Using a Context Quality Measure for Improving Smart Appliances

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Particle Computer
every thing communicates

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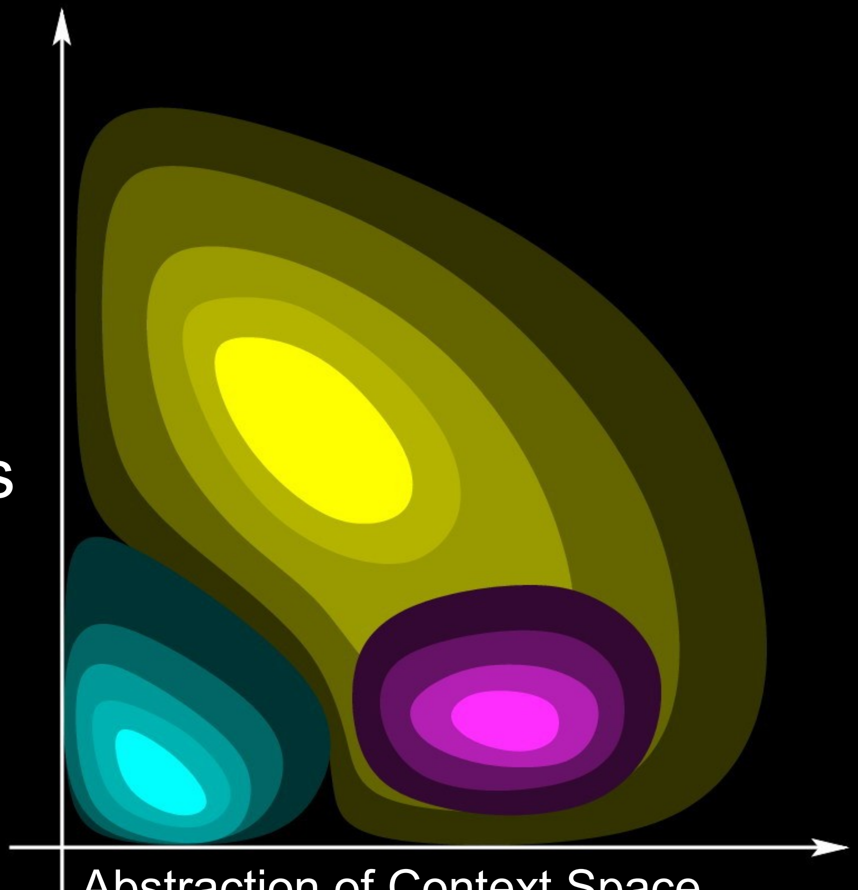
Problem of Context Recognition

- **Context recognition is not reliable**
  - → context classification is faulty
  - → error lies in used sensors and/or algorithm
  - → dependability on faulty systems
  - → improvement only to a certain degree



Abstraction of Context Space for three Fuzzy Context States

Reasoning in Large Scale Ubiquitous Environments

- Reasoning is depending on faulty knowledge

  → Reasoning increases error exponentially

  → Error is known only in absolute manner

  → Single data error is mostly not known at runtime

- Combination of reliable with unreliable data should be avoided

  → Possible errors should not be included in further reasoning

  → Filtering out faulty data can save communication and calculation resources

Existing Systems for Context Recognition

- Existing systems for recognizing context want to be reused
  - → Obtaining a Context Quality Measure (CQM) should not interfere with existing algorithms
  - → User of Quality Analyzing System should need no knowledge of existing recognition system
  - → Each piece of context data should be equipped with a CQM

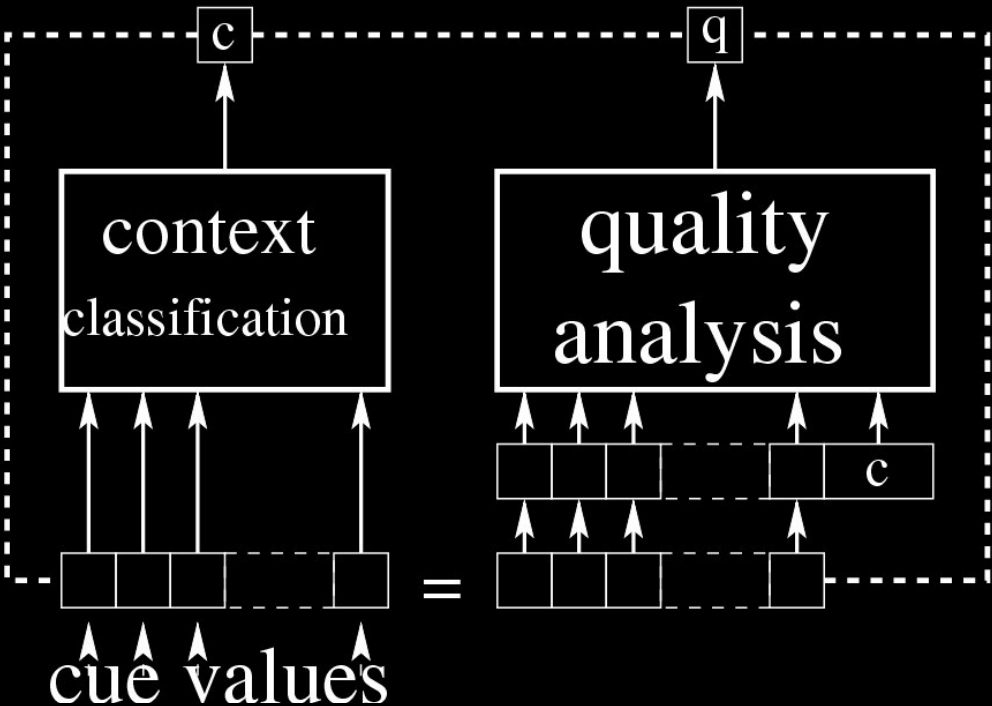
→ Our system for quality analyzing can meet these demands and provides a CQM to filter out faulty data!

Fuzzy Inference System (FIS) → Non-Linear Error Approximation

- Adaptation on system error
  → Systems mostly non-linear
  → System error is non-linear
- Fuzzy Inference Systems (FIS)
  → FIS is universal approximation function
  → Infinite set of rules → infinite precise approximation [1]
- TSK-FIS [2] can deal with non-complete data
  → Lack of data for one state yields to zero mapping of the data → zero mapping concludes highest error in our model

[1] L X Wang. *Adaptive Fuzzy Systems and Control*. Prentice-Hall, Englewood Cliffs, 1998.
[2] T Tagaki and M Sugeno. *Fuzzy identification of systems and its application to modelling and control*. *IEEE Trans. Syst. Man and Cybernetics, 1985, vol SMC-15, no. 1, pp 116-132*, 1985.

Quality Analysis → Context Quality Measure (CQM)



- Context classification is considered as a ‘Black-Box’
- Quality analysis input = input of context classification + classification output → quality analysis does not interfere with existing contextual algorithms
- Knowledge of classification error is stored in FIS due to automated construction and training

  → CQM is representing the error due to elements of the interval [0,1]

Automated Construction and Training of Qualitative FIS

- **Designated output:**

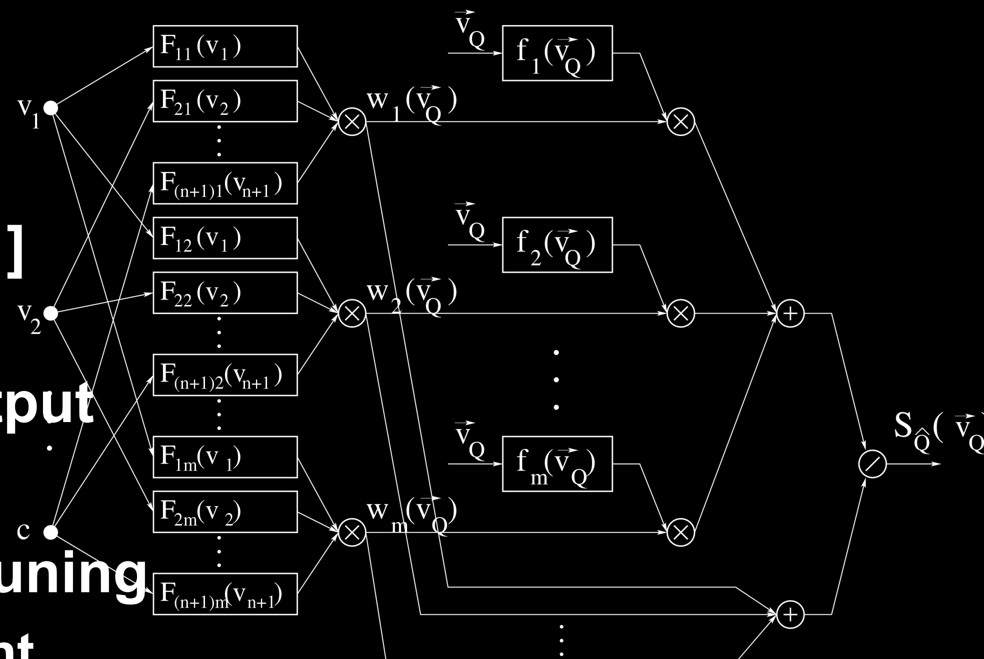
  1 → right classification

  0 → false classification
- **Clustering determines rules [1]**
- **Linear regression fits output functions onto designated output**
- **ANFIS [2] enables training →**
- **Hybrid training for fine grain tuning**

  backward-pass: gradient descent

  → Back-Propagation

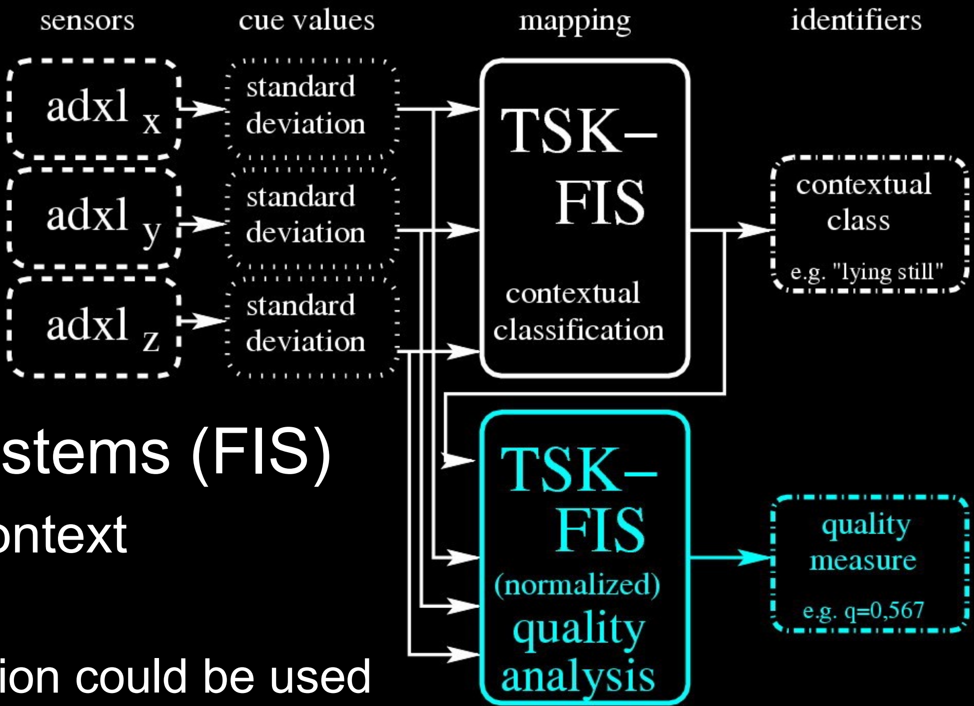
  forward-pass: linear regression on bases of Back-Propagation changes



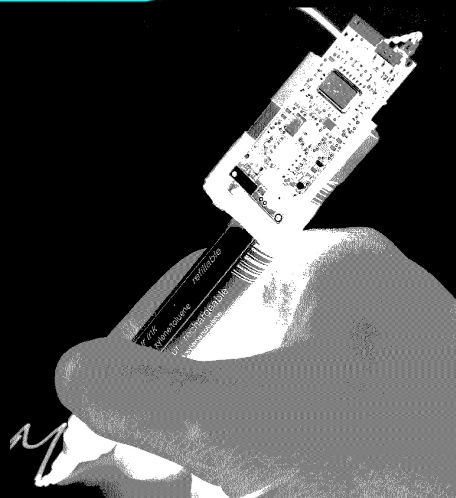
[1] Stephen Chiu. *Method and software for extracting fuzzy classification rules by subtractive clustering. IEEE Control Systems Magazine, 1996, vol. pp. 461-465*, 1996.

[2] Jyh-Shing Roger Jang. ANFIS*: Adaptive-network-based fuzzy inference system. IEEE Transactions on Systems, Man and Cybernetics, 1993, vol. 23 pp. 665-685*, 1993.

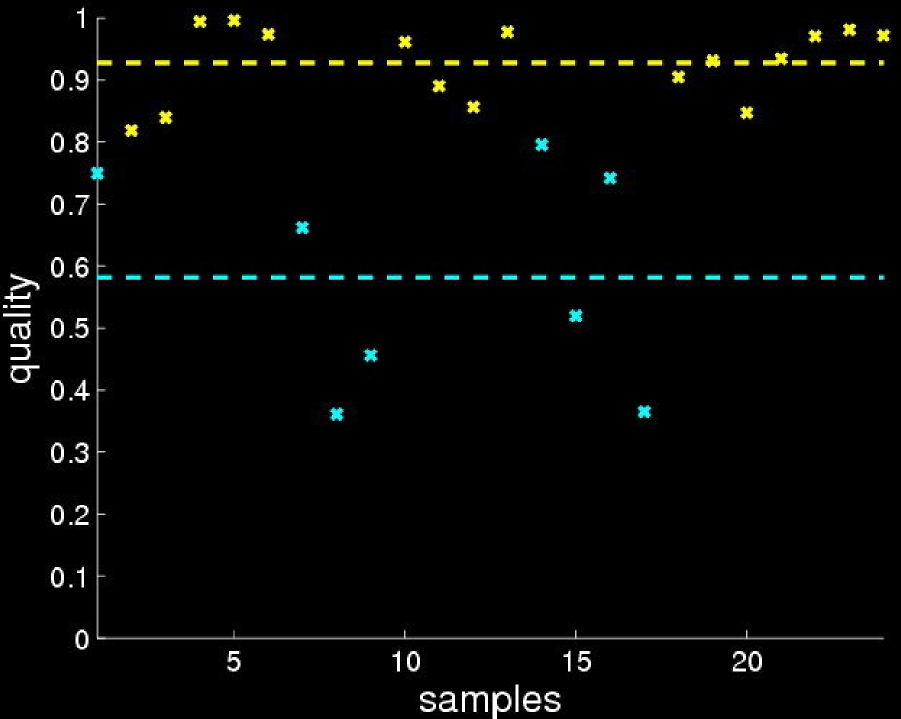
The AwarePen with CQM

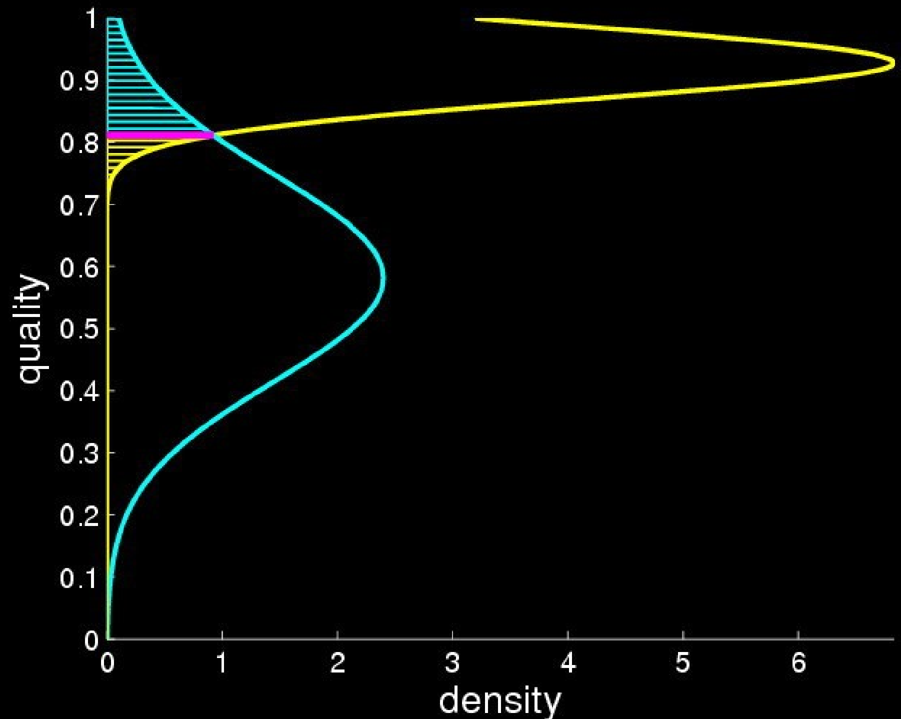


- **Input:** ADXL-sensors
  - → x-, y- and z- acceleration
- **Cueing:** standard deviation
  - → sliding window over 24 values
- **Mapping:** Fuzzy Inference Systems (FIS)
  1. FIS: mapping cue values onto context
     - → classification of result
     - → instead of FIS any other projection could be used
  2. FIS: holds knowledge about error of 1. FIS
     - → normalization of result
- **Output:** tuple of context identifier and CQM
  - → Identifier of current contextual state
    - → ‘lying’, ‘writing’ and ‘playing’
  - → CQM is element of interval [0,1]



Using CQM to Filter Contexts





Context Quality Measure (CQM)

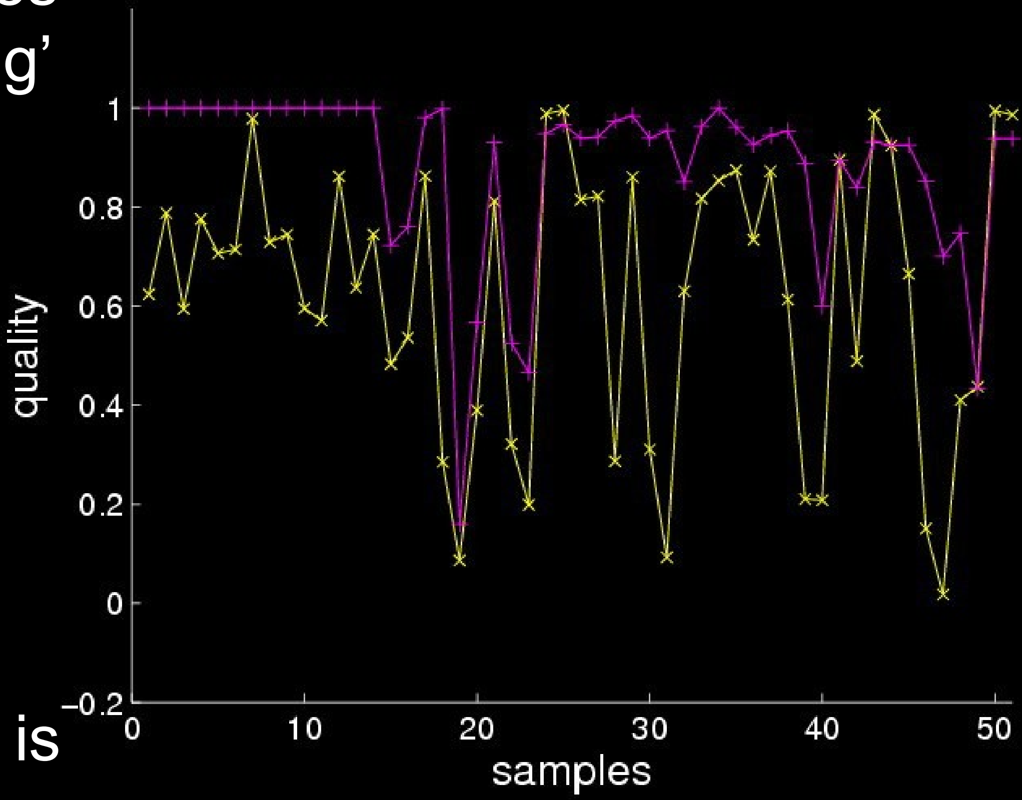
- Right Classified Contexts
  - → Yellow with mean (dashed line)
- False Classified Contexts
  - → Turquoise with mean (dashed line)

Probabilistic Analysis of CQM

- Density of Right Classified
  - → Yellow curve
- Density of Wrong Classified
  - → Turquoise curve
- Possible Filter Threshold
  - → Purple line

Argument for Separate CQM-System

- CQM for consecutive states ‘lying’, ‘writing’ and ‘playing’
  → Purple line
- Normalized distance of contextual FIS output to class-centre
  → Yellow line



→ QCM contains less noise

→ Reliability of classification is state dependent

→ High correlation proofs comparability

Conclusion and Future Work

- **Introduction of a system that can provide a Context Quality Measure (CQM)**
  - Quality analyzing system is independent of contextual algorithm
  - Quality analyzing system can be used for error representation of any contextual algorithm
  - Filtering contextual knowledge upon CQM is possible with high odds
- **Future Work**
  - Suitability of quality analysis for other contextual algorithms and systems other than context recognition
  - Combination of quality analysis with context recognition and preservation of state dependability
  - Reasoning with CQM according to reasoning with contextual knowledge