Collaborative transmission in wireless sensor networks

Context aware computing

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April 8, 2010

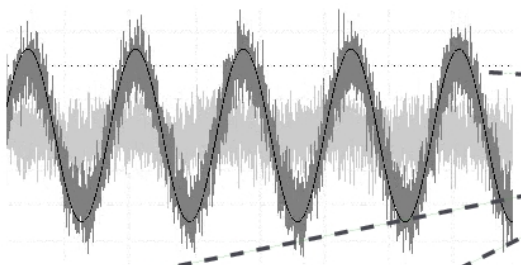
Motivation

A scenario of distributed adaptive Beamforming

- Nodes achieve phase coherency
- Synchronous transmission
- Constructive interference
- No inter-node communication

Motivation

A scenario of distributed adaptive Beamforming



Algorithms

- Distributed adaptive beamforming (Chapter 8)
- Cooperative transmission (Chapter 7)

Concepts

- Evolutionary Algorithms (Chapter 6)
- Introduction to probability theory (Chapter 5)

Theoretical foundation

- Communication technology (Chapter 4)
- Wireless sensor networks (Chapter 3)
- Context Awareness (Chapter 2)

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Overview and Structure

- Introduction to context aware computing
- Wireless sensor networks
- Wireless communications
- Basics of probability theory
- Randomised search approaches
- Cooperative transmission schemes
- Distributed adaptive beamforming
  - Feedback based approaches
  - Asymptotic bounds on the synchronisation time
  - Alternative algorithmic approaches
  - Alternative Optimisation environments

Overview and Structure

- **Introduction to context aware computing**
- Wireless sensor networks
- Wireless communications
- Basics of probability theory
- Randomised search approaches
- Cooperative transmission schemes
- Feedback based distributed adaptive beamforming
  - Feedback based approaches
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Outline

Introduction to context aware computing

Introduction

Can devices respond on our situation?

Traditional computing devices have a static, often deterministic behaviour

- An electronic dictionary presents the translation of words
- An electronic cook book will present identical receipes in identical order each time started
- A word processor presents will present a user the same user interface with every startup

Introduction

Can devices respond on our situation?

Recently, we become used to applications that respond to multiple input sources

- Services might find restaurants in the proximity of a person, based on its GPS position or Cell-ID.
- Devices can be controlled by gestures utilising accelerometers
- The operating system changes preferences based on the location of internet access

Introduction

Can devices respond on our situation?

When we think further along this line, how does the future device then look like?

- Seamlessly integrates into everyday life
- Utilisation of inexplicit inputs
- Reduced amount of attention resources requried

Devices and applications will react on inexplicit inputs and derive situational behaviour rules from multiple input sources.

Outline

Introduction to context aware computing

Context aware computing

Introduction

The vision of context-awareness

The vision of context-awareness is that applications become sensitive to environmental stimuli and adapt their behaviour to the current situation.

- Vision far ahead of technology of the time first formulated
- First implementations:
  - Xerocx PARCTAB[a]
  - Media Cup[b]

[a] R. Want et al, The PARCTAB Ubiquitous Computing Experiment, In: The International Series in Engineering and Computer Science, vol. 353, 1996.

[b] M. Beigl et al, MediaCups: Experience with Design and Use of Computer-Augmented Everyday Objects, Computer Networks, Special Issue on Pervasive Computing, Elsevier, 2001

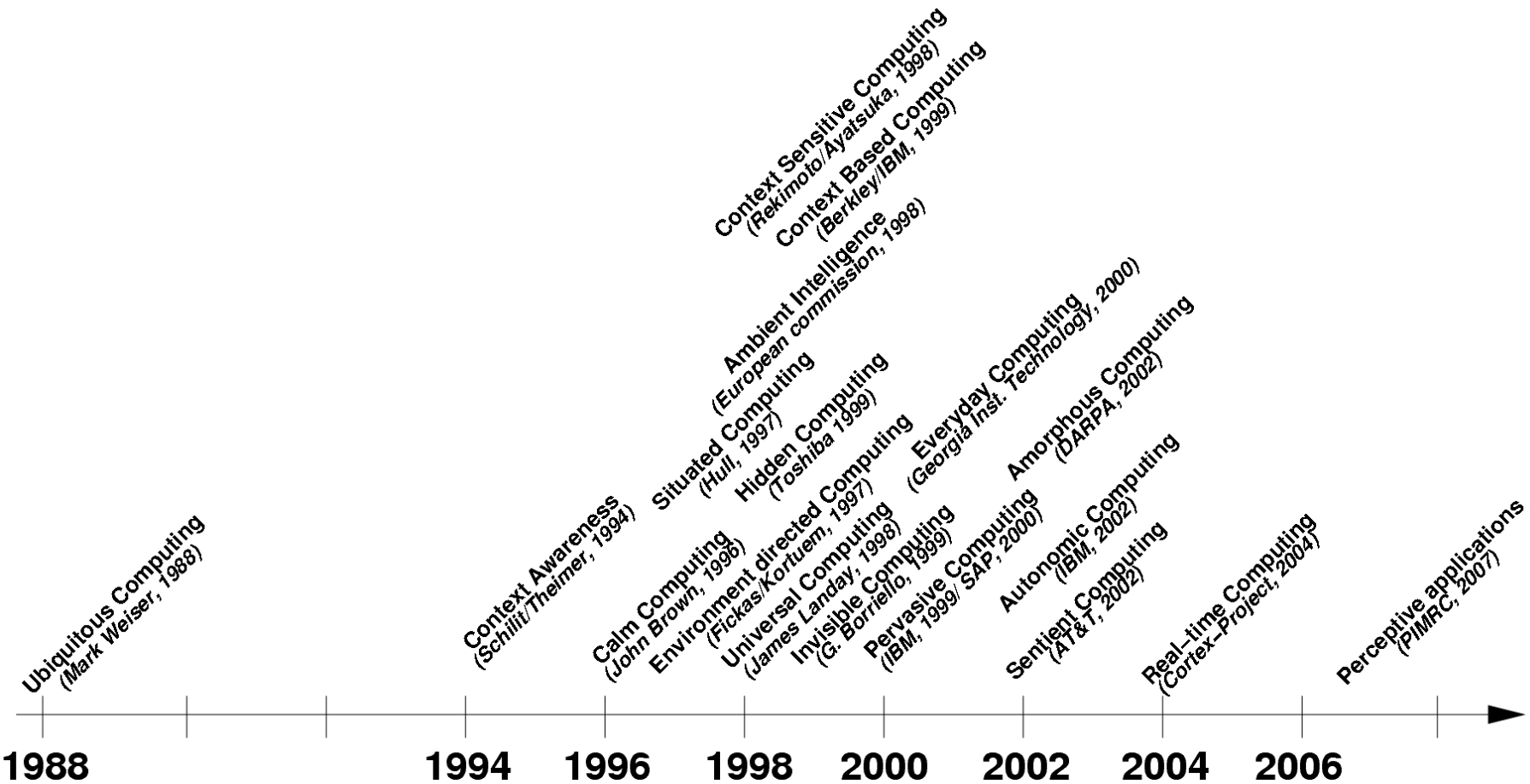
Context aware computing

Introduction

- Design paradigm for applications shifted from application-centric to environment-centric approach.
- Applications become integrated into environment and react to environmental stimuli.
- Input no longer restricted to explicit instructions
- Interface extended and coupled by an interface to the environment.
- Behaviour of applications evolves from passive to active, environment guided operation.
- Environmental stimuli trigger situation dependent actions (richer experience, adaptation to personal needs)
- Required explicit interaction minimised or reduced.

Context aware computing

Introduction



Context aware computing

Definitions of Context

Numerous and diverse definitions of context exist[1]

- What is context?
  - "the set of facts or circumstances that surround a situation or event"
  - The parts of a discourse that surround a word or passage and can throw light on its meaning
  - The interrelated conditions in which something exists or occurs (Webster)
  - ...

[1] Paul Dourish, What we talk about when we talk about Context, Personal and Ubiquitous Computing, 2008.

Context aware computing

Definitions of Context

- A most commonly utilised definition of context has been stated by Anind K Dey[2]:

Definition: Context

Context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves.

[2] A.K. Dey.: Providing architectural support for building context-aware applications. PhD thesis, Georgia Institute of Technology, 2000.

Context aware computing

Context-awareness

- Intuitively, applications that utilise context are context-aware
- A.K. Dey formulates this intuition as[3]:

Definition: Context awareness

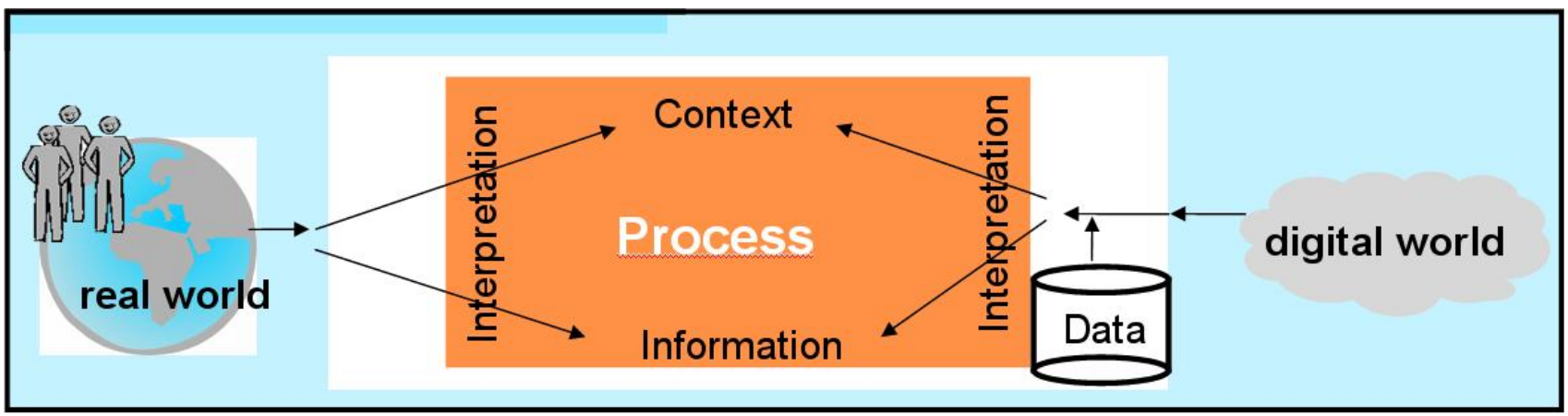
A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task.

[3] A.K. Dey.: Providing architectural support for building context-aware applications. PhD thesis, Georgia Institute of Technology, 2000.

Context aware computing

Context processing

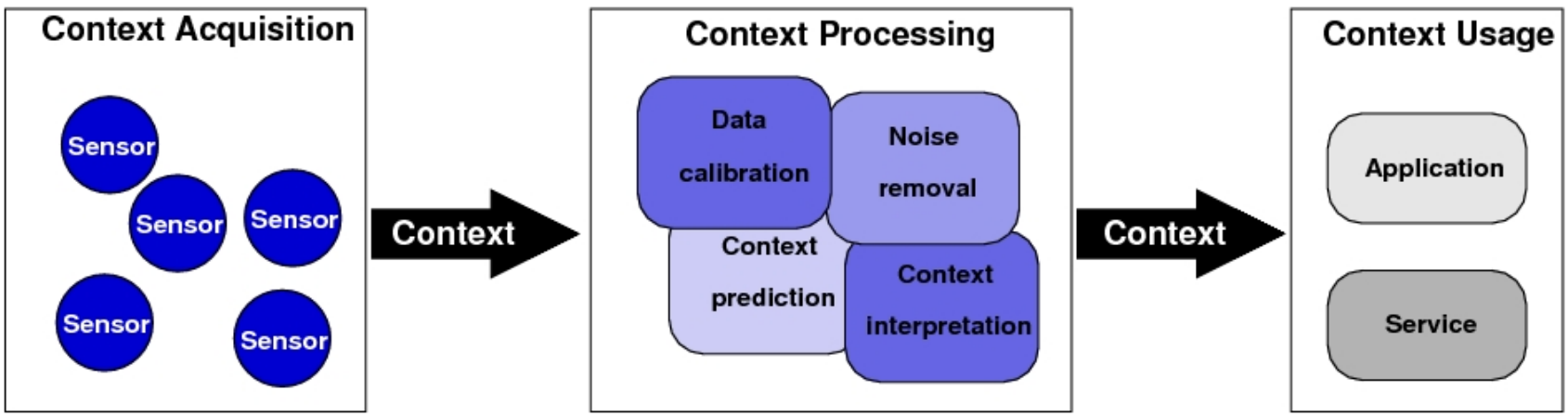
- Actual view of a process defines what is taken for context and what for information.
- Also "context-only" or "information-only" models possible
- Context from the 'digital world' from other computers or from internal data
- Context is obtained by sensory inputs



Context aware computing

Context processing

- Context processing and utilisation



Context aware computing

Context processing

- Various sensors for data acquisition





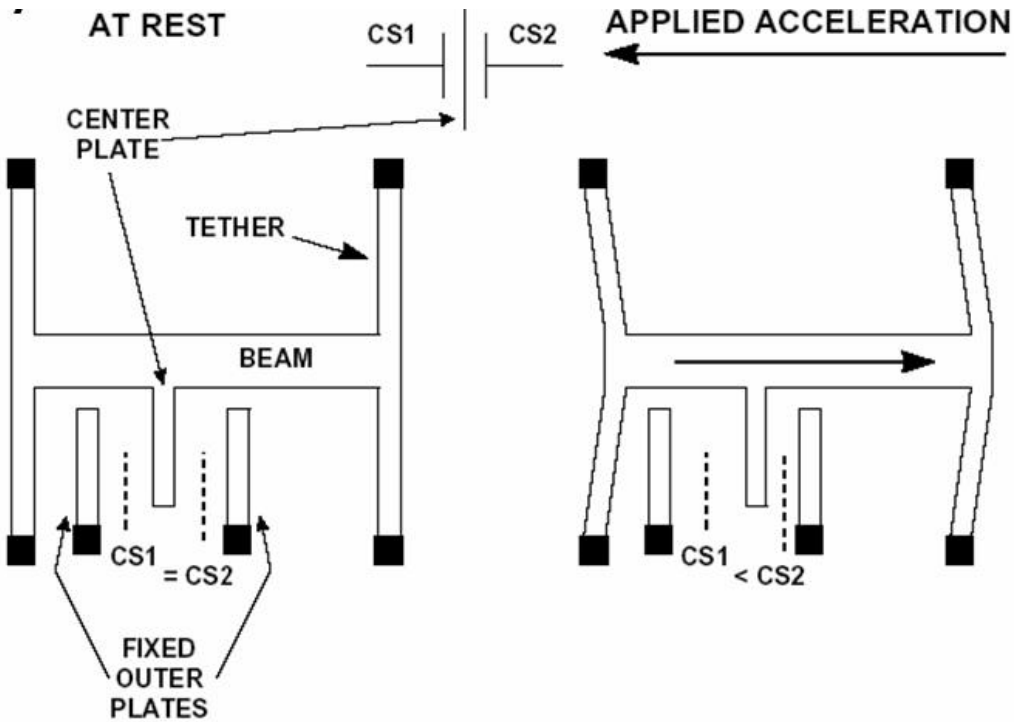




Context aware computing

Context processing

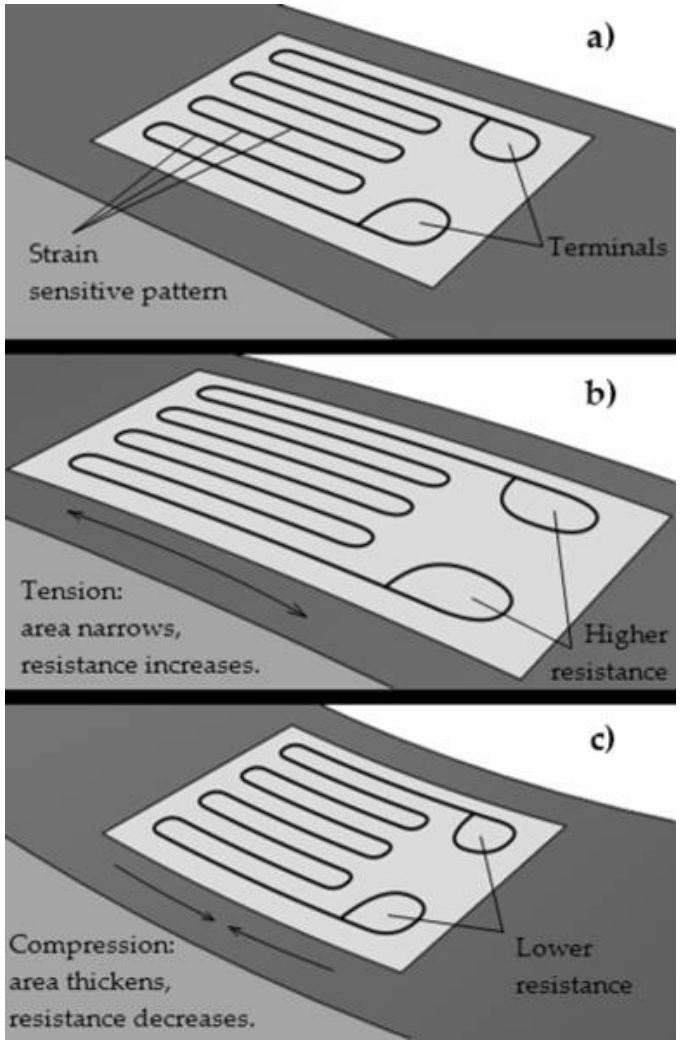
- MEMS acceleration sensors
  - E.g. Analog Devices ADXL
  - Low energy consumption, small, cheap, medium precision
  - MEMS = Micromechanical System:Mechanik in Silizium
  - Here: Comparison of capacity CS1 and CS2 leads to acceleration



Context aware computing

Context processing

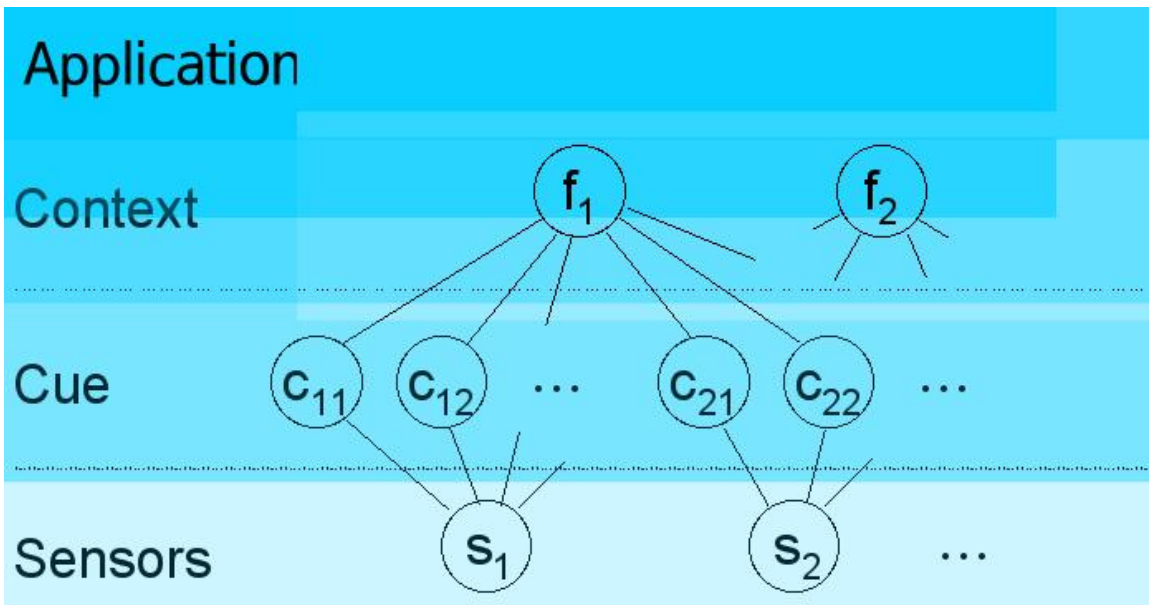
- Pressure sensors
  - Z.B. IEE ca 3-10 Euro
  - Very imprecise



Context aware computing

Context processing

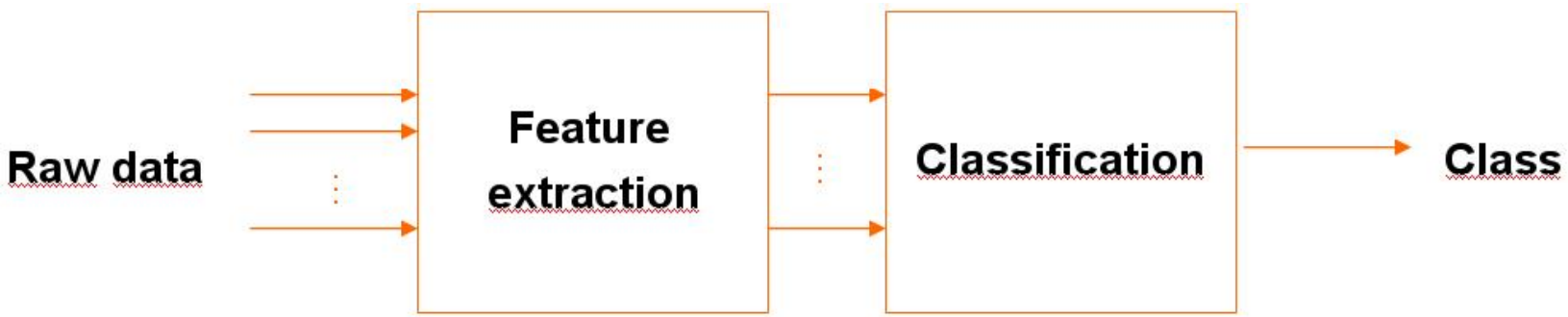
- Context processing stages
  - Raw electrical signals
  - Interpretation of signals as electic values
  - Aggregation, first abstraction of signals
  - Further abstraction based on semantics
  - Interpretation of abstracted data to contexts



Context aware computing

Context processing

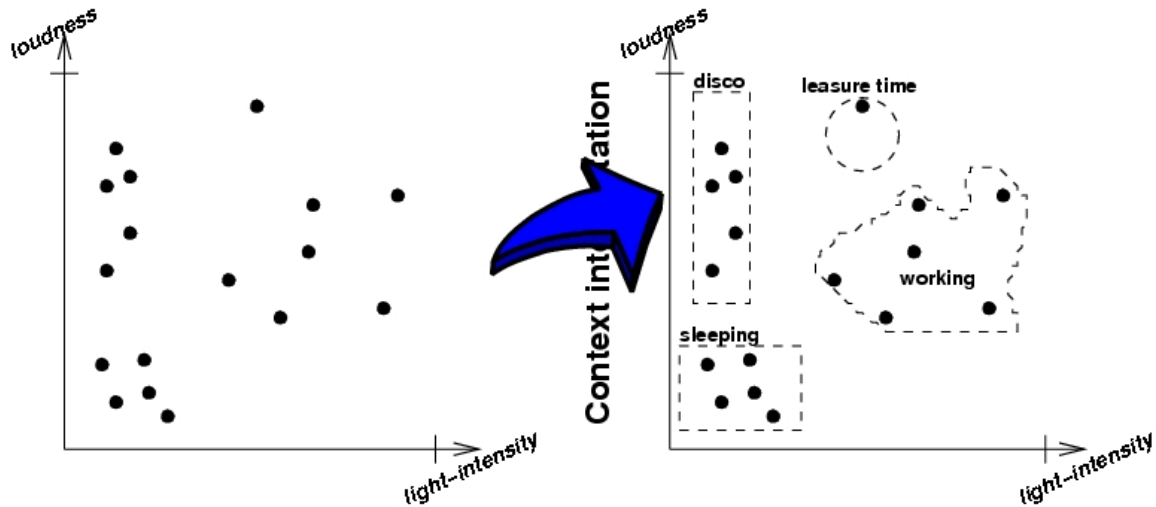
- Classical pattern recognition
  - Obtain features from raw data by utilisation of prior knowledge
  - Mapping of features onto classes by utilisation of prior knowledge
  - What are characteristic features?
  - Which approaches are suitable to obtain these features?



Context aware computing

Context processing

- From features to context
  - 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)
  - Stochastic: HMM, NN, SOM, SVM, Bayes Nets ...

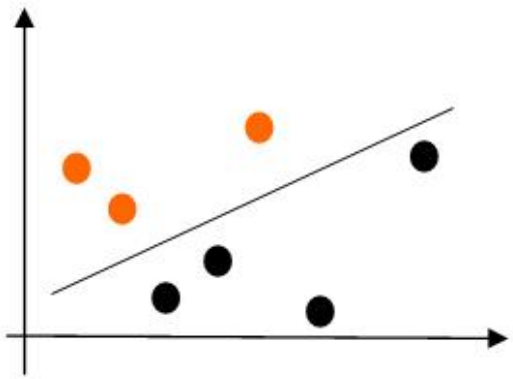


Context aware computing

Context processing

- Allocation of sensor value by defined function
  - Correlation of various data sources
  - Several methods possible – simple approaches
  - Template matching
  - Minimum distance methods
  - 'Integrated' feature extraction
    - Nearest Neighbour
    - Neural Networks
- Problem
  - Measured raw data might not allow to derive all features required
  - Therefore often combination of sensors

Not enough features



Sufficient feature count

Context aware computing

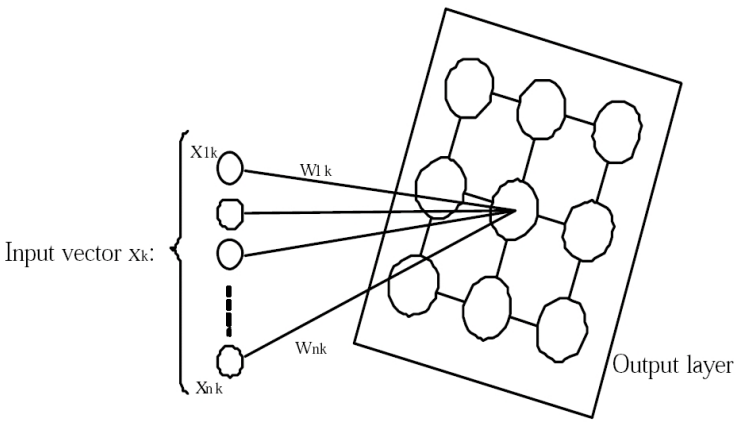
Context processing – Context reccognition

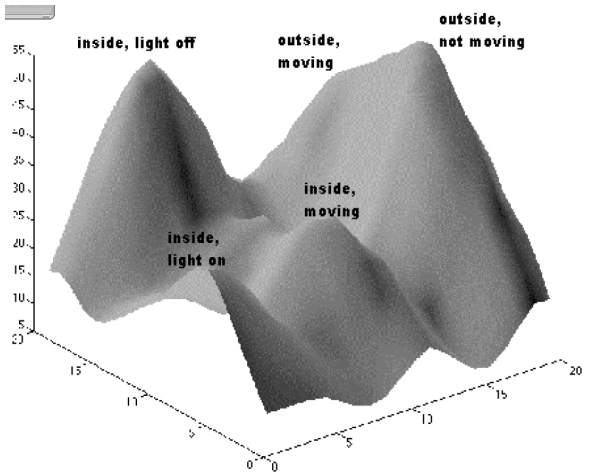
- Methods – Syntactical (Rule based)
  - Idea: Description of Situation by formal gramma (Symbols and Rules)
  - Description of a (agreed on?) world view
  - Example: RuleML
- Comment
  - Pro:
    - Combination of rules and identification of loops and inpossible conditions feasible

    Contra:
    - Very complex with more elaborate situations
    - Extension or merge of rule sets typically not possible without contradictions

Context aware computing

Context processing – Context reccognition





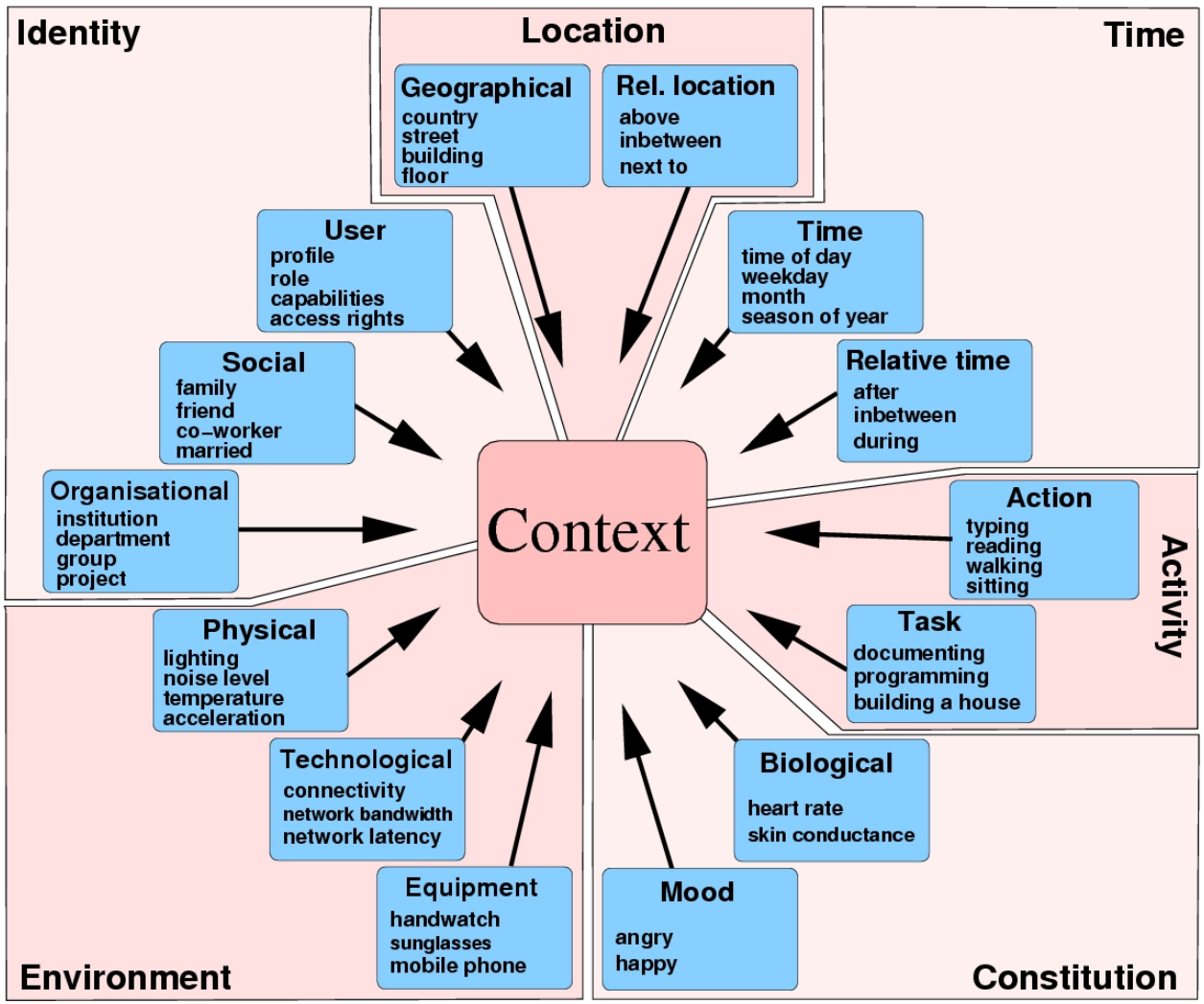
- Methods – Statistical
  - Idea: Modelling of situation by probability theoretic measures
  - Examples
    - HMM, NN, SOM, SVM, Bayes Nets . . .
  - Probabilistic world model
    - Adaptation to changing environment possible

Outline

Introduction to context aware computing

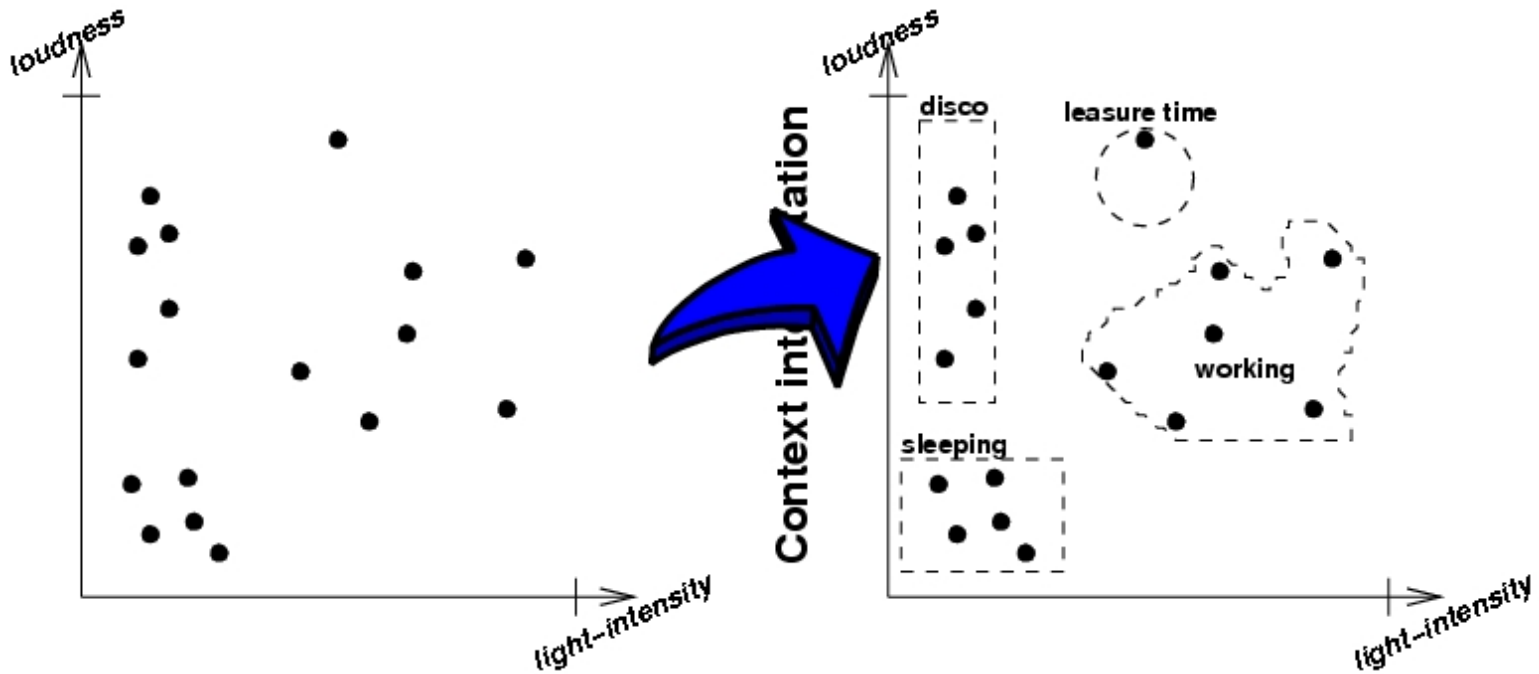
Concepts and definitions

Context and context types



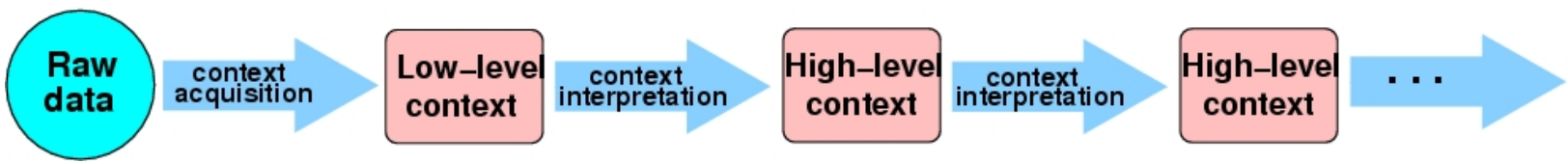
Concepts and definitions

Representation and illustration of context



Concepts and definitions

Representation and illustration of context



Concepts and definitions

Representation and illustration of context

High-level context	Low-level context	Raw data	Context source
walking	14°C	001001111	thermometer
walking	57.2°F	001001111	thermometer
watching movie	64dB	109	microphone
listening music	64dB	109	microphone
at the beach	47° 25.5634'N; 007° 39.3538'E	GPRMC[3]	GPS sensor
swimming	47° 25.5634'N; 007° 39.3538'E	GPGGA[4]	GPS sensor
writing	z	0x79	keyboard [en]
writing	ы	0x79	keyboard [ru]
writing	z	0x7a	keyboard [de]
office occupied	z	0x7a	keyboard [de]

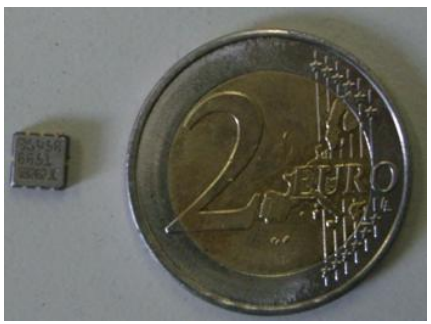
Outline

Introduction to context aware computing

Context aware computing

Examples and case studies: Media Cup

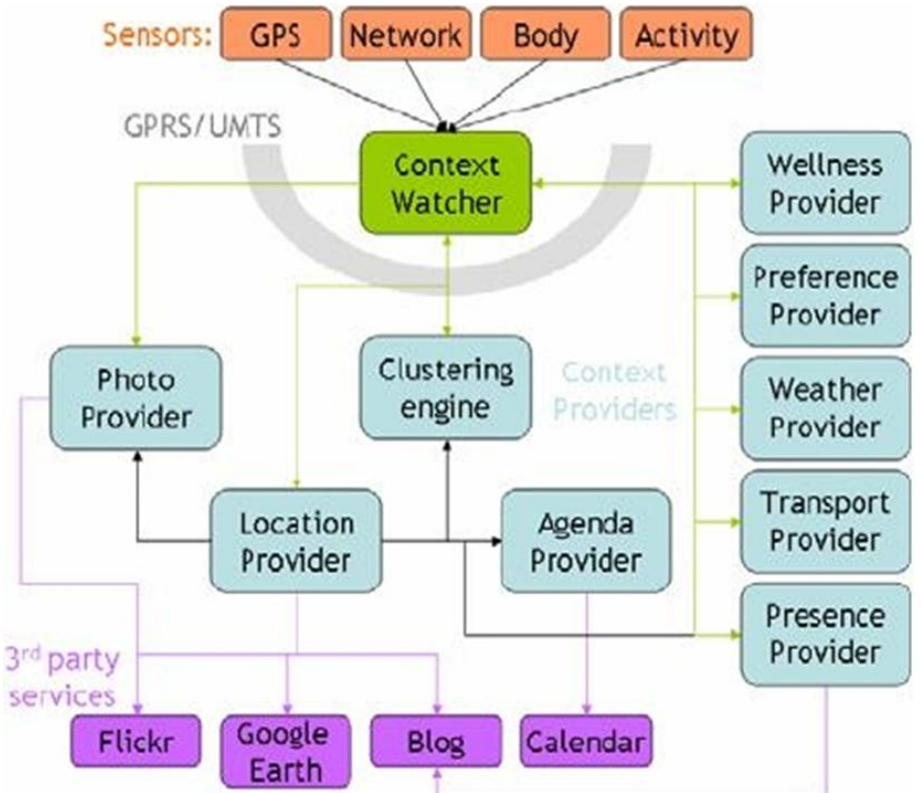
- Media Cup: Context recognition
  - Activity: Trigger sleep mode (save energy)
  - Level of activity
  - Own context: Object movement, person is nervous, specific handling of objects
  - Environmental context: Vibration, earthquake
- Sensor: Ballswitch
  - (nearly) no quiescent current
  - Various types, filled with gas/liquid
  - e.g. Acceleration with fixed value (liquid)
  - Vibration (filled with gas)



Context aware computing

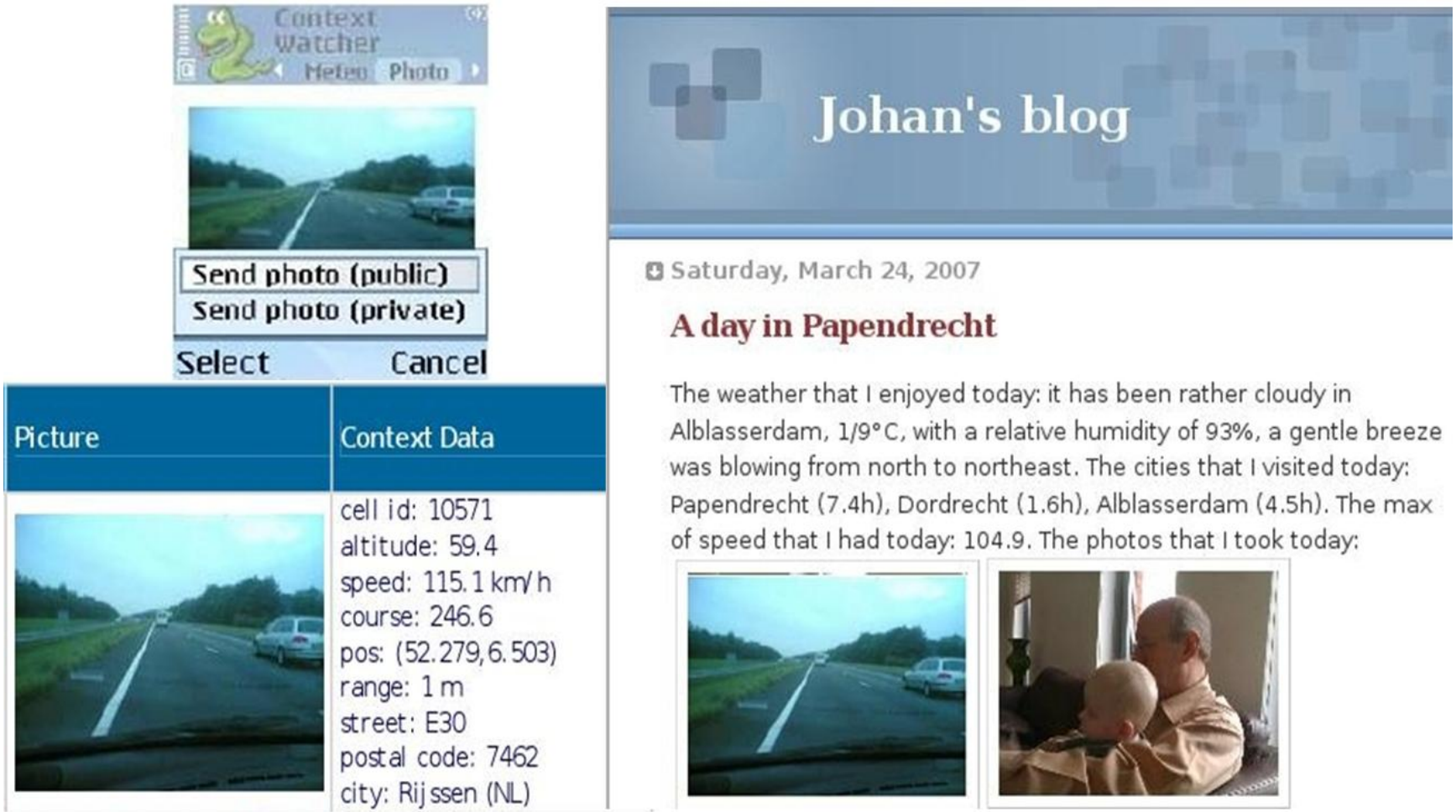
Examples and case studies: Context Watcher

- Context Watcher
  - 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



Context aware computing

Examples and case studies: Context Watcher



Context aware computing

Examples and case studies: TEA

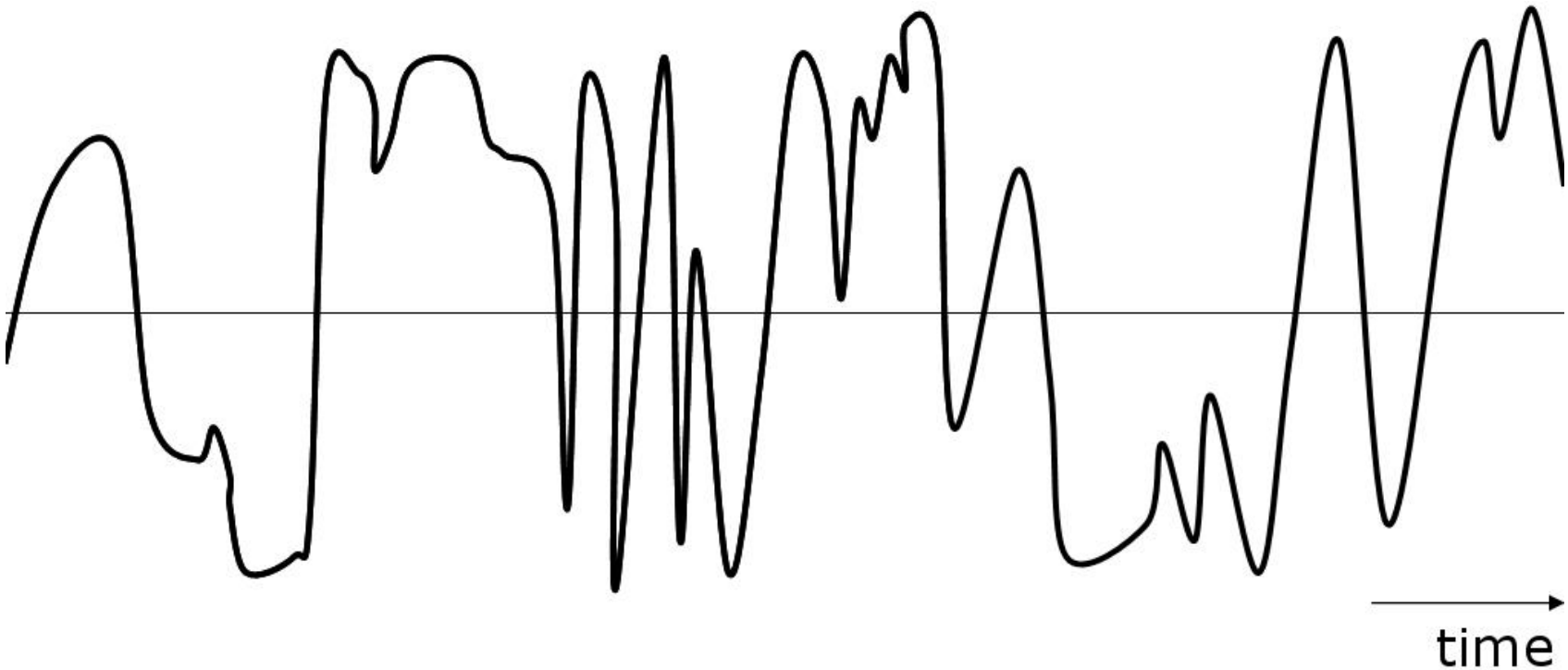
TEA-Audio

- Requirements
  - Restricted memory space
  - Computing power restricted
- Benefit
  - Many sensors $\longrightarrow$ Many features
- Example approach
  - Utilise time domain (no transformation)
  - Utilise statistic measures
  - Feature extraction based on small amount of data

Context aware computing

Examples and case studies: TEA

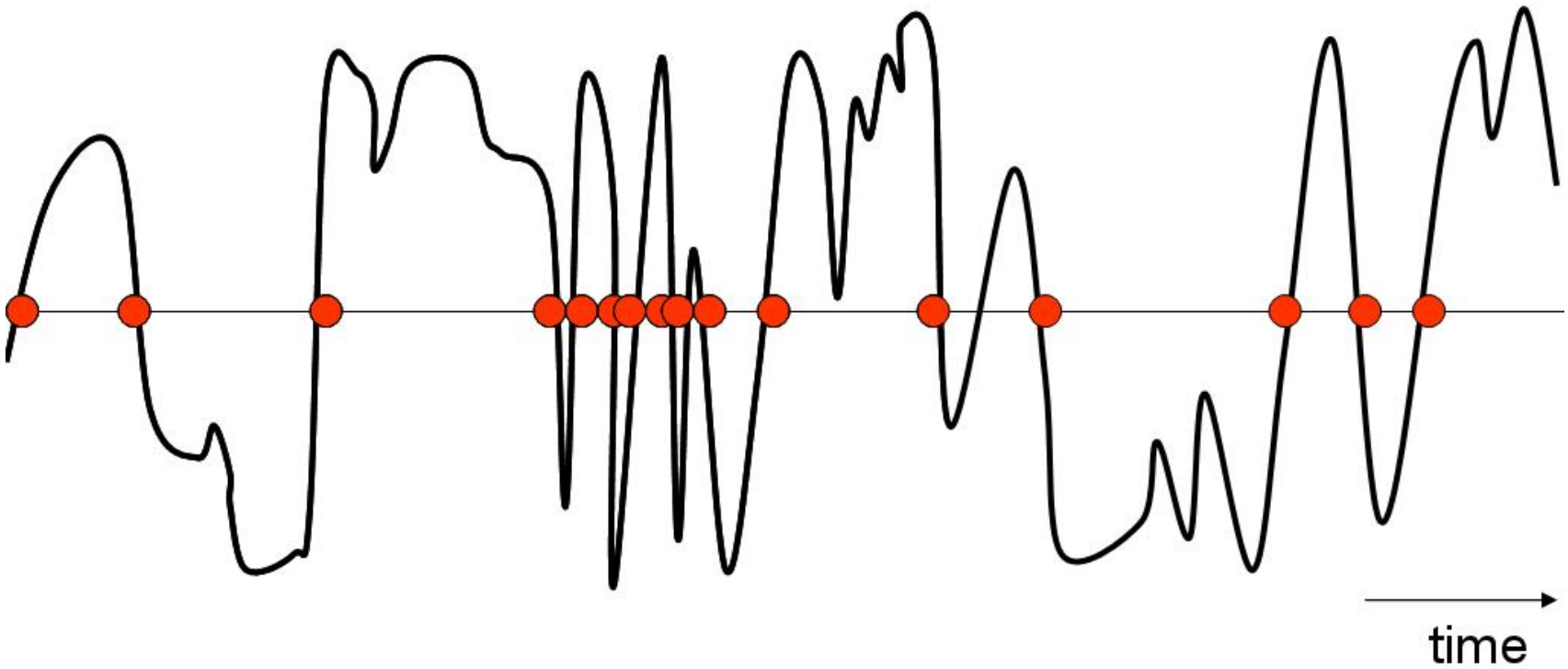
- Audio data in time domain



Context aware computing

Examples and case studies: TEA

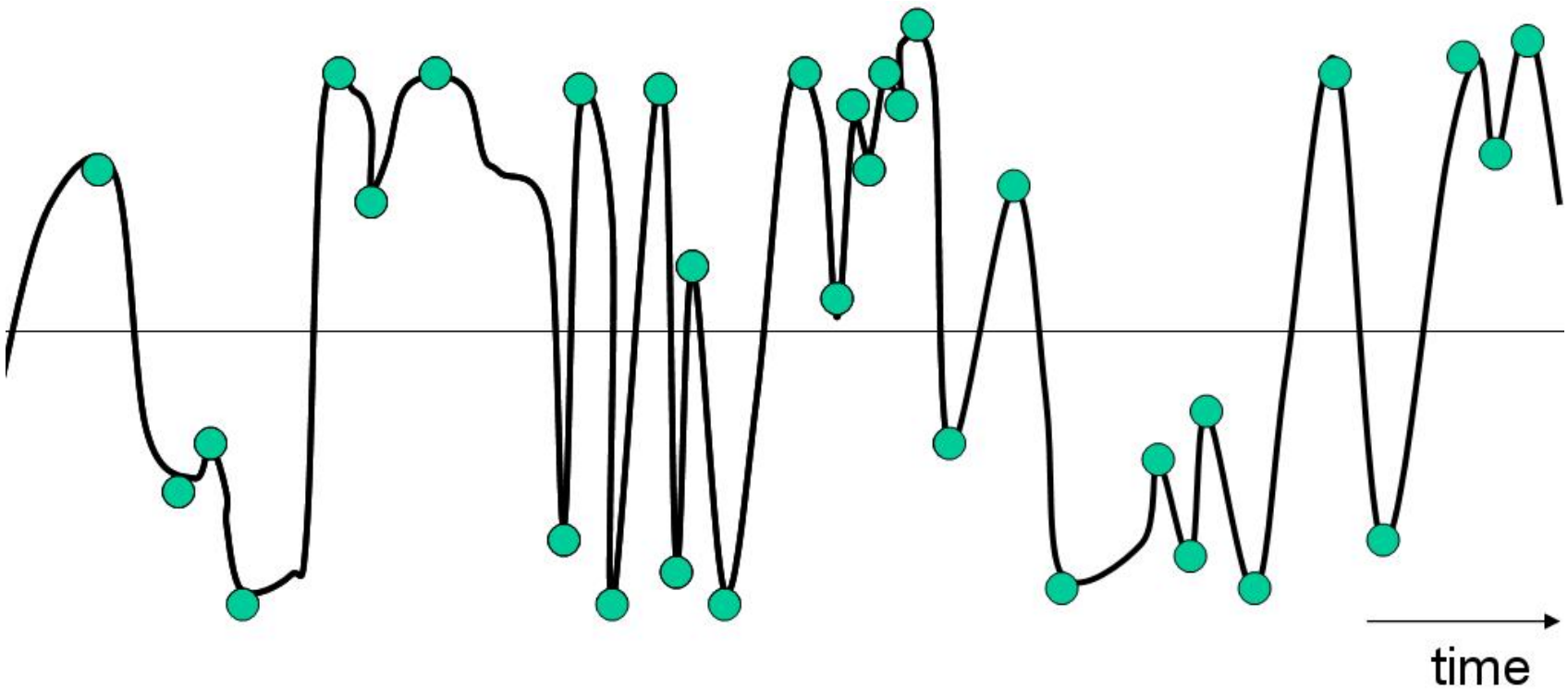
- Count zero crossings
- Distance between zero crossings



Context aware computing

Examples and case studies: TEA

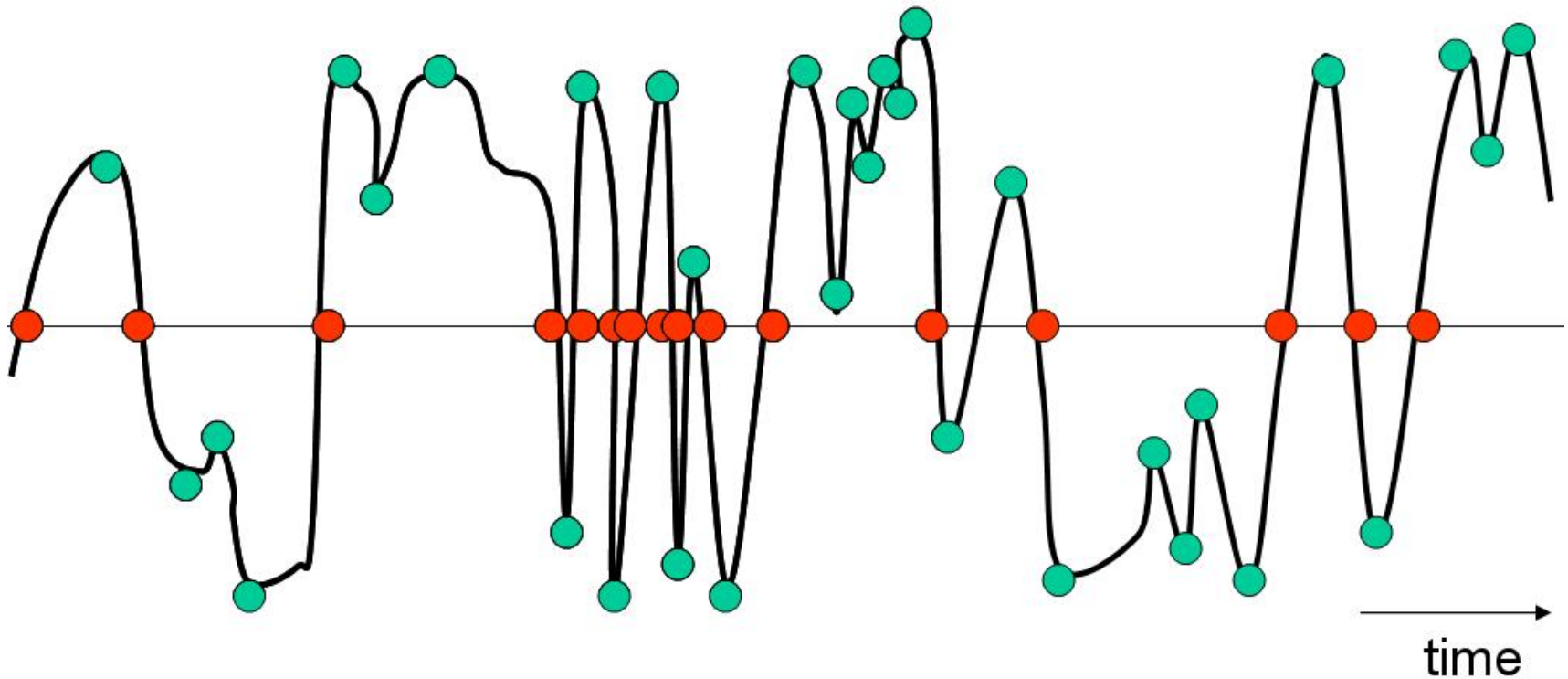
- Count of direction changes



Context aware computing

Examples and case studies: TEA

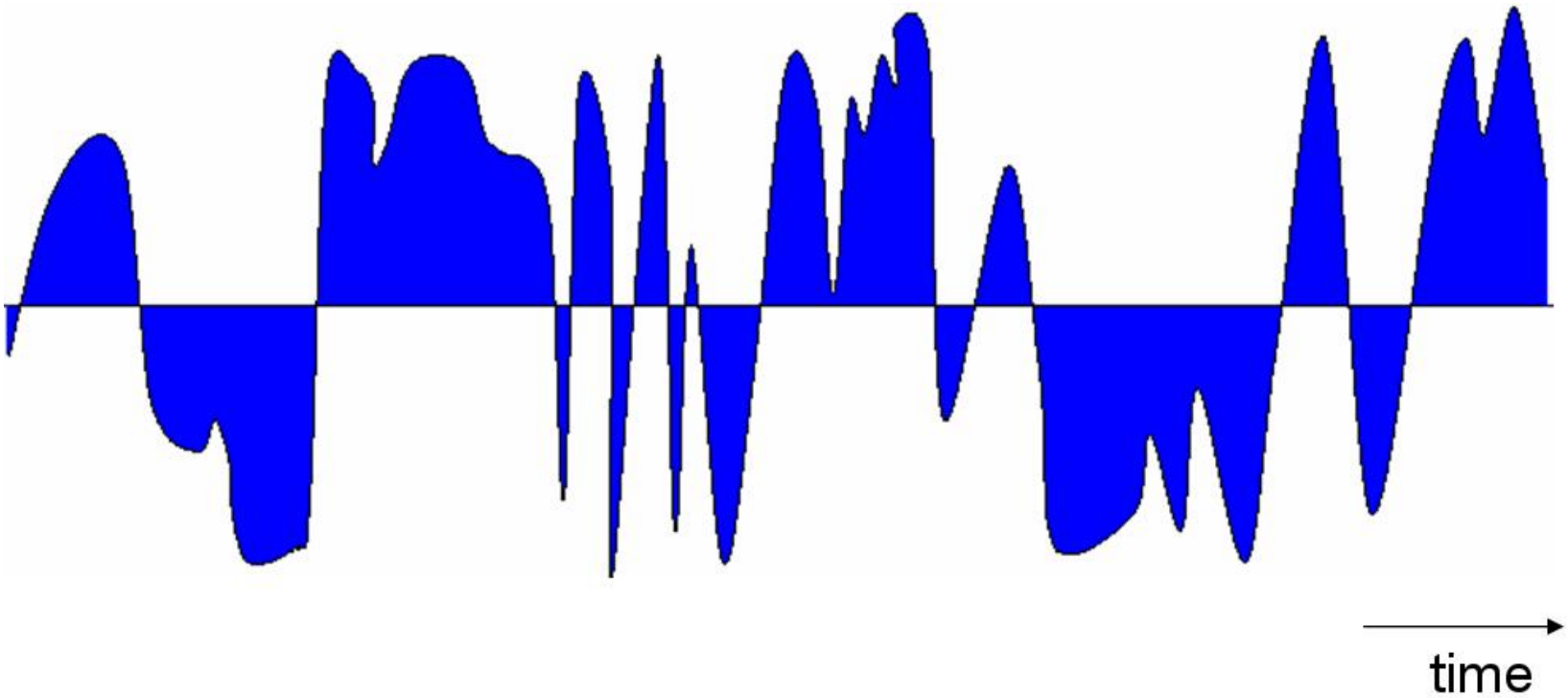
- ratio: $\frac{\text{direction changes}}{\text{zero crossings}}$



Context aware computing

Examples and case studies: TEA

- Integral

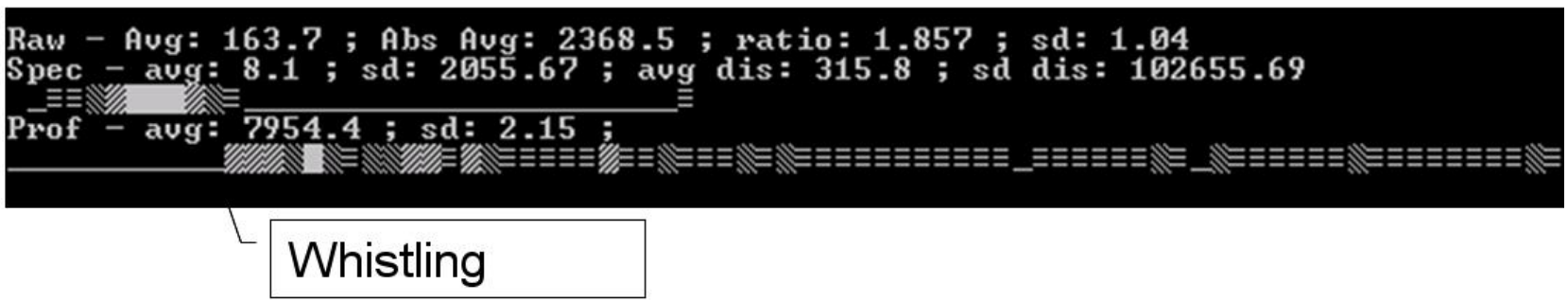


Context aware computing

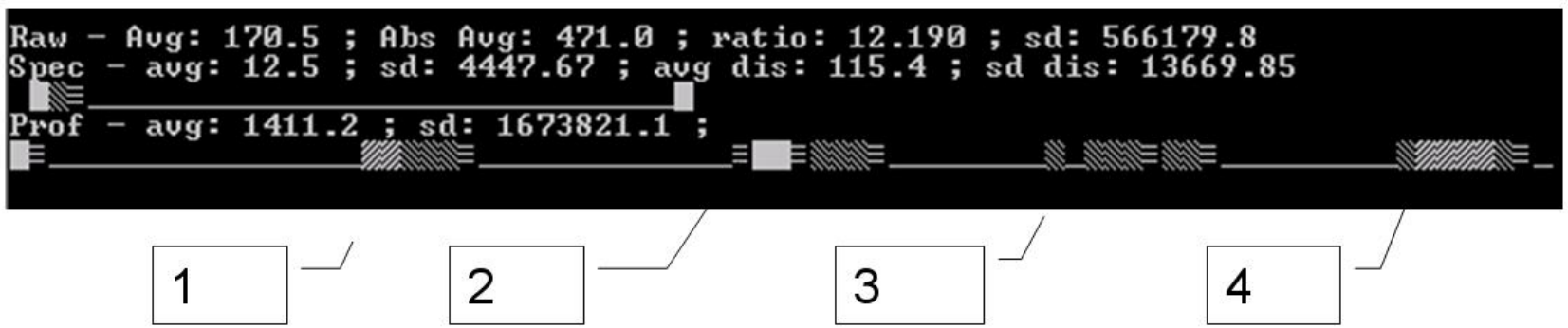
Examples and case studies: TEA

- Several chunks for speech

whistling



speech

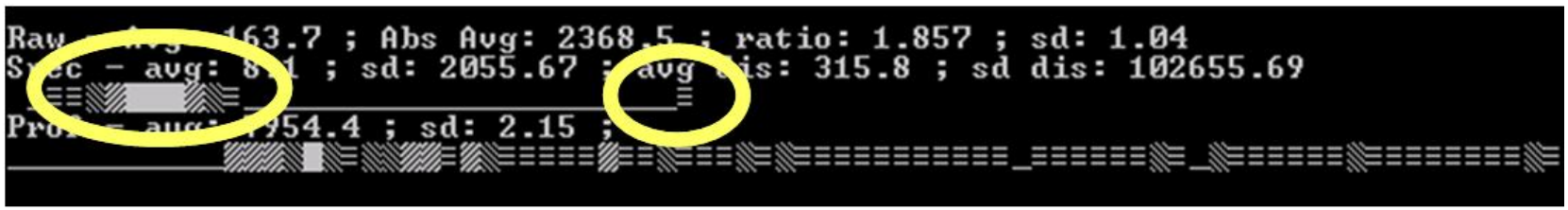


Context aware computing

Examples and case studies: TEA

- Distance between zero crossings: distinct behaviour of oscillation at start and end

whistling



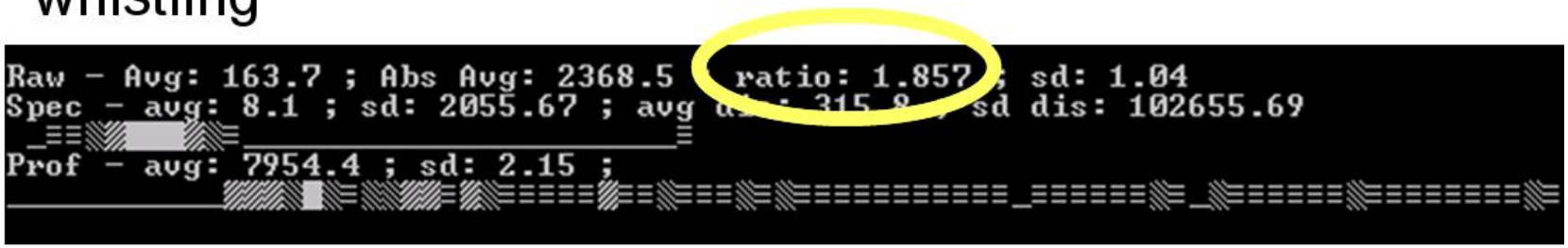
speech

Context aware computing

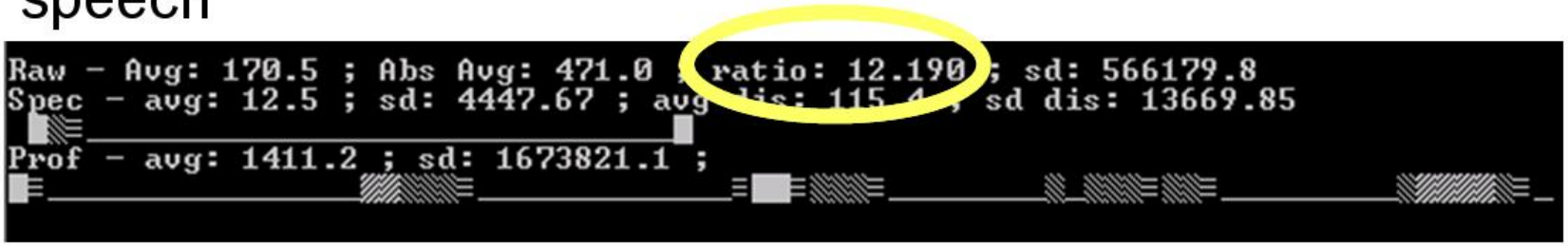
Examples and case studies: TEA

- Distinct ratio: $\frac{\text{zero crossings}}{\text{direction changes}}$

whistling



speech

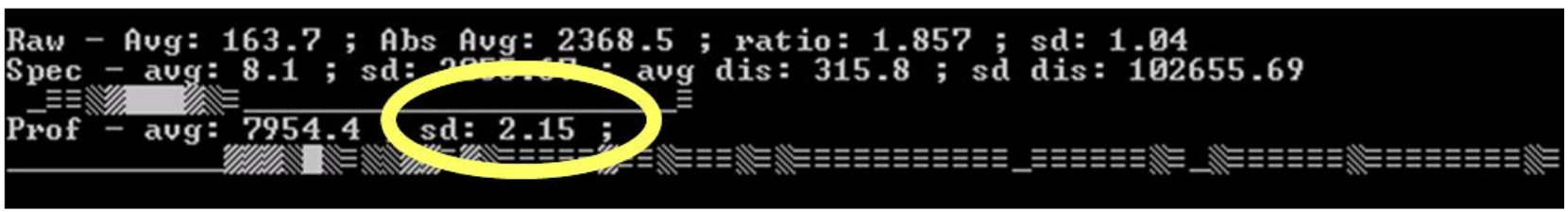


Context aware computing

Examples and case studies: TEA

- Significant change in standard deviation of chunks

whistling



speech