# Subjective Logic Extensions for the Semantic Web

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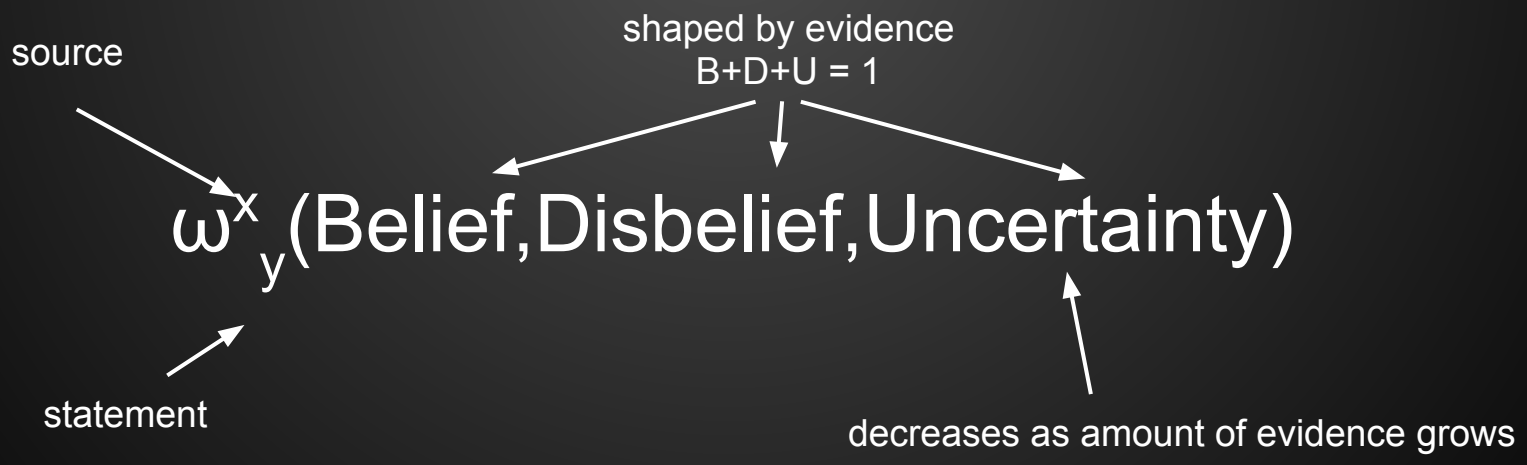
# Outline

- Subjective Logic guided tour
- Subjective Logic and the Semantic Web
- Subjective Logic extensions
  - Semantic Similarity Weighing
  - Partial Evidence Observations
  - Open World Opinions
- Conclusions
- Future Work

# Subjective Logic (Jøsang et al.)

It's a Probabilistic Logic
(i.e. truth value of statements are probabilities).

Key element:



# Binomial vs. Multinomial opinions

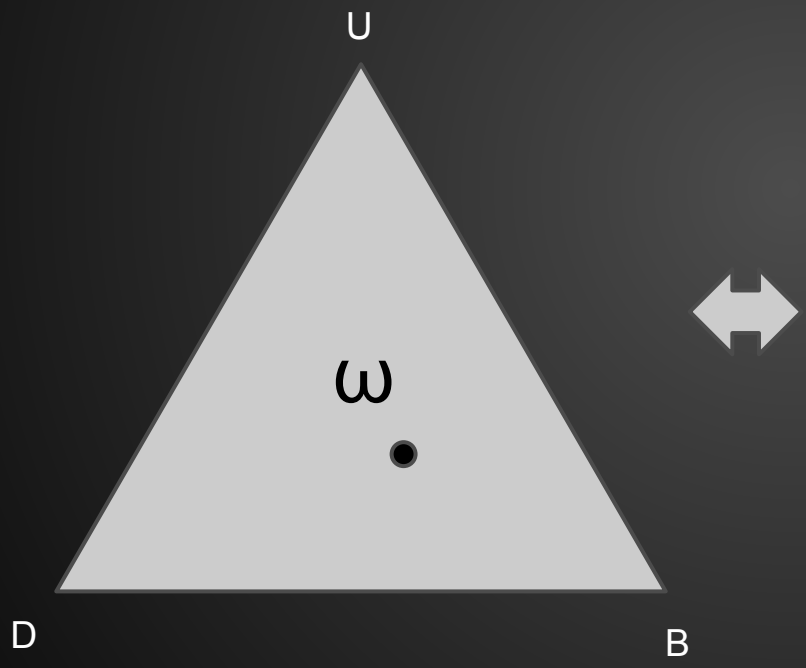
$$\omega^{x}_{y}(\text{Belief},\text{Disbelief},\text{Uncertainty})$$

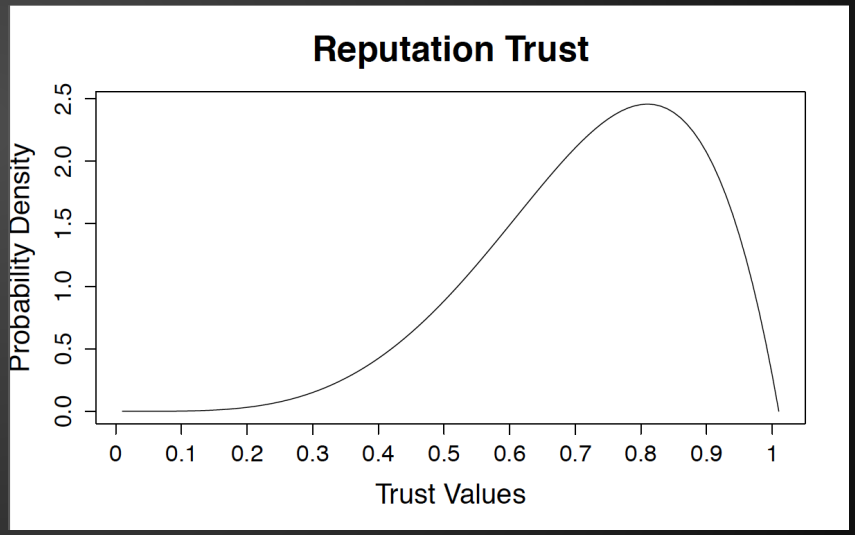
is a binomial opinion: y can be true or false

If y can assume more values, then we use multinomial opinions:

$$\omega^{x}_{y}(\text{Belief}_1,\ldots,\text{Belief}_n,\text{Uncertainty})$$

# Opinions as probability distributions



# Subjective Logic Operators

Subjective Logic provides several operators:

- boolean: and, or, not, ...
- fusion ($\oplus$): merges opinions from many sources about the same statement
- discount ($\otimes$): weighs an opinion on the opinion on the source
- ...

Operators allow to combine statements (e.g. to build Bayesian networks)

# Subjective Logic and the Semantic Web

Subjective Logic allows to reason about uncertain statements.

The Web offers lots of data (although spurious, heterogeneous, ...)

We can use Subjective Logic to reason on Web data properly managed.

We propose extensions tailored for the case.

# Semantic Similarity Weighing

Idea: an opinion on x can be built by considering also evidence about z, if $x \approx z$.

Evidence on z has to be weighed.

Limitation: for the moment, only for deterministic measures (e.g. WordNet-based).

# Semantic Similarity Weighing

$\omega_x(B,D,U)$ using evidence on x and z (evidence on z weighed on sim(x,z))

is statistically equivalent to

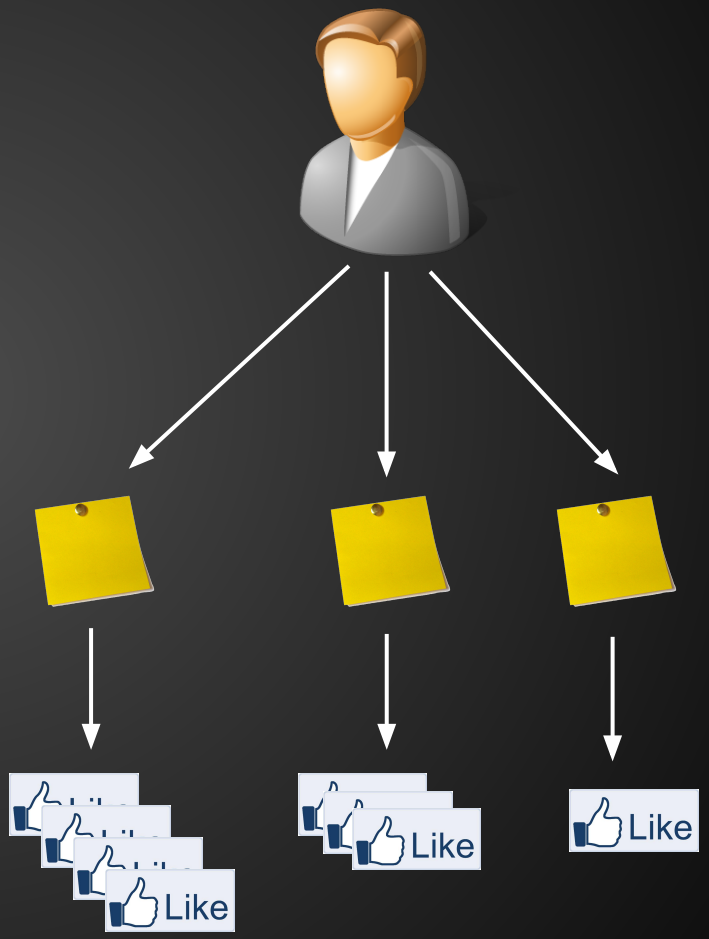
$$\omega_x(B_1,D_1,U_1) \oplus \omega_z(B_2,D_2,U_2) \otimes \omega^{WN}_{x=z}(B_3,D_3,U_3)$$

hence we can just build opinions on weighed evidence.

# Partial Evidence Observations

Opinions about entities (users, Web sites, ...) can be obtained from the content they provide.

This is partially evaluated through #likes, #links, ... to their posts, pages, ...



# Partial Evidence Observations

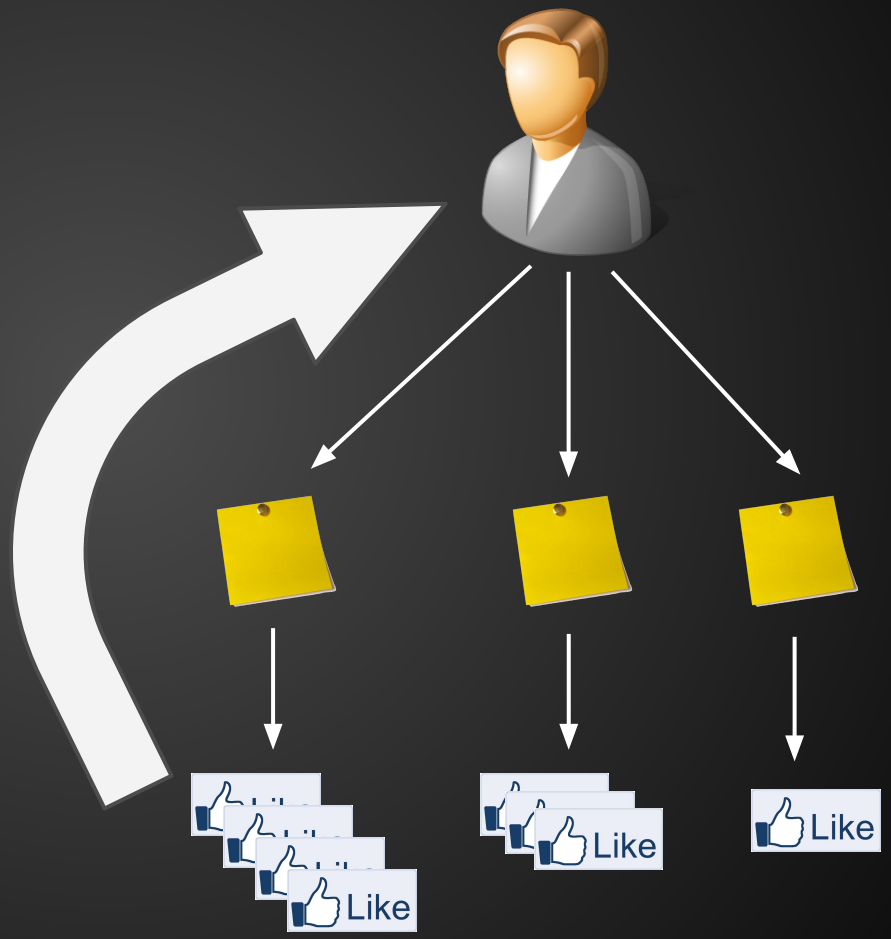
$$b = \frac{1}{l(l+2)} \sum \frac{p_i + 1}{p_i + 2}$$

$$d = \frac{1}{l(l+2)} \sum \frac{1}{p_i + 2}$$

$$u = \frac{2}{l(l+2)}$$

$l$ = #posts

$p_i$ = #likes (ith post)



# Open World Opinions

Subjective logic's opinions are equivalent to Beta/Dirichlet distributions.

Beta/Dirichlet have a finite range.

Dealing with Web data, we might not know the entire range of some data. (E.g. types of piracy attacks. [Ceolin et al., URSW 2011])

# Open World Opinions

Dirichlet Process:

$$X \sim DP(\alpha, H)$$

$$obs_{n+1} = \begin{cases} x_i^*(i \in [1 \dots k]) & \text{with probability } \frac{n(x_i^*)}{n+\alpha} \\ H & \text{with probability } \frac{\alpha}{n+\alpha} \end{cases}$$

Open World Opinions are equivalent to DPs:

$$\omega_x(\overrightarrow{B}, U, H) \quad B_{x_i} = \frac{p_{x_i}}{\alpha + \Sigma_{x=1}^{k} p_{x_i}} \quad U = \frac{\alpha}{\alpha + \Sigma_{x=1}^{k} p_{x_i}} \quad 1 = U + \Sigma_{x_i} B_{x_i}$$

Possible values of ω are no more finite: they are drawn from H (Gaussian, Uniform, etc.)

# Open World Opinions

- They behave similarly to multinomial opinions:
  - beliefs are shaped by evidence counts

- They allow to reason on statements that have a non-finite amount of candidate values, like "the type of a given piracy attack" or "the favourite color of a user".

# Conclusions

We introduced three extensions that facilitate the management of and the reasoning on Web data in Subjective Logic:

- semantic similarity weighing
- partial evidence observations
- open world opinions

# Future Work

We plan to:

- extend semantic similarity weighing to non-deterministic measures (e.g. Google distance)
- refine the partial evidence observations
- extend the Subjective Logic operators in order to deal with Open World Opinions

# Thank you!
# Questions?

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