Evaluating Trustworthiness through Monitoring

the foot, the horse and the elephant

7th International Conference on
Trust & Trustworthy computing

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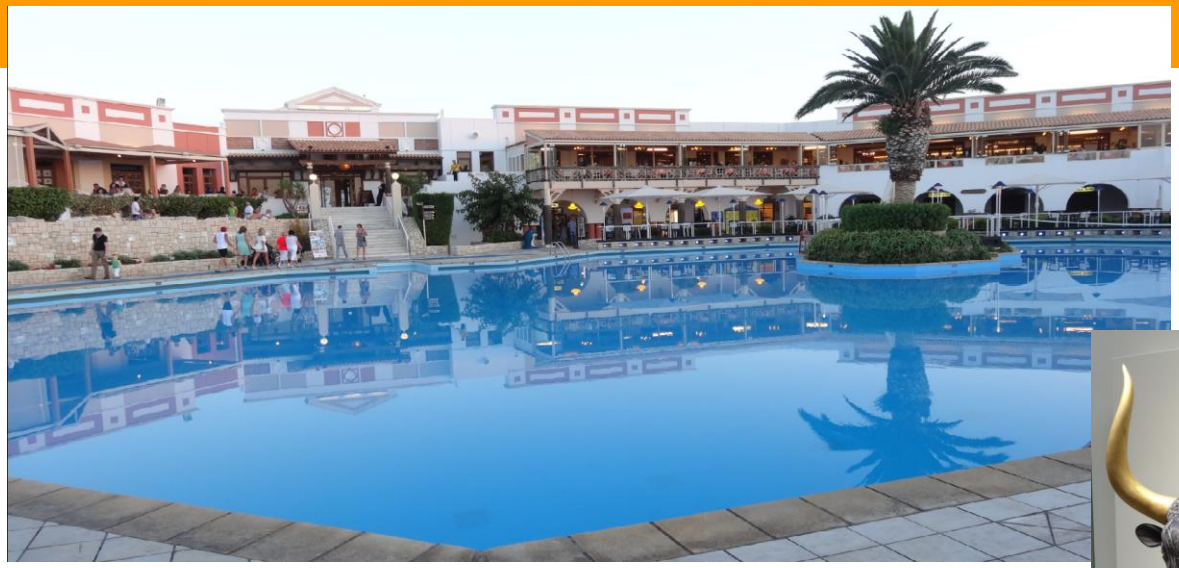
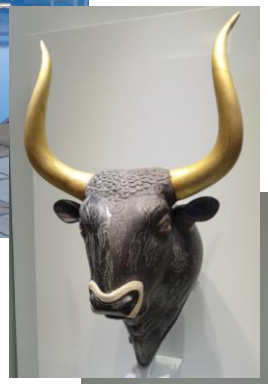
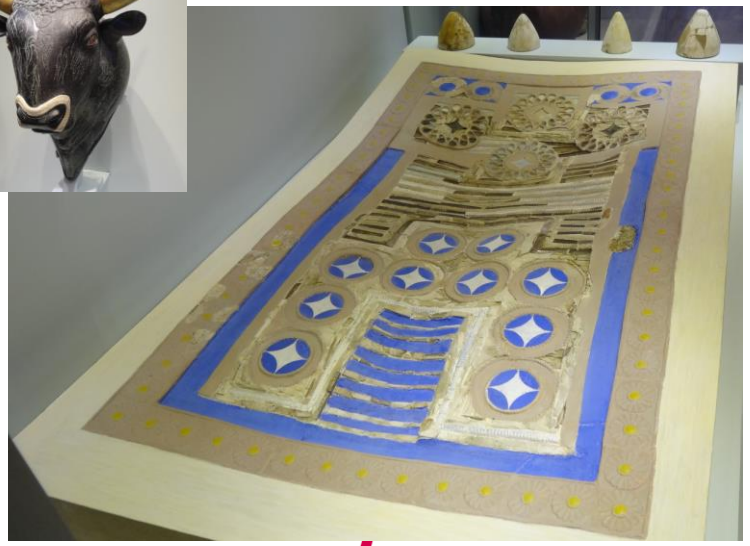
Where innovation starts

Some hard work….







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….on Crete

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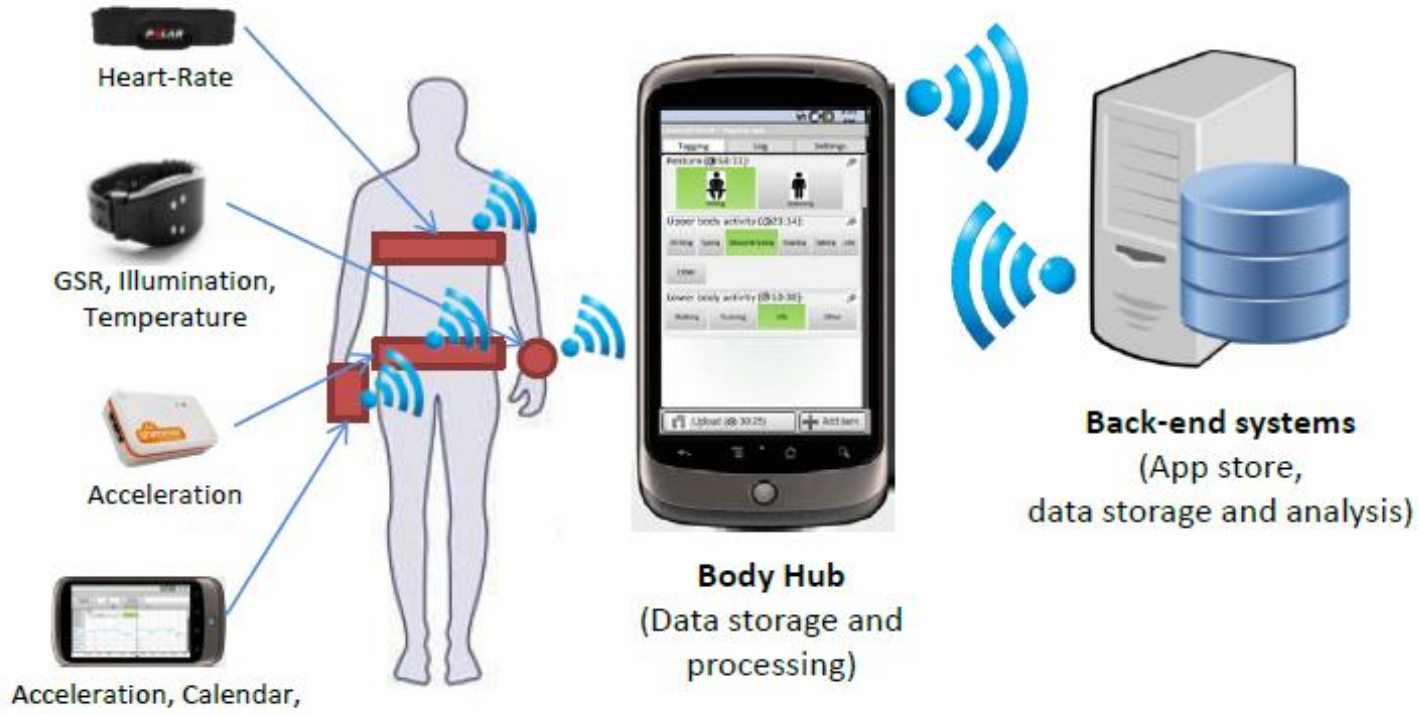
Where innovation starts

Outline

- Motivation and problem statement
- Monitoring chain
- Monitoring models and requirements
- Examples
- Conclusion

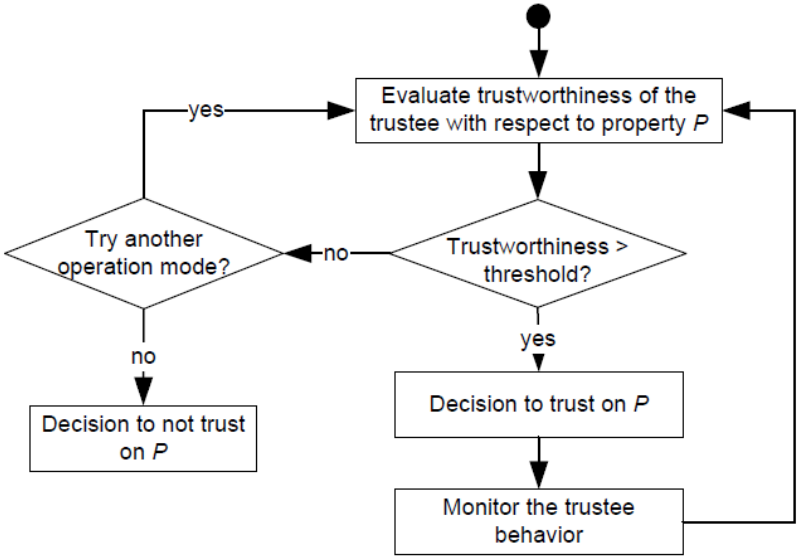
Motivation: VITRUVIUS project



- Trustworthy Body Sensor platform

Trustworthiness concerns

- *Doctor*
  - quality of measurements
  - dependability of the system
    - e.g. how long it will run
- *Wearer, owner*
  - protection, control of personal data
- *System management*
  - maintain trustworthiness under changes
    - new software components
    - upload data to backend
  - manage resources



Global Vitruvius Monitoring & Decision scheme

Problem statement

- Design an integrated *Monitoring and Decision method* for maintaining trustworthiness
  - deal with *subjectivism* and *uncertainty*
    - local, partial knowledge of a *Trustor* about a *Trustee*
    - obtained directly through monitoring or indirectly through referral
  - generic
    - aim at a light-weight ‘kernel’
    - parameterized by monitoring and decision parameters, and primitives

Monitoring, trust statements

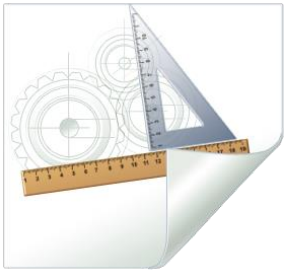
- Define *indicators* that together address a particular trustworthiness concern
  - e.g. levels of resource use, volume of communication, connections with remote machines, pattern of sensor reading, frequency of location checking, …
- Define a *monitoring state* and criteria for this state to be safe
- Model: a Trustor ***A*** develops trust in a trust statement ***P = (T, p, c, t)***
  - ***T****:* trustee
  - ***p****:* statement / predicate about an underlying indicator
    - can refer to any property that admits monitoring, e.g. ‘memory usage < 90%’
  - ***c****:* context
  - ***t****:* time (duration that *p* holds)

Monitoring and decision chain for a trust statement *P*

World

Measurement

Observation about *P*



Update rule

Evidence about *P*

Opinion Generation

Opinion about *P*

Extraction

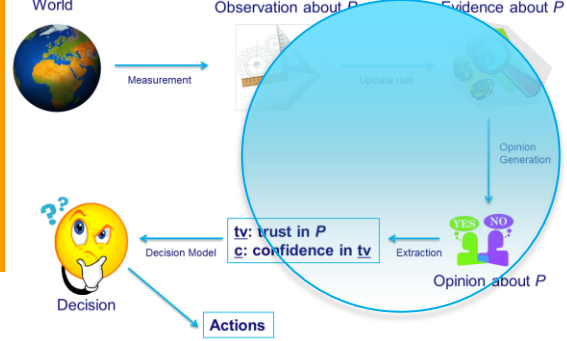
tv: trust in *P*
c: confidence in tv

Decision Model

Decision

Actions

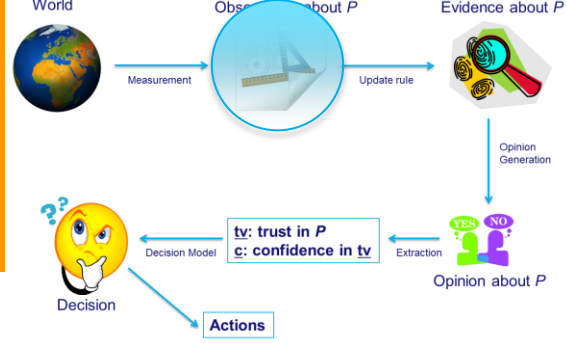
Monitoring requirements



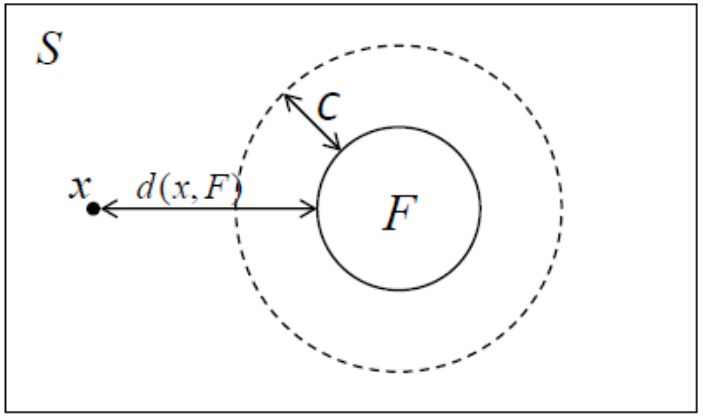
- **`Soundness'**
  - a long series of success (failures) leads to trust and confidence going to 1 (0) (or at least non-decreasing (-increasing))
  - relatively frequent failure leads to low trust
  - confidence decreases upon missing observations

- **Expressive power**
  - take *time* into account: more recent observations (could) count more
  - parameterization, to achieve particular behavior:
    - slow increase, quick decrease of trust (the foot and the horse)
    - do not forget failures in the past (the elephant)

Observations



- An observation is the outcome of a measurement *x*
- We consider a *success, failure* outcome: *(s(x), f(x))*
  - *f(x) = 1-s(x)*
- *Discrete*: *(1,0)* or *(0,1)*, i.e. truth of a statement
  - e.g. 'the message has been delivered'
- *Continuous*: success represents distance to a failed state (generalization of the discrete case)
  - e.g. *x* is fraction of memory usage, *F* = 90%, *C* = 10%



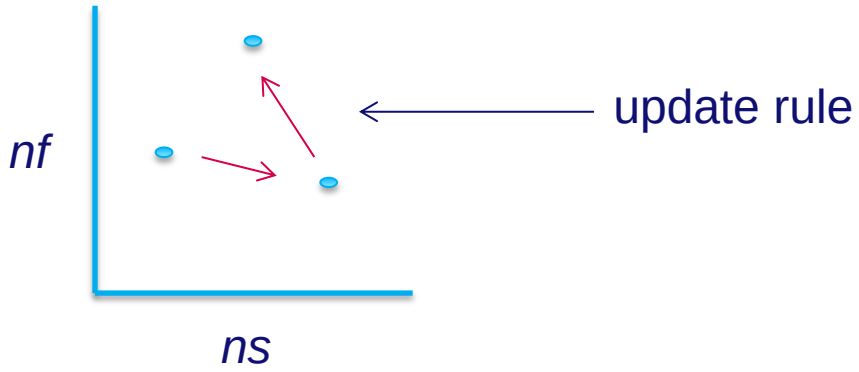
$$s(x) = \begin{cases} (\frac{d(x,F)}{C})^{\alpha}, & \text{if } d(x,F) < C \\ 1, & otherwise \end{cases}$$

Evidence and update rules

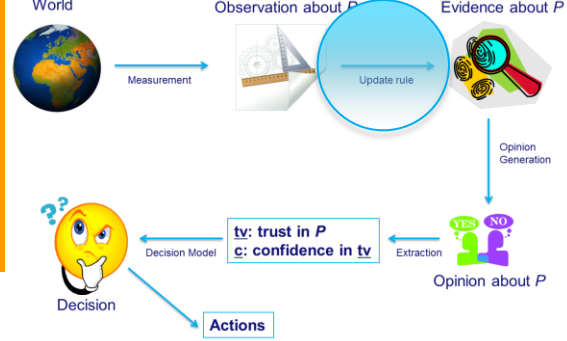
- *Evidence*: representation that captures the history of observations

- *Update rules*: adjust the evidence (periodically) based on
  - an observation
  - (optionally) a timer: 'unknown' observation leading to a decay of evidence

- We consider a representation with two variables: *ns* and *nf*
  - representing positive (success) and negative (failure) aspects



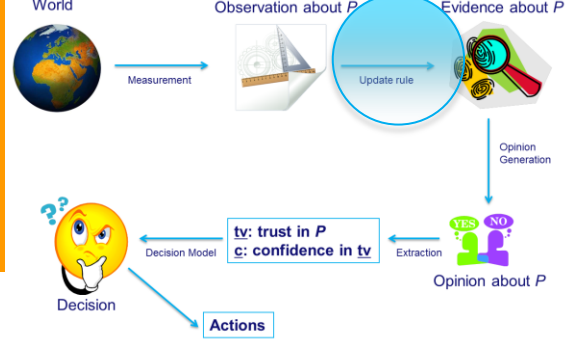
Update rules



- *'Classical' update rule* (from subjective logic):
  - discrete: (*s*,*f*) = (0,1) or (1,0)
  - add up all positive and negative contributions
    - upon success: $ns \leftarrow ns + 1$
    - upon failure: $nf \leftarrow nf + 1$
  - problem:
    - always symmetric
    - effect of new observations vanishing

- Introduce parameters: $0 < \delta, \gamma, \zeta \leq 1$
  - modeling reduction of evidence components upon new observations

Proposed update rules

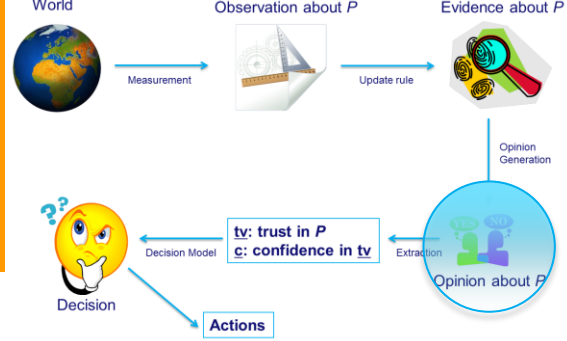


- Observation: *(s, f =1-s):*
$$ns \leftarrow \delta^f \cdot ns + s$$
$$nf \leftarrow \gamma^s \cdot nf + f$$
- Outcome *unknown:*
$$ns \leftarrow \zeta \cdot ns;\ nf \leftarrow \zeta \cdot nf$$

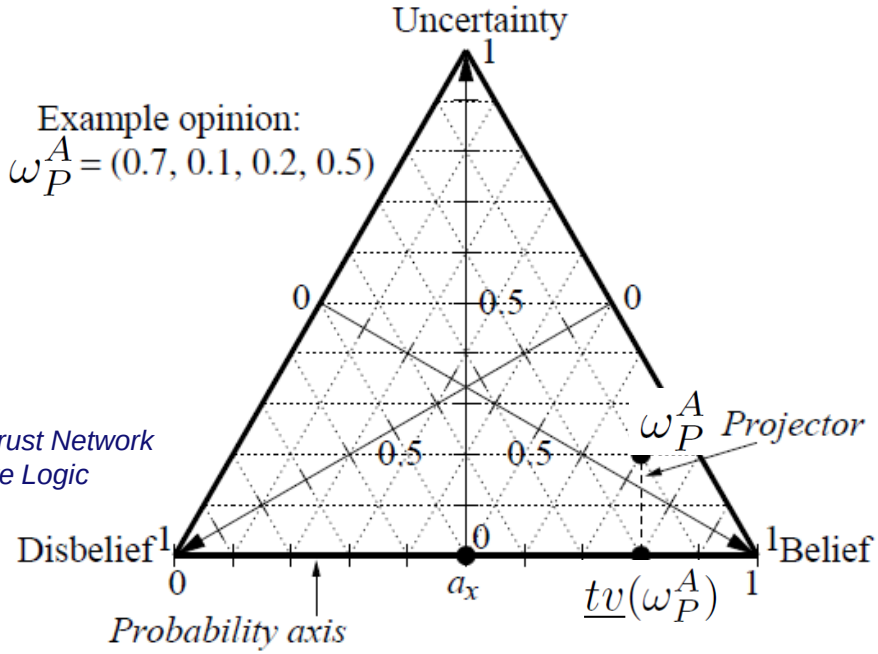
- Discrete case:
  - upon success:
$$ns \leftarrow ns + 1;\ nf \leftarrow \gamma \cdot nf$$
  - upon failure:
$$nf \leftarrow nf + 1;\ ns \leftarrow \delta \cdot ns$$

- 'Classical': discrete, with $\gamma = \delta = \zeta = 1$

Opinions



- Following the concepts of *subjective logic (*cf. Audun Jøsang (’97, ‘06))
- Belief model: an *opinion*, consisting of a tuple of *belief*, *disbelief* and *uncertainty,* and a ‘*base rate*’
  - $\omega_P^A = (b, d, u, a)$: opinion of a trustor *A* about a trust statement *P*
  - base rate represents belief taken from uncertainty



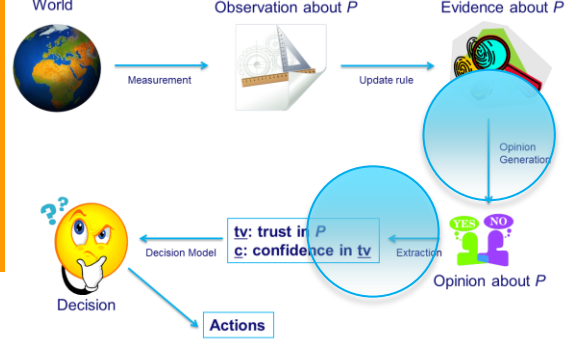
$$b + d + u = 1$$

$$0 \leq b, d, u \leq 1$$

$$\underline{tv}(\omega) = \omega.b + \omega.u \cdot \omega.a$$

Jøsang et al. (2006), *Trust Network Analysis with Subjective Logic*

Opinions, evidence and trust



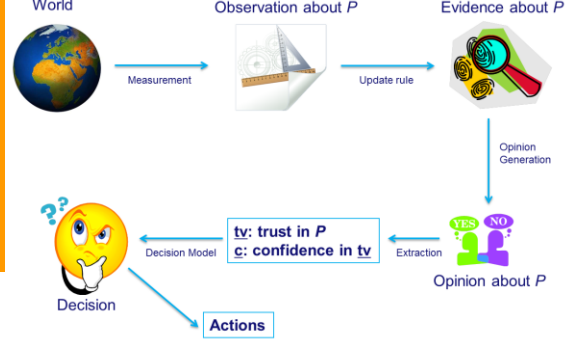
- An opinion is computed from evidence (Jøsang):

$$b = \frac{ns}{ns + nf + \epsilon}; \quad d = \frac{nf}{ns + nf + \epsilon}; \quad u = \frac{\epsilon}{ns + nf + \epsilon}.$$

- ϵ represents an initial uncertainty
- base rate *a* remains free to choose by the trustor

- a trust value is derived from an opinion: $\underline{tv}(\omega) = \omega.b + \omega.u \cdot \omega.a$
- a confidence gives the degree of certainty: $\underline{c}(\omega) = 1 - \omega.u$

Example (discrete)



success: $ns \leftarrow ns + 1;\ nf \leftarrow \gamma \cdot nf$

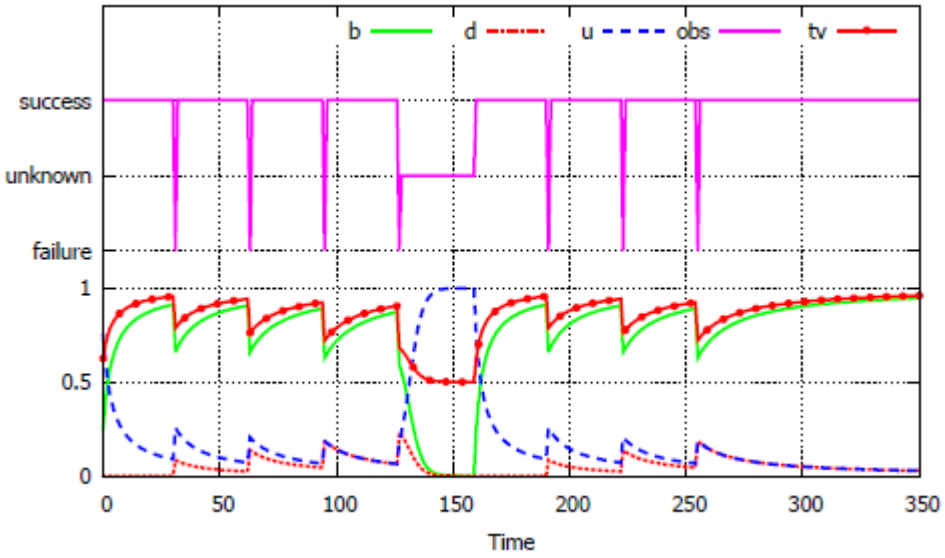
failure: $nf \leftarrow nf + 1;\ ns \leftarrow \delta \cdot ns$

unknown: $ns \leftarrow \zeta \cdot ns;\ nf \leftarrow \zeta \cdot nf$

discrete input

rapid decrease upon failure

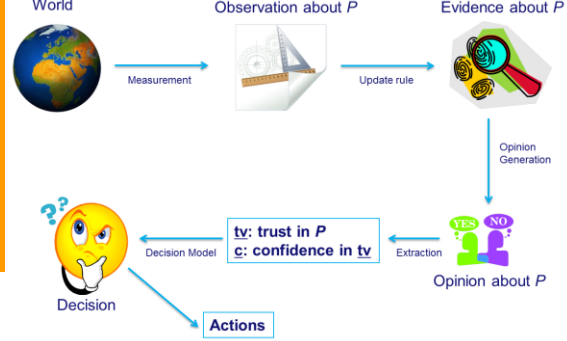
low confidence around150



recovery increasingly slow (failure is only 'forgotten' through decay)

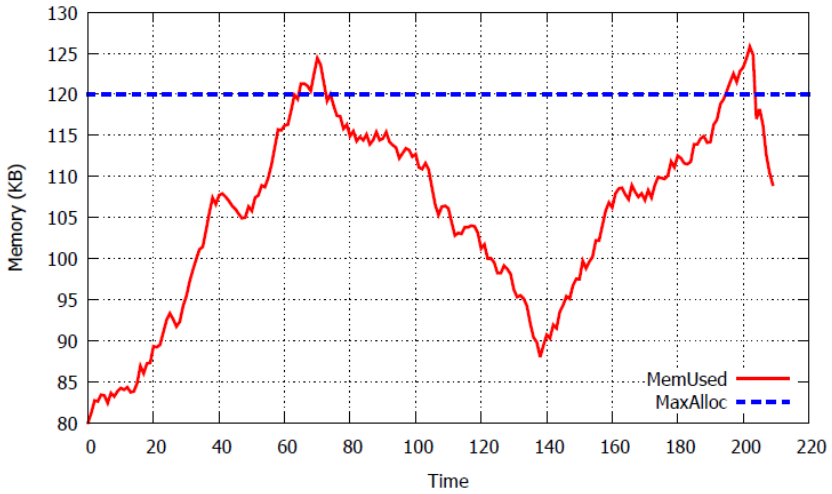
$\gamma = 1.0, \delta = 0.25, \zeta = 0.7$

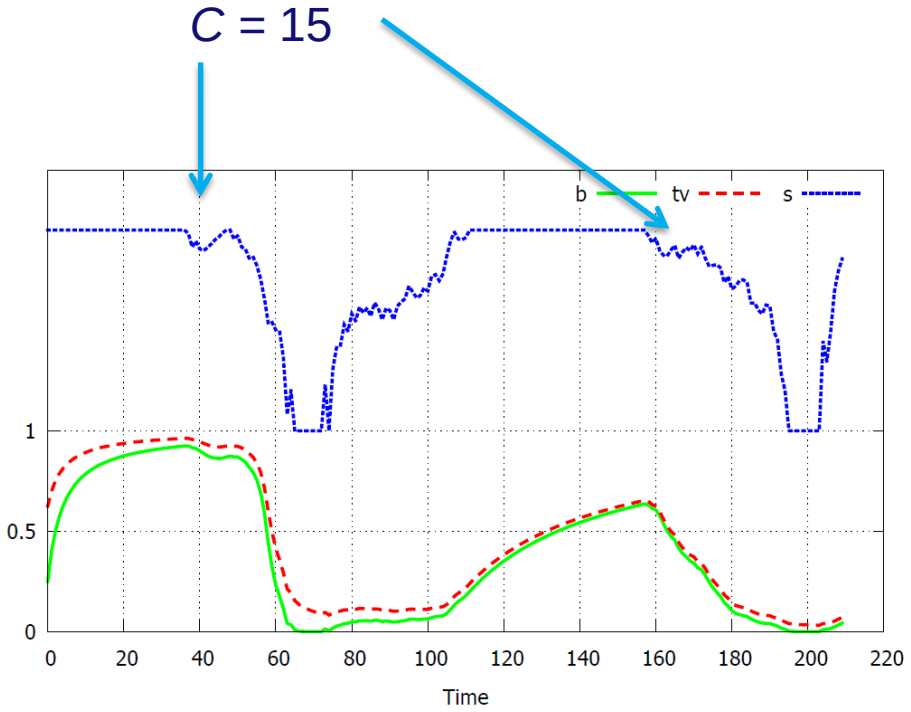
Example (continuous)



$$nf \leftarrow \gamma^s \cdot nf + f$$

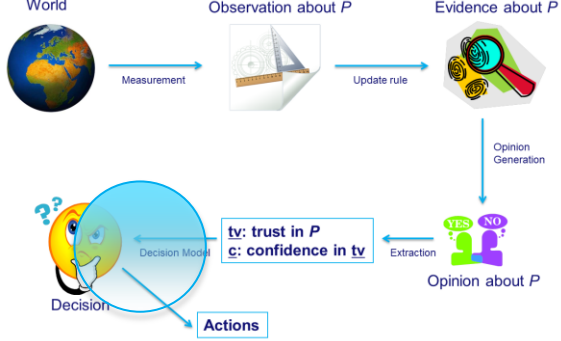
$$ns \leftarrow \delta^f \cdot ns + s$$





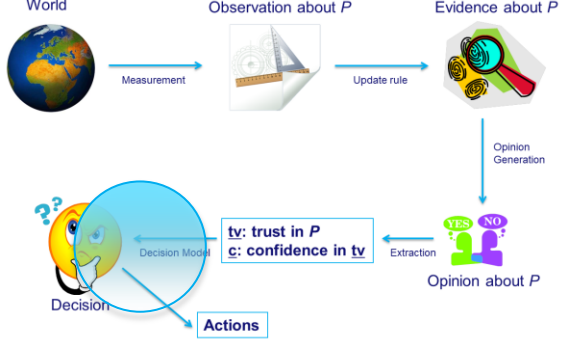
$$\gamma = 1.0, \delta = 0.25, \zeta = 0.7$$

Decision model



- Use weighted sums of trust values (and confidences) and compare with a threshold
- Weights allow to trade trust values of different properties
- Thresholds capture a context
  - e.g. importance (= threshold) of a privacy property goes down upon a medical condition

Decision model



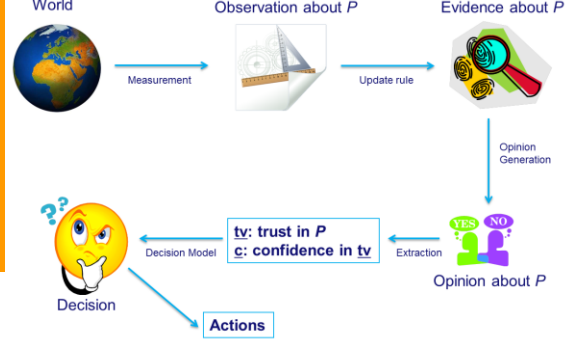
- Maintain trust and confidence values for *n* different trust statements
  - vectors of length *n*: **tv, cv**

- Specify *m* weight vectors of length *n* for both trust and confidence
  - *m* x *n* matrices: **TW, CW**
- Specify *m* thresholds for both
  - vectors of length *m:* **tThr, cThr**

- Safe state:

$$\mathbf{TW\ tv \geq tThr}$$
$$\mathbf{CW\ cv \geq cThr}$$

Example (model)

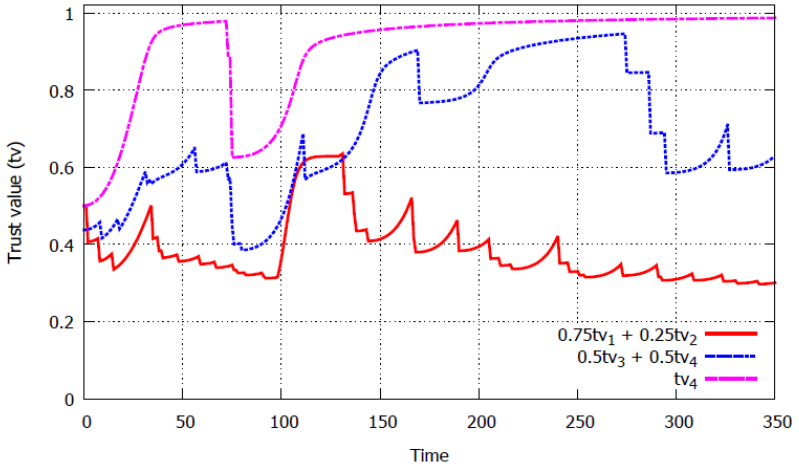


- Monitoring 4 properties, leading to $tv_1, \ldots, tv_4$

p_1: CPU usage is less than 60%.
p_2: Memory usage is less than 40%.
p_3: Network bandwidth usage is less than 25%.
p_4: The degree of privacy is larger than 90%.

- Decision model

$$0.75tv_1 + 0.25tv_2 \geq 0.9$$
$$0.5tv_3 + 0.5tv_4 \geq 0.6$$
$$tv_4 \geq 0.8$$



Related work (see references)

- Monitoring in Sensor Networks for specific goals
  - e.g. reliability of packet forwarding, malicious node detection
- Monitoring for system health as occurs in, e.g., device driver subsystems
- Intrusion detection
- Various applications of subjective logic, based on the simple update rules
- Mode-based resource management

Conclusion & further work

- Proposed a general M&D framework based on monitoring
  - decay
  - uncertainty
  - decision model

- Further work
  - consistency between evidence composition and opinion composition
  - the shape of trust increase should not be convex (‘the foot’)
  - machine learning of cues
  - elaborate on the role of context

- **Questions?**