfOf :bilbao_city_concil }
```

would have no results, so

$$trust_{authority} = 0$$

Popularity

Is the piece of information **referenced by other users?**

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In Bilbao 311, we measure *popularity* in terms of visits that a report receive:

$$trust_{popularity} = \frac{visits_{report}}{visits_{open\ reports}}$$

Given John Does report has 100 visits and there has been 550 visits to all open reports...

$$trust_{popularity} = \frac{100}{550} = 0.18$$

Recommendation

Is the data **relevant** for other users?

Recommendation

Is the data **relevant** for other users?

In Bilbao 311, we measure *recommendation* with a simple voting system (+1/-1):

$$trust_{recommendation} = \frac{positive\ votes_{report}}{total\ votes_{report}}$$

Given John Does report has 10 of 12 positive votes...

$$trust_{recommendation} = \frac{10}{12} = 0.83$$

Provenance / Reputation

Can I trust the user who generated the data? What's his/her reputation?

Provenance / Reputation

Can I trust **the user** who generated the data? What's his/her **reputation**?

In Bilbao 311, we use the historical reputation algorithm by *Ceolin et al.* 3 steps:

1. *Evidence selection*: Get every report of the user.
2. *Evidence weighting*: Apply *recommendation* function for every report, taking in account invalidation / validation.
3. *Evidence aggregation*: Subjective logic algorithm

$$trust_{provenance} = 0.65$$

Recency / Timeliness

Is the data up-to-date?

Recency / Timeliness

Is the data **up-to-date**?

In Bilbao 311, we measure *recency* with the model by *Hartig et al.*

$$trust_{recency} = \left(\max\left(1 - \frac{currency}{volatility}\right), 0 \right)^{sensitivity}$$

where...

$$currency = DeliveryTime - InputTime$$

$$volatility = ExpiryTime - InputTime$$

$$sensitivity = \begin{cases} high & \text{if report constantly updated} \\ low & \text{if report not changing} \end{cases}$$

Recency / Timeliness

$$\textit{currency} = 1\textit{day}$$

$$\textit{volatility} = 7\textit{day}$$

$$\textit{sensitivity} = 1$$

Recency / Timeliness

Given...

currency = 1day

volatility = 7day

sensitivity = 1

Recency / Timeliness

Given...

$$\textit{currency} = 1\textit{day}$$

$$\textit{volatility} = 7\textit{day}$$

$$\textit{sensitivity} = 1$$

Then...

$$\textit{trust}_{\textit{recency}} = \left(\max\left(1 - \frac{1 \textit{ day}}{7 \textit{ day}}, 0\right) \right)^1 = \max(0.86, 0) = 0.86$$

Other trust factors

The model is **flexible** enough to include other factors depending on the context of the application.

e.g. in Bilbao 311, the distance between reporting and reported places is a key trust factor:

$$trust_{distance} = \frac{1}{geodistance(loc_{report}, loc_{reportedplace})}$$

Given John Doe is very close to reporting place...

$$trust_{distance} = 0.95$$

Results of the trust model

After applying our model we will get a trust value between 0 and 1.

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If we assume that α_p is equal for every property, John's report would have a trust value of...

$$\text{trust}(\text{report}) = \frac{\sum_{p=[\text{auth}, \text{agree}...]}^n \alpha_p * \text{trust}_p(\text{report})}{n} = \frac{0 + 0.18 + 0.83 + 0.65 + 0.86 + 0.95}{6} = 0.58$$

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That would be represented in the provenance graph as:

```
:report_23456 up:contentConfidence "0.58"
```

Enabling SPARQL queries like:

```
SELECT ?report WHERE {  
  ?report up:contentConfidence ?confidence .  
  FILTER (?confidence < 0.5)  
}
```



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Conclusions

- An approach that allow to **represent and evaluate the provenance** of user-submitted data in IES Cities' platform, providing an extra **confidence layer**.
- **Flexible** trust model that allows developers and admins to develop custom functions.
- Using a model based on RDF makes simple the **publication and querying** (trough SPARQL) of these data over the web.
- Smartphones give us the **possibility to capture** lots of provenance data that can be used to measure trust.

Future work

- Work-in-progress: **Finish the implementation** of the trust layer in IES Cities platform.
- **Evaluation and validation** of the proposed model against other implementations using RDF provenance models.
- Research the possibility of adding **new relevant metrics**.

Bibliography

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