Algorithms for context prediction in ubiquitous systems

Lecture in WS08/09

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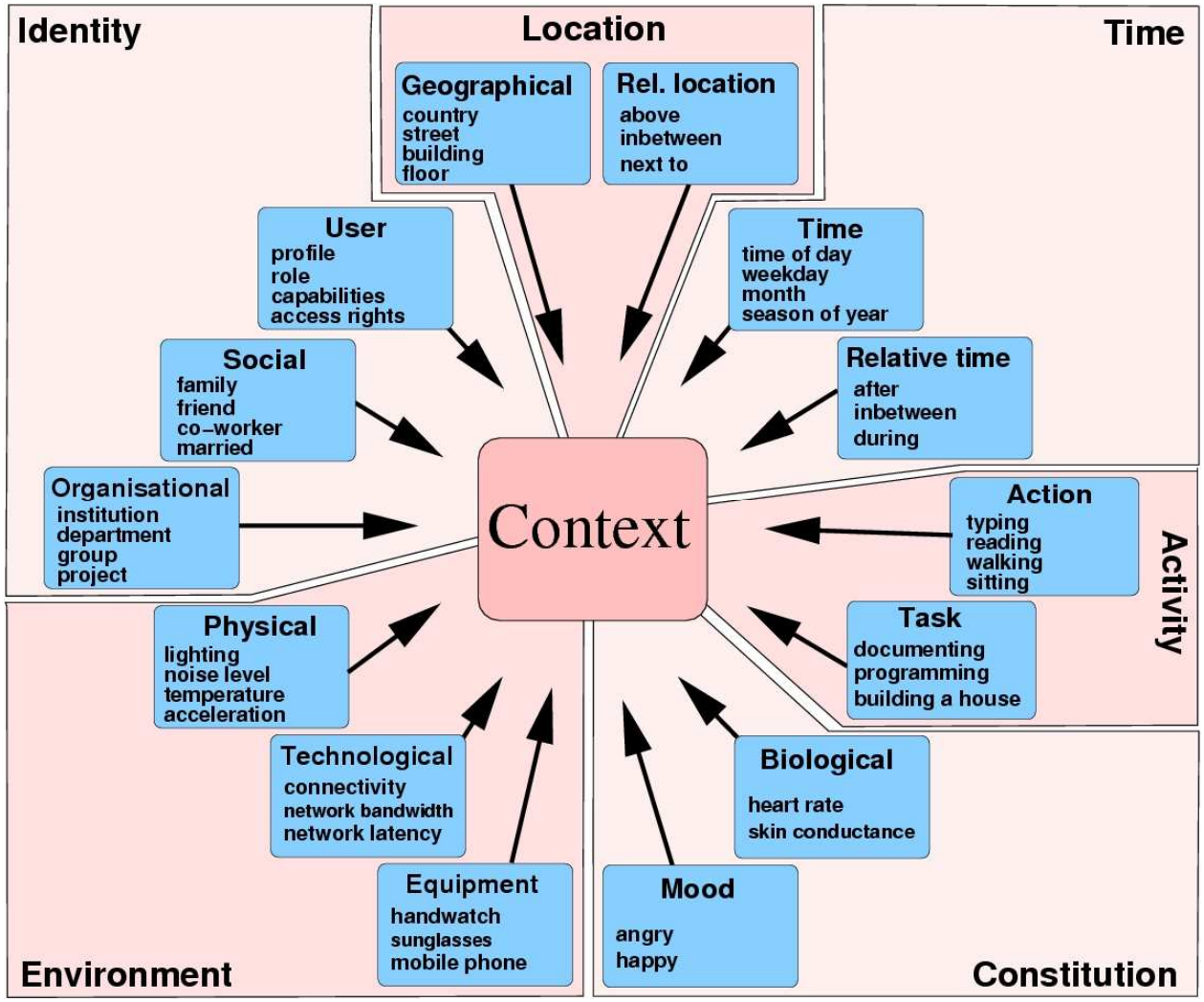
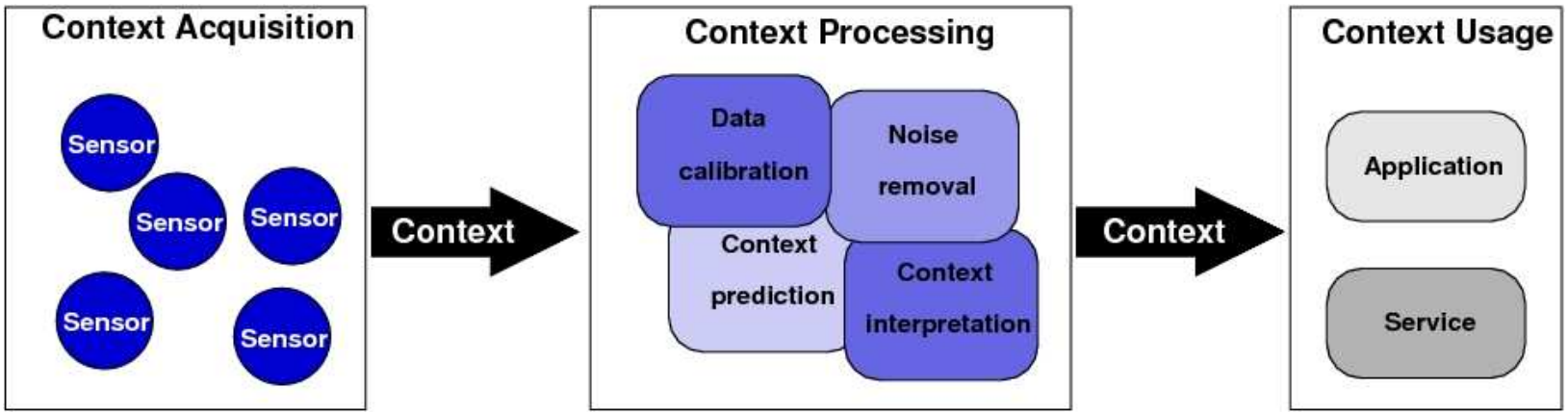
What is context?



Example sensors

Context processing and context utilisation

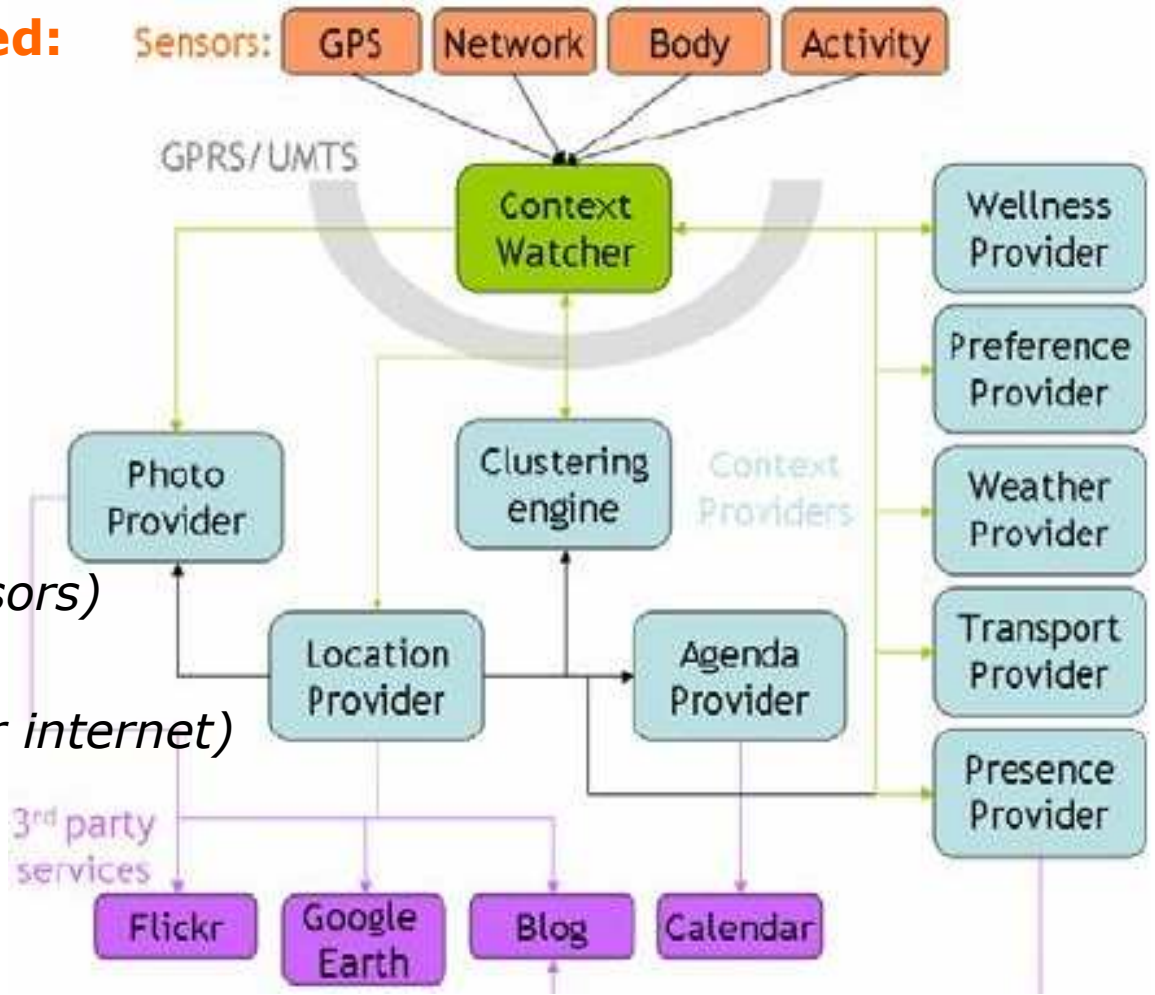


Example sensors

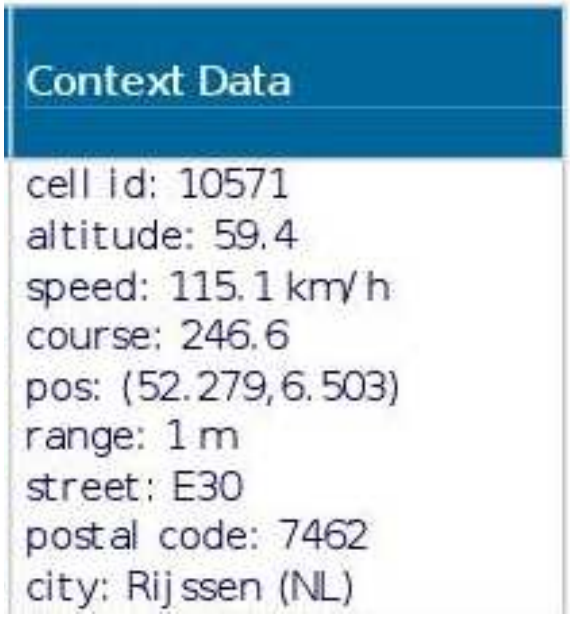
Example: Context Watcher

Context sources utilised:

- Location
  - *(GSM cell-ID; GPS)*
- Mood
  - *(user input)*
- activity
  - *(calender based)*
- Bio-data
  - *(heart and foot sensors)*
- Weather
  - *(location based over internet)*
- Photo/picture
  - *(camera)*



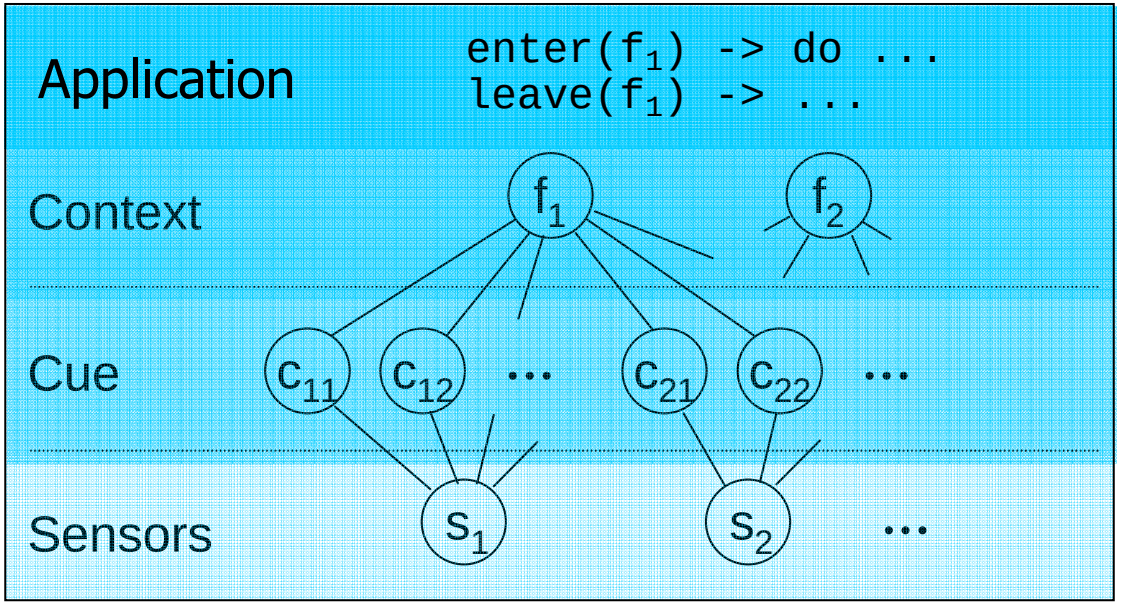
Example: Context Watcher

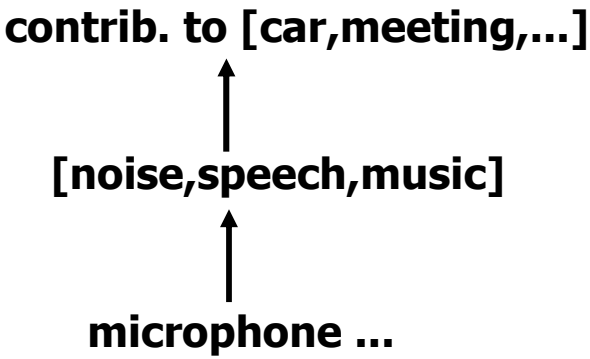


Context recognition

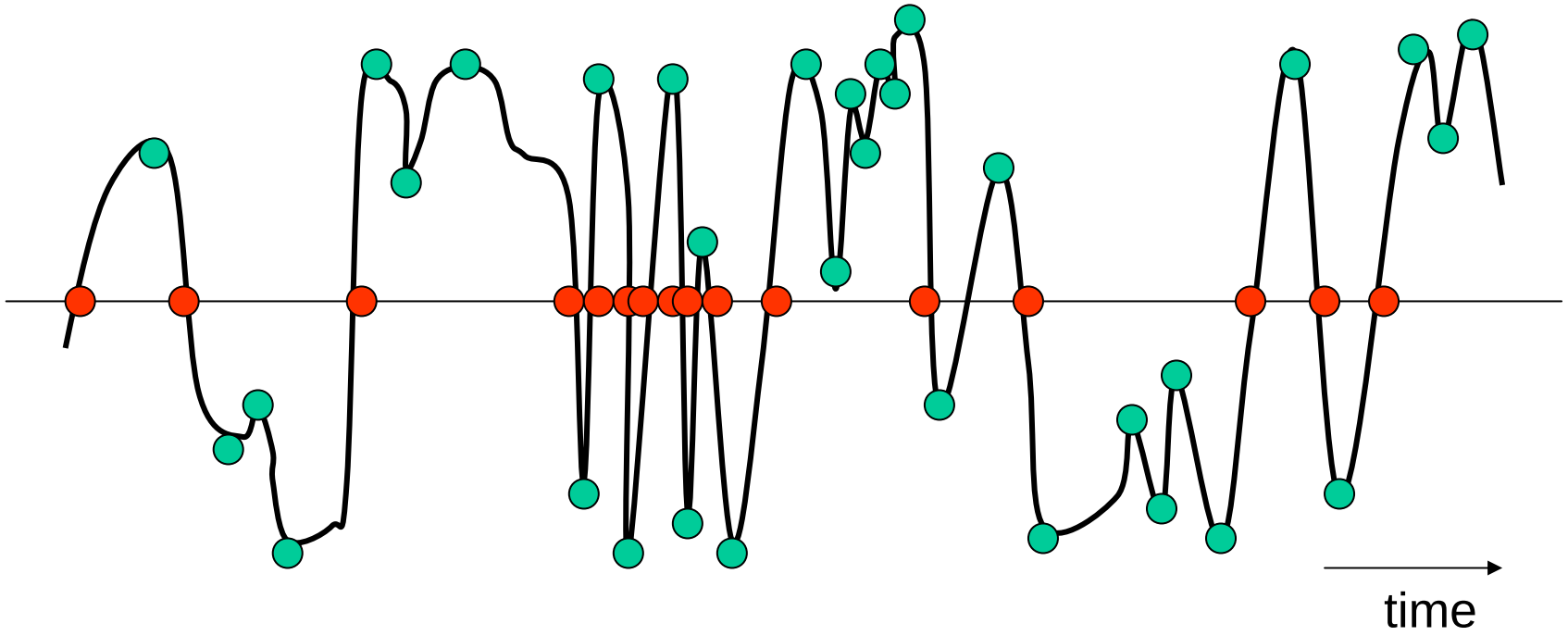
Context processing stages

- Raw electrical signals
- Interpretation of signals as electic values
- Aggregation, first abstraction of signals
- Further abstraction based on semantics
- Interpretation of abstracted data to contexts





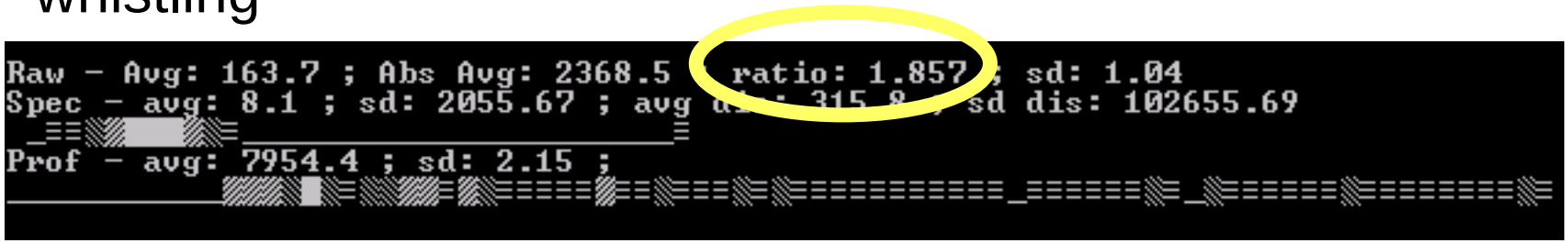
Processing ratio



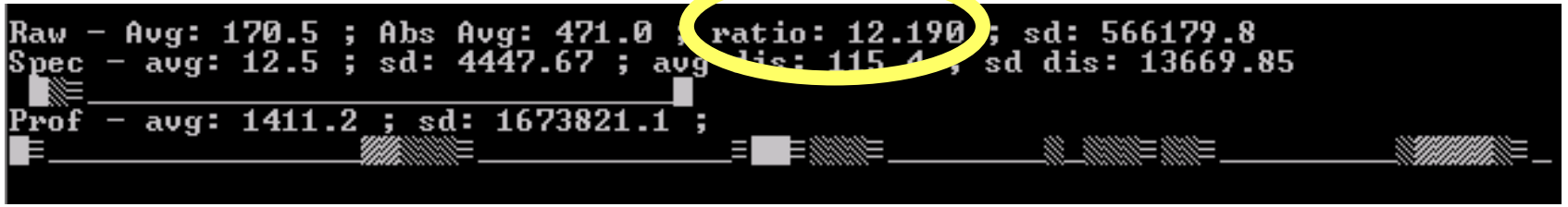
- ratio = Direction changes / Zero crossings

Processing

whistling



speech

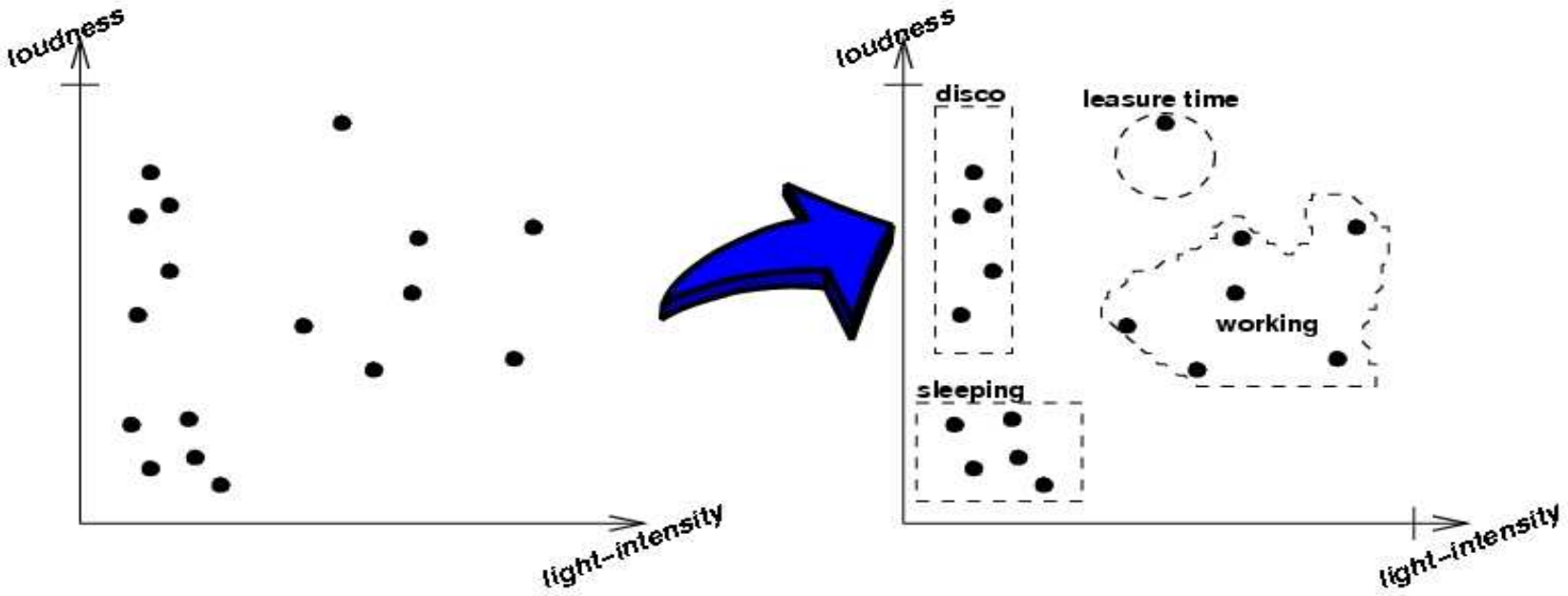


- Distinct ratio zero crossings / direction changes

Context recognition

From features to contexts

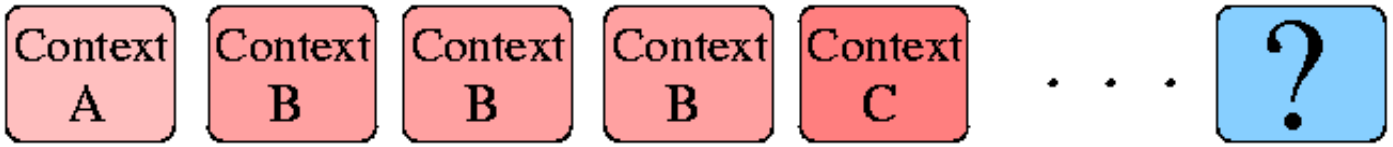
- Measure available data on features
- Probably with regard to probability distribution
  - Measured value always approximation of actual value
- Context reasoning by appropriate method
  - Syntactical (rule based ; e.g. RuleML);
  - Statistical: HMM, NN, SOM, SVM, Bayes Nets …



What is context prediction?

Informal descriptions:

- *„Context Prediction […] aims at inferring future contexts from past (observed contexts).“* [Mayr04]
- *„In Kombination mit verschiedensten bekannten Informationen soll aus dem augenblicklichen Kontext heraus der nächste Kontext vorhergesagt werden.“*[Petz05]



Literature:

[Mayr04] **Mayrhofer, R.M, An Architecture for Context Prediction, PhD-Thesis, 2004.**

[Petz05] **Petzold, J, Zustandsprädiktoren zur Kontextvorhersage in ubiquitären Systemen, PhD-Thesis, 2005.**

What is context prediction?

Formal definition of context prediction:

- Let k, n, i ∈ N and t_i describe any interval in time. Furthermore, let T be a context time series. Given a probabilistic process $\pi(t)$ that describes the context evolution at time t_i , context prediction is the task of learning and applying a prediction function $f_{t_i} : T_{t_{i-k+1},t_i} \rightarrow T_{t_{i+1},t_{i+n}}$ that approximates $\pi(t)$.

What is context prediction?

Context prediction is a search problem:

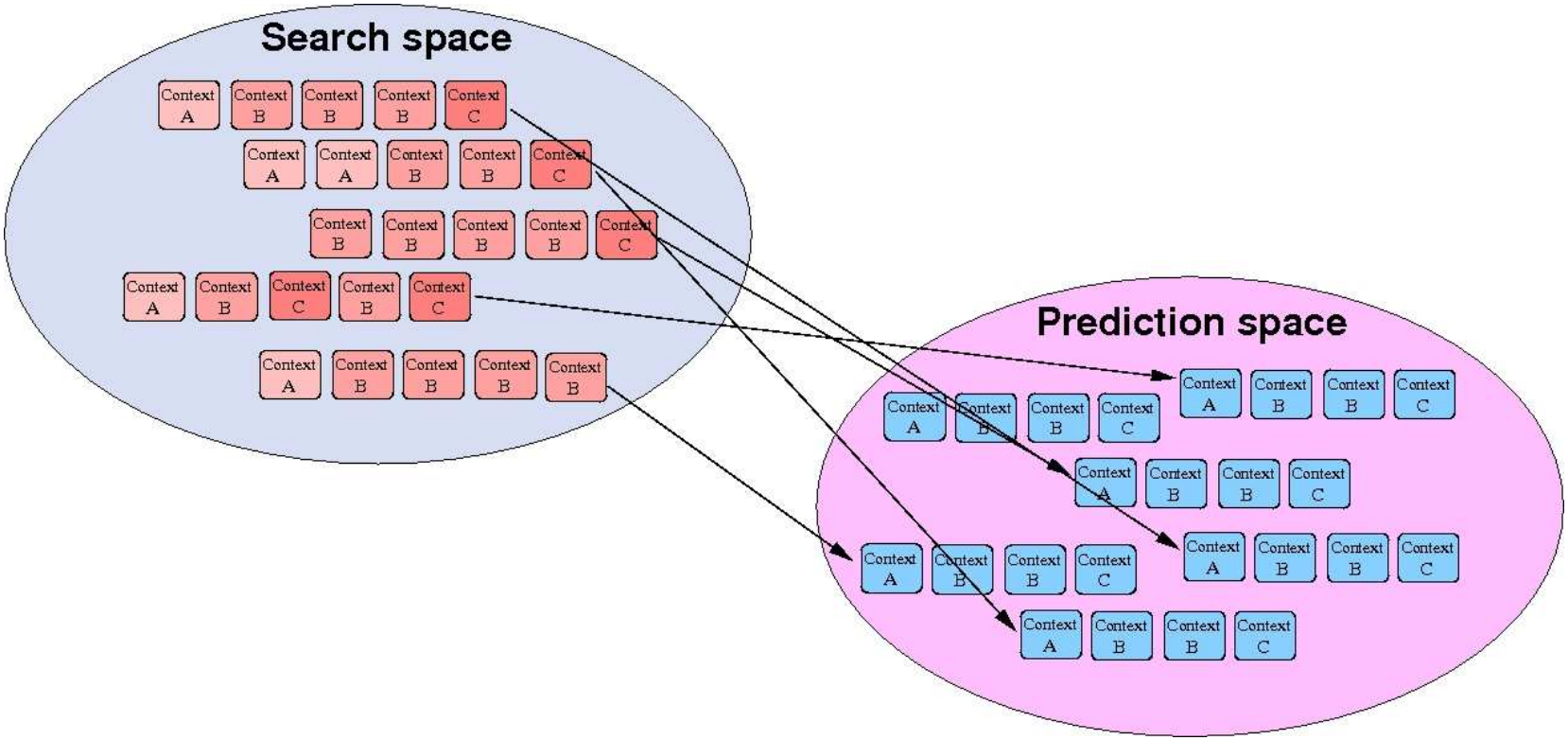
- A search problem Π is described by
  1. the set of valid inputs Λ_Π
  2. for $I \in \Lambda_\Pi$ the set $\Omega_\Pi(I)$ of solutions

  An algorithm solves the search problem Π if it calculates for $I \in \Lambda_\Pi$ an element $\Omega_\Pi(I)$ if $\Omega_\Pi(I) \neq \varnothing$ and rejects otherwise.

What is context prediction?

Context prediction is a search problem:

- Context prediction is mainly to find the correct mapping between search space and prediction space



What is context prediction?

Possible distance metrics between contexts:

- Table-Look-up for non-numeric context types
  - Alternatively, non-numeric contexts might be mapped onto numeric context types

- Various approaches for numeric context types:
  - One-dimensional: simple difference between values
  - Multi-dimensional:
    - Euclidic distance between input vectors
    - RMSE

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (p_i - d_i)^2}{n}}$$

    - BIAS

$$BIAS = \frac{\sum_{i=1}^{n} |p_i - d_i|}{n}$$

- Further approaches feasible

What is context prediction?

Requirements:

- In order for context prediction to be feasible, the input sequence has to be predictable in any sense:
  - Periodic patterns
  - Trends
  - Repetitions of typical patterns
  - …
- Problem:
  - Mood is part of definition of context but hardly accessible by sensors

What is context prediction?

Input sequence typically predictable in UbiComp:

- Human behaviour patters are reproducible [Ande01]
  - Cognitive psychology: 'script' describes actions and circumstances that characterise specific context or context pattern.
  - Scripts similar for groups of individuals; small alterations between different cultures or societies
- "Behaviour consists of patterns in time" [Magn04]
- Typical behaviours in team–sport games like soccer [JBGB03]
- It is possible to recognise the software programmer of a piece of programming code based on her programming style [Krsu94].

Literature:

[Ande01] Anderson, J.R., Cognitive psychology and its implications, Spectrum, 2001.

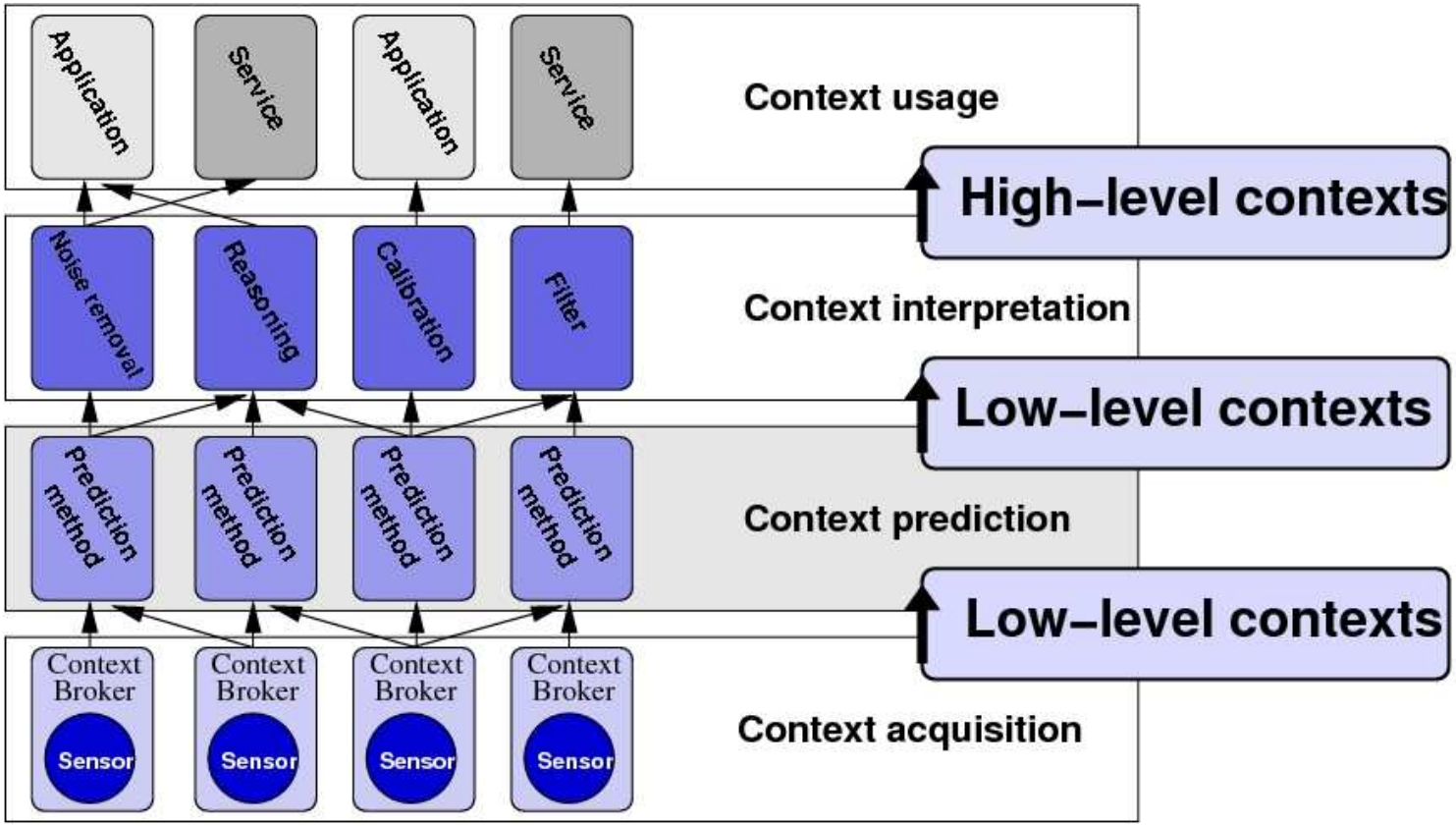
[Magn04] Magnusson, M.S., Repeated patterns in behaviour and other biological phenomena, In: Oller, K., Gabriel, U.: Evolution of Communication systems: A comprehensive approach, MIT Press, 2004.

[JBGB03] Jonsson, G.K., Bjarkadottir, S.H., Gislason, B., Borrie, A., Magnusson, M.S., Detection of real time patterns in sports: Interactions in football, L`ethologie applique aujourd`hui, 2003.

[Krsu94] Krsul, I., Authorship analysis: Identifying the author of a program, 1994

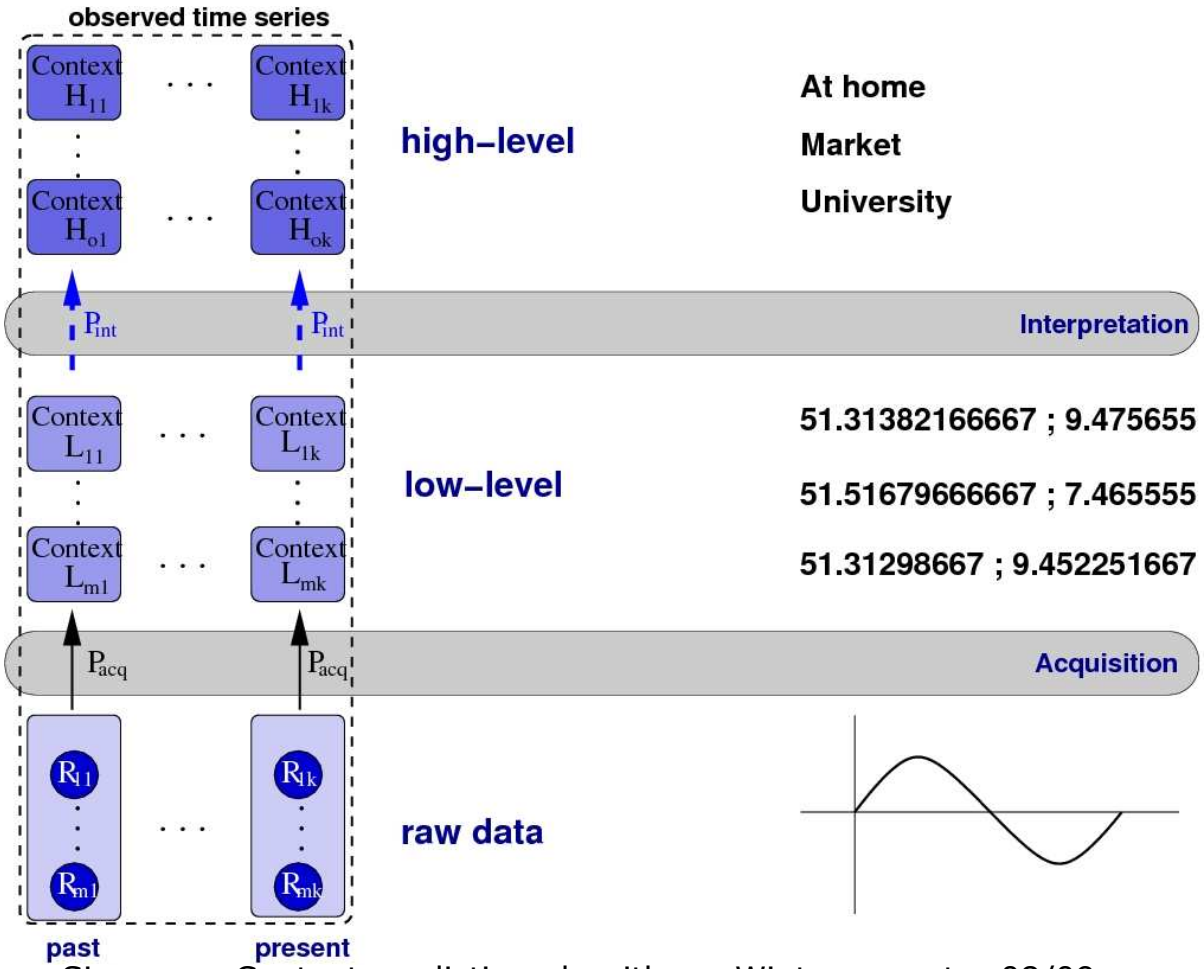
Context prediction architectures

Context prediction architectures:



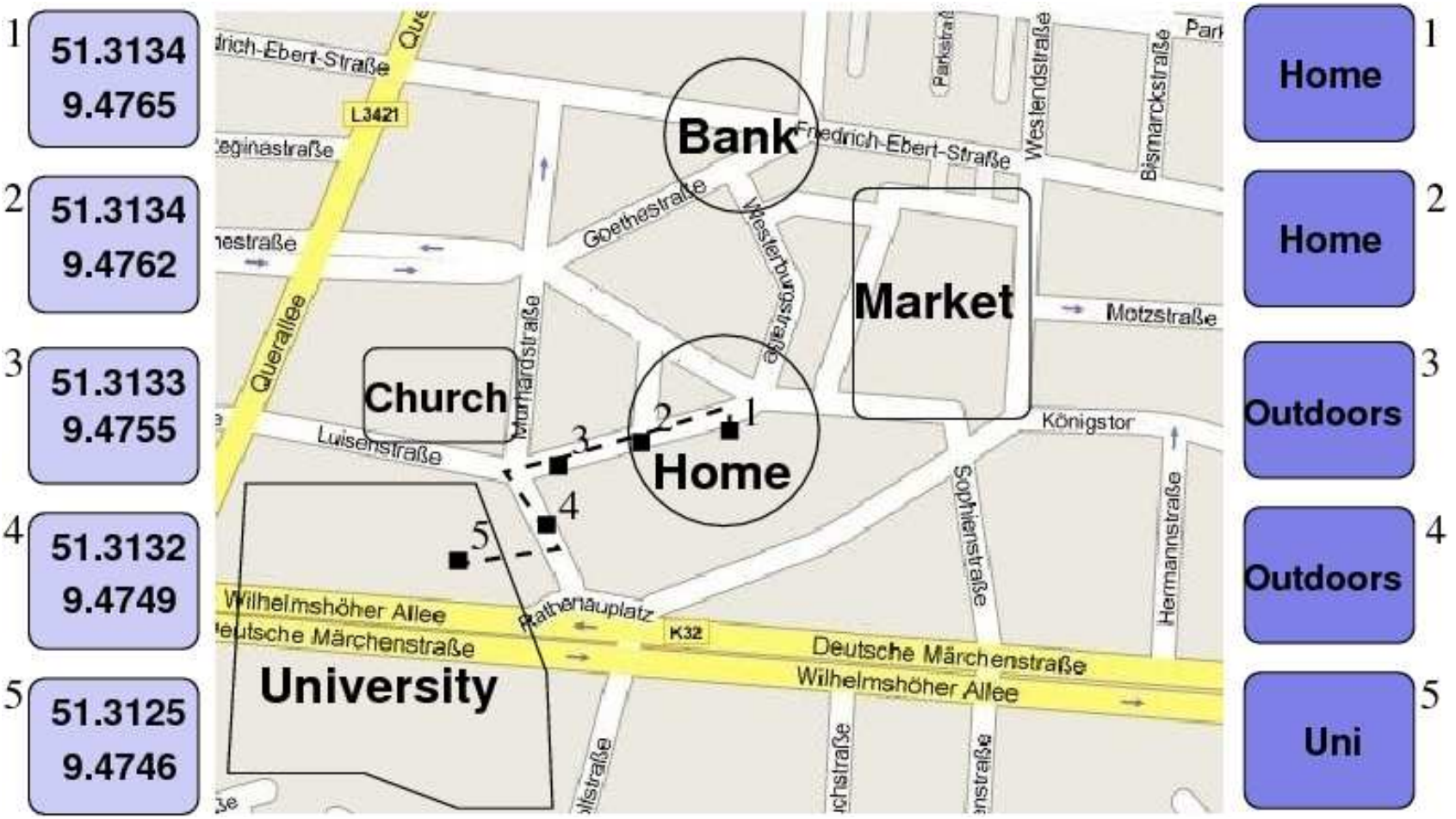
Context abstraction levels

High-level and low-level context prediction:



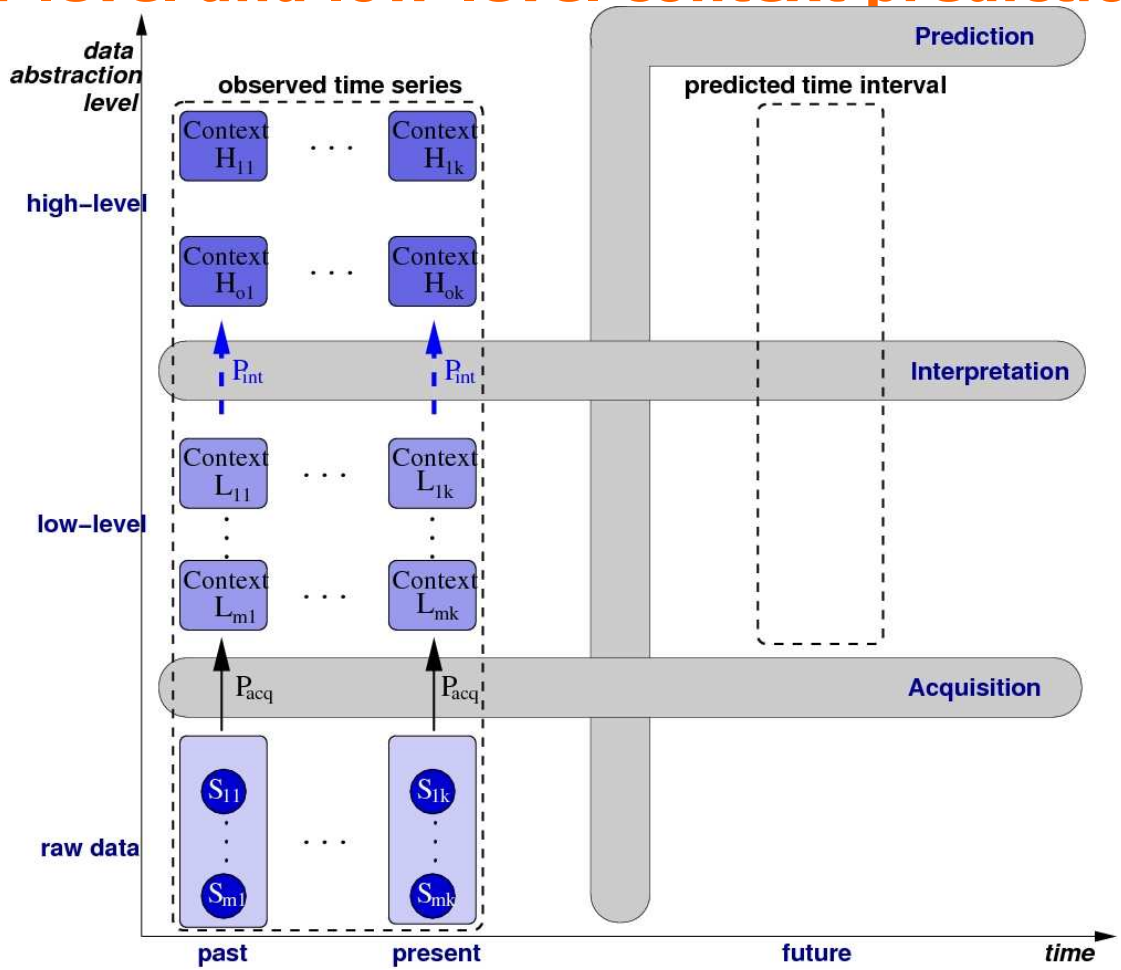
Context abstraction levels

Example: Location prediction:



Implication of abstraction levels

High-level and low-level context prediction:



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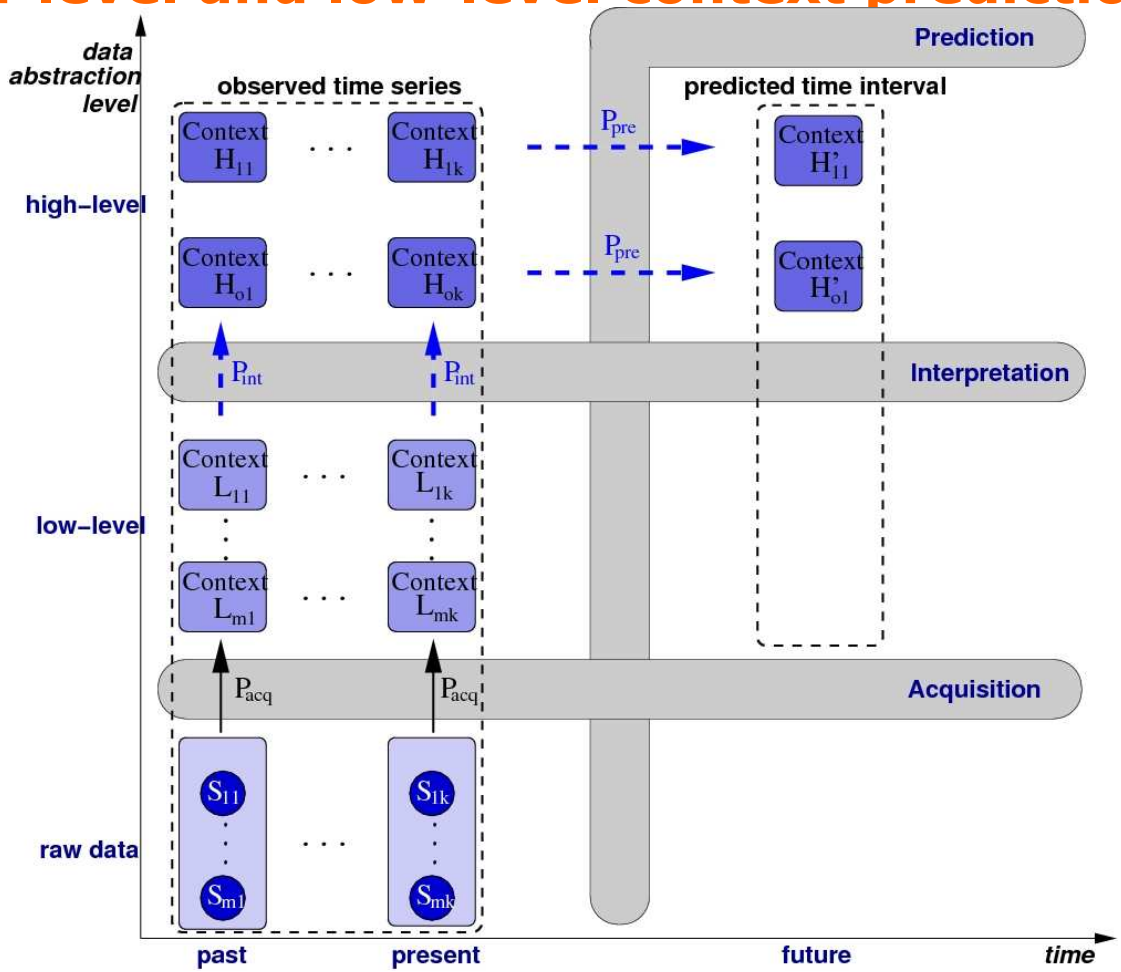
High-level and low-level context prediction:



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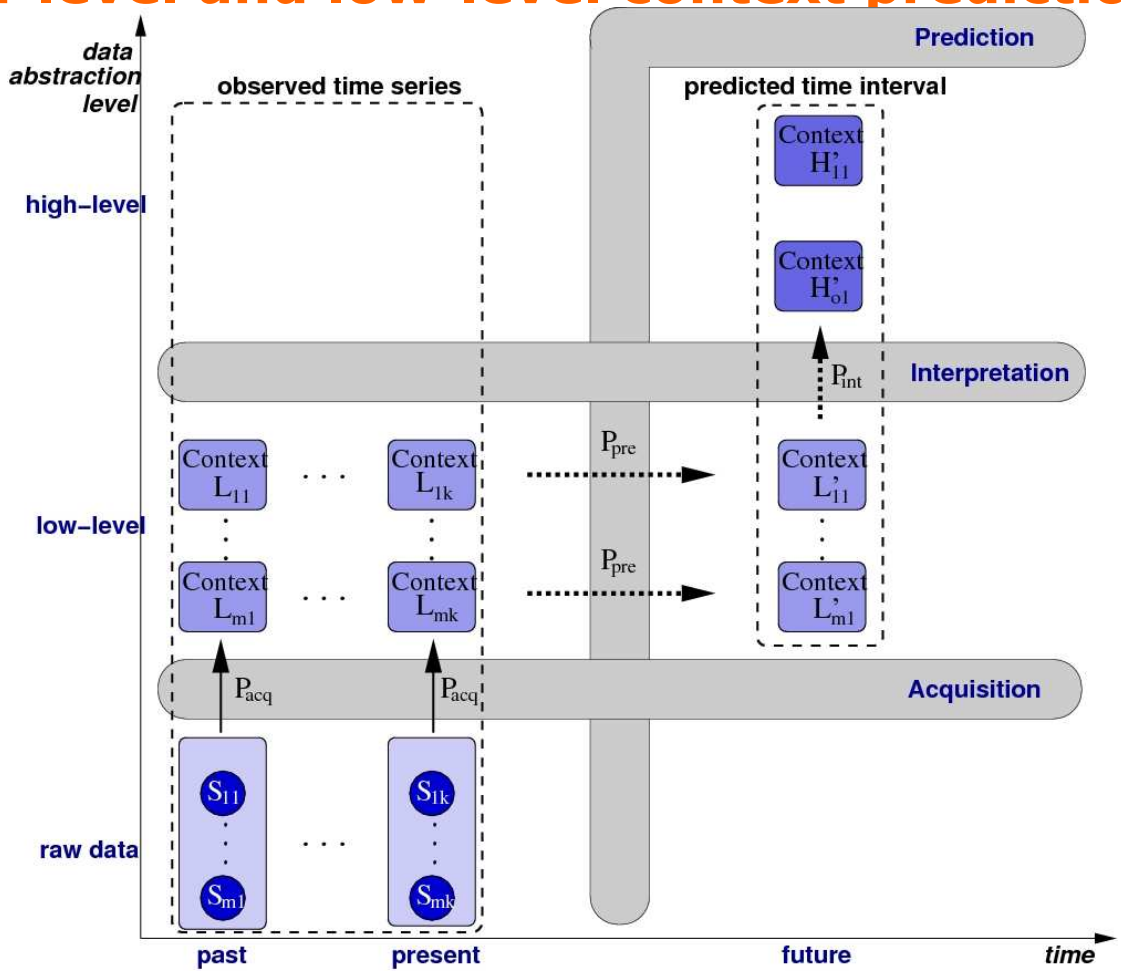

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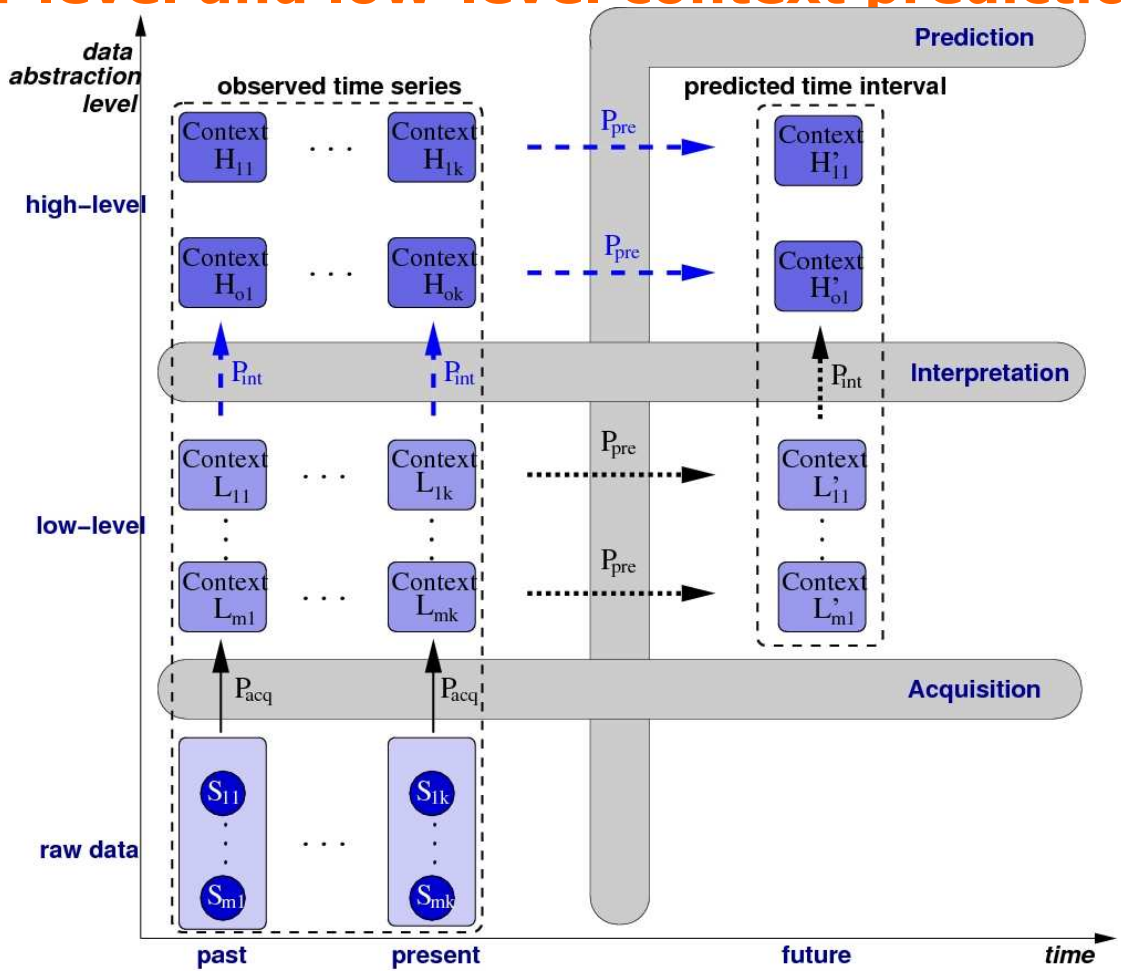


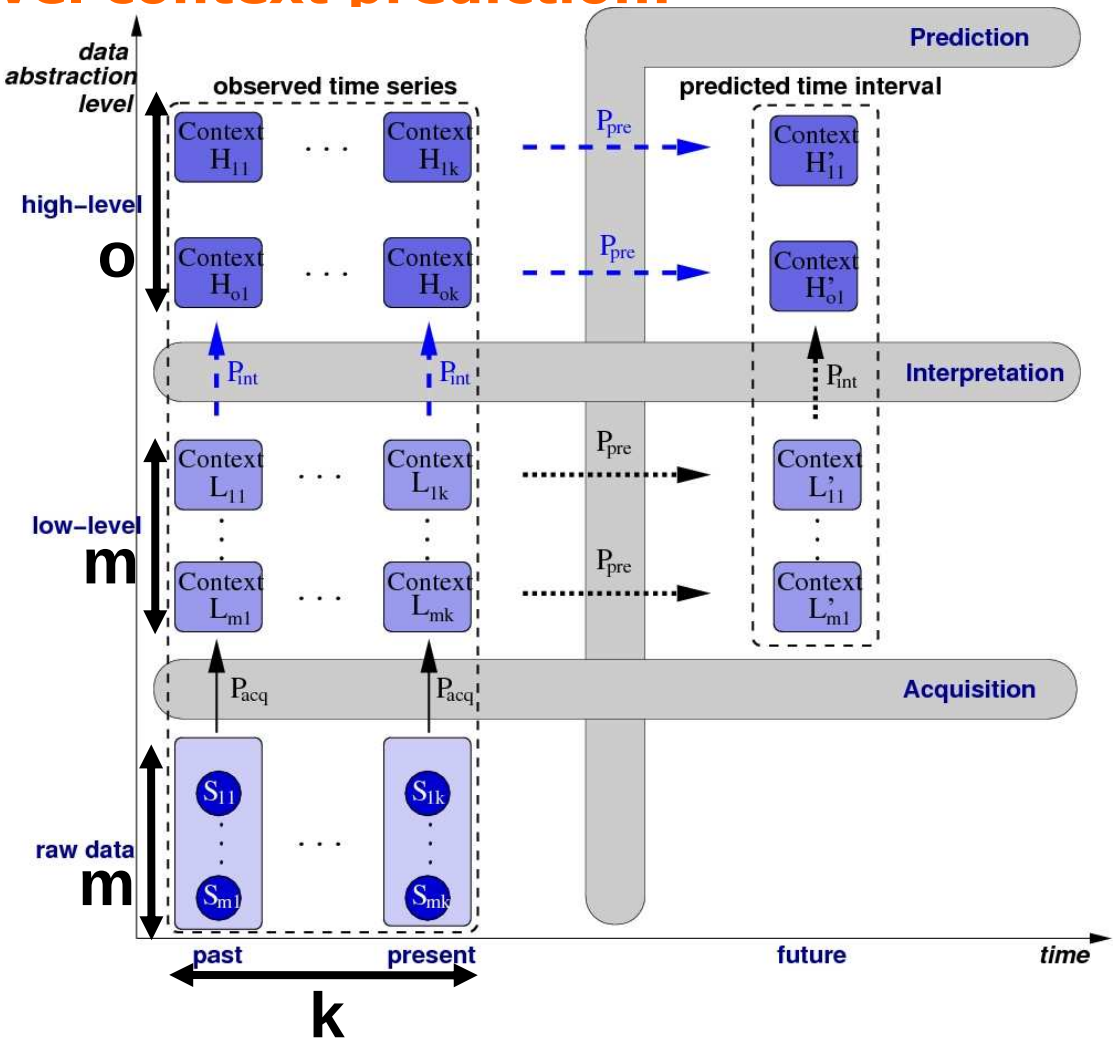
Implication of abstraction levels

High-level and low-level context prediction:

$$P_{acq}^{km} \cdot P_{int}^{ko} \cdot P_{pre}^{o}$$

$$P_{acq}^{km} \cdot P_{pre}^{m} \cdot P_{int}^{o}$$

k: # of input time intervals
m: context sources per interval
o: high-level contexts per interval
P_{acq}: Probability: No acquisition error
P_{pre}: Probability: No prediction error
P_{int}: Probability: No interpretation er



Implication of abstraction levels

Exact probabilitiy estimation:

$$P_{hl}(i) = \left(P^m_{acq} P^o_{int} + P^{int}_{cor}\right)^k P^o_{pre}(i) + \left(1 - \left(P^m_{acq} P^o_{int} + P^{int}_{cor}\right)^k\right) \frac{1 - P^o_{pre}(i)}{v^o_h - 1}.$$

Implication of abstraction levels

Exact probabilitiy estimation:

$$P_{hl}(i) = \left(P_{acq}^{m} P_{int}^{o} + P_{cor}^{int}\right)^{k} P_{pre}^{o}(i) + \left(1 - \left(P_{acq}^{m} P_{int}^{o} + P_{cor}^{int}\right)^{k}\right) \frac{1 - P_{pre}^{o}(i)}{v_h^o - 1}.$$

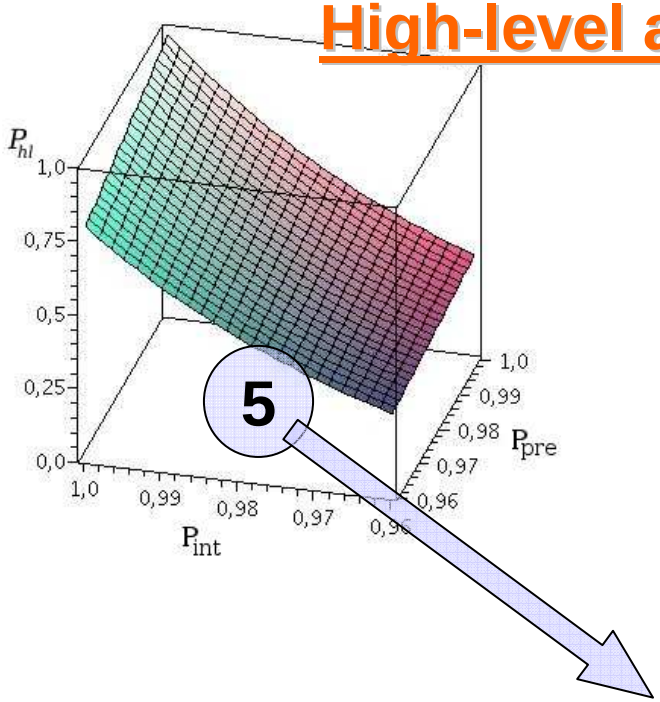
$$P_{ll}(i) = \left(P_{acq}^{k} P_{pre}(i) + P_{cor}^{pre}\right)^{m} P_{int}^{o} + \left(1 - \left(P_{acq}^{k} P_{pre}(i) + P_{cor}^{pre}\right)^{m}\right) \frac{1 - P_{int}^{o}}{v_h^o - 1}.$$

Implication of abstraction levels

Study: When to utilise which prediction scheme

Implication of abstraction levels

High-level accuracy - Increasing parameters



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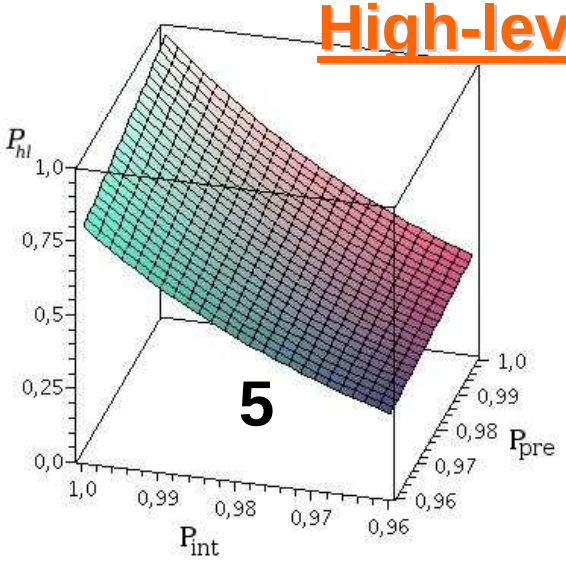
Parameters:

k:	# of input time intervals	= 5
m:	context sources per interval	= 5
o:	high-level contexts per interval	= 5
P_{acq}:	Probability: No acquisition error	= 0.99
P_{pre}:	Probability: No prediction error	= 0.9
P_{int}:	Probability: No interpretation er	= 0.9

Implication of abstraction levels

High-level accuracy - Increasing parameters



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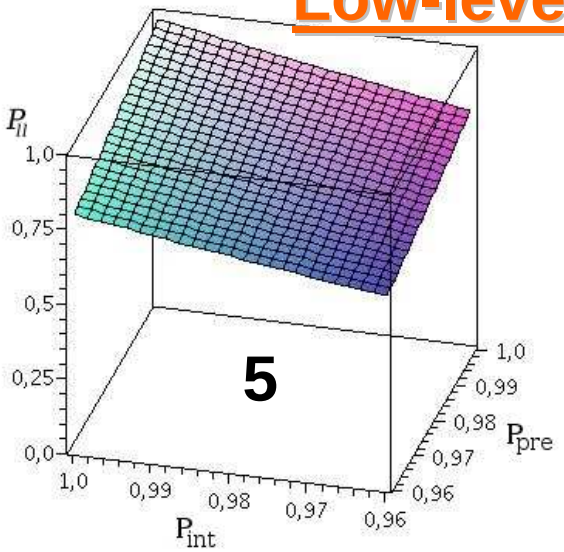
Low-level accuracy – Increasing parameters



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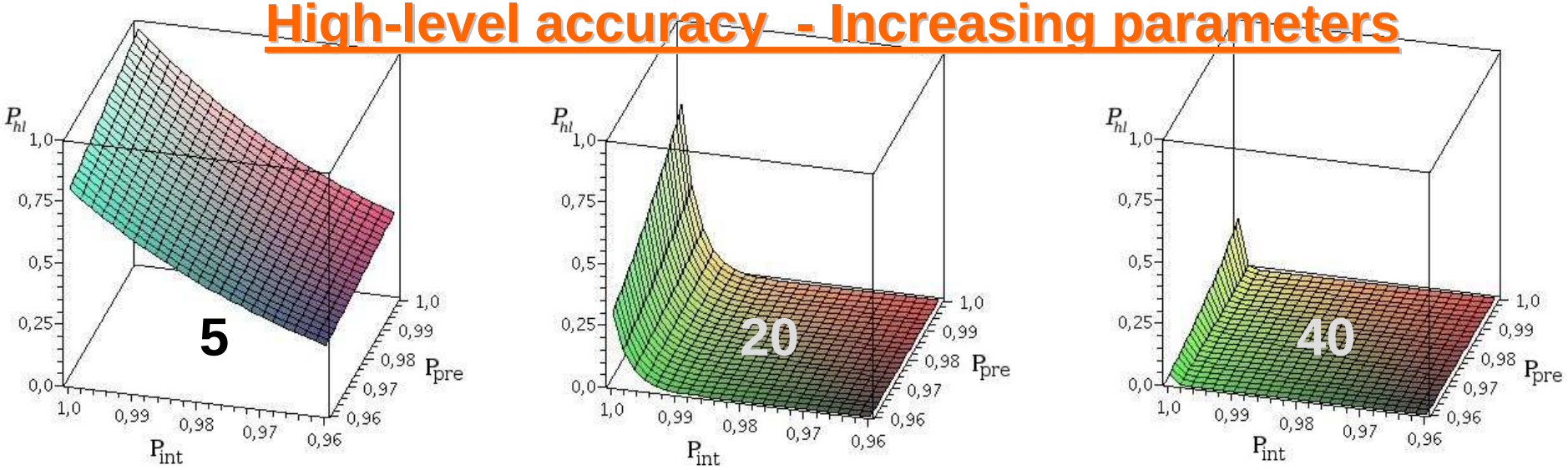
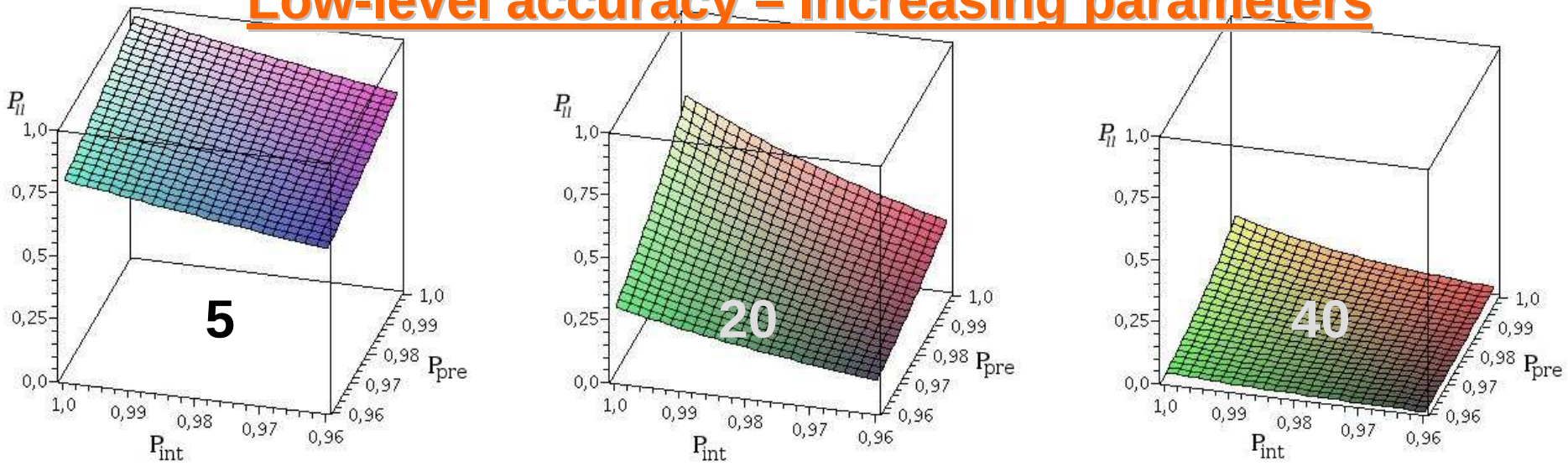
Implication of abstraction levels

High-level accuracy - Increasing parameters



Low-level accuracy – Increasing parameters



Implication of abstraction levels

Conclusion – Context abstraction levels:

- Analyse scenario in advance to implementation
- Environmental parameters and error probabilities of context processing modules impact prediction accuracy
- Prediction accuracy differs with context abstraction level of input data.