Ambient Water Usage Sensor for the Identification of Daily Activities

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2 Agenda

- Introduction
- Detection of Activitities of Daily Living
- State of the Art of Water Usage Detection
- Ambient Water Usage Sensor
  - Test Setup
  - Feature Generation
  - Feature Analysis
- Test & Results
- Discussion

gefördert durch:

3 Project QuoVadis
What are we doing?

- Foundation by the Central Federal Association of the Health Insurance Funds of Germany
- Project Goal: Interconnected living in a quarter for persons with dementia
  - Start: 01.02.2015
  - Keep dementia patients at home as long as possible
  - Combination of caregiving an technology
  - Since March, 2017: Field evaluation with 8 users

gefördert durch:

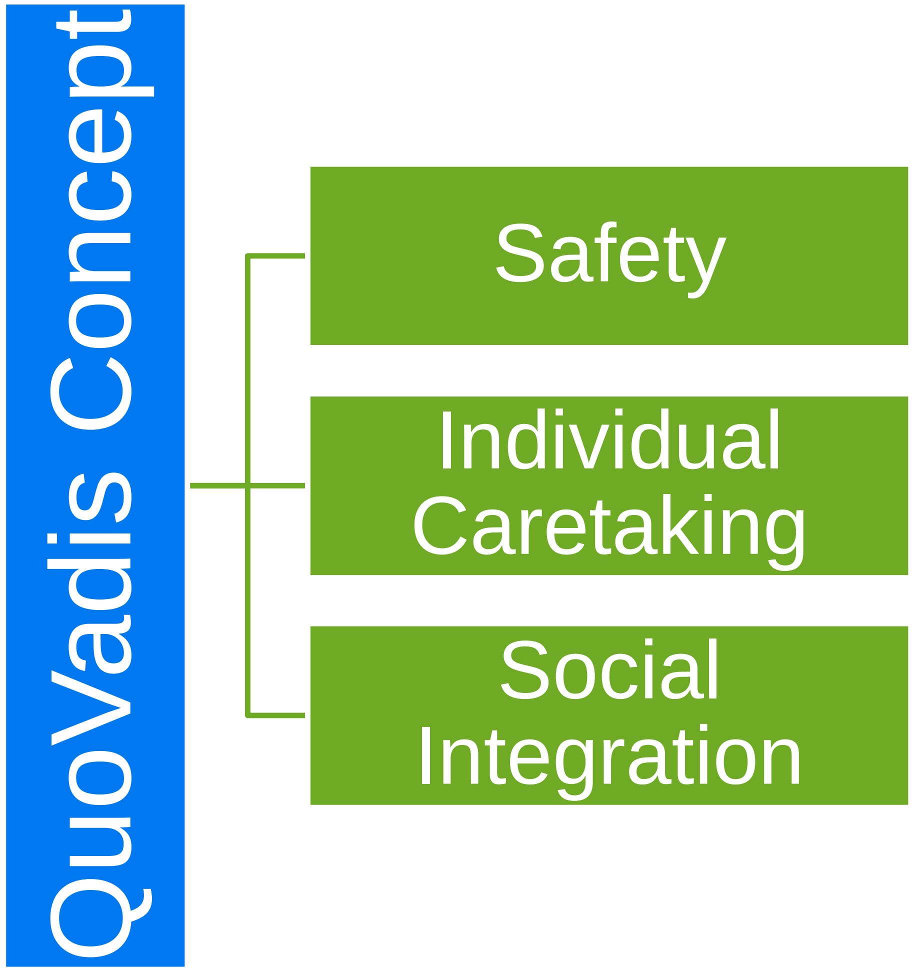
4 Project QuoVadis

Who are we?

- Johanniter Unfall-Hilfe e.V.
  - Nursing service provider
  - Staff: 12.000 (+30.000 Volunteers)
  - Research departement for assistive technologies
- GSG Oldenburg
  - Housing provider in Oldenburg
  - Over 8.000 apartments
- OFFIS: Insitute for Information Technology
  - 3 Division: Health, energy and transportation
  - Associated Institute of the Carl von Ossietzky University Oldenburg
  - 250 employees

gefördert durch:

5 QuoVadis Concept



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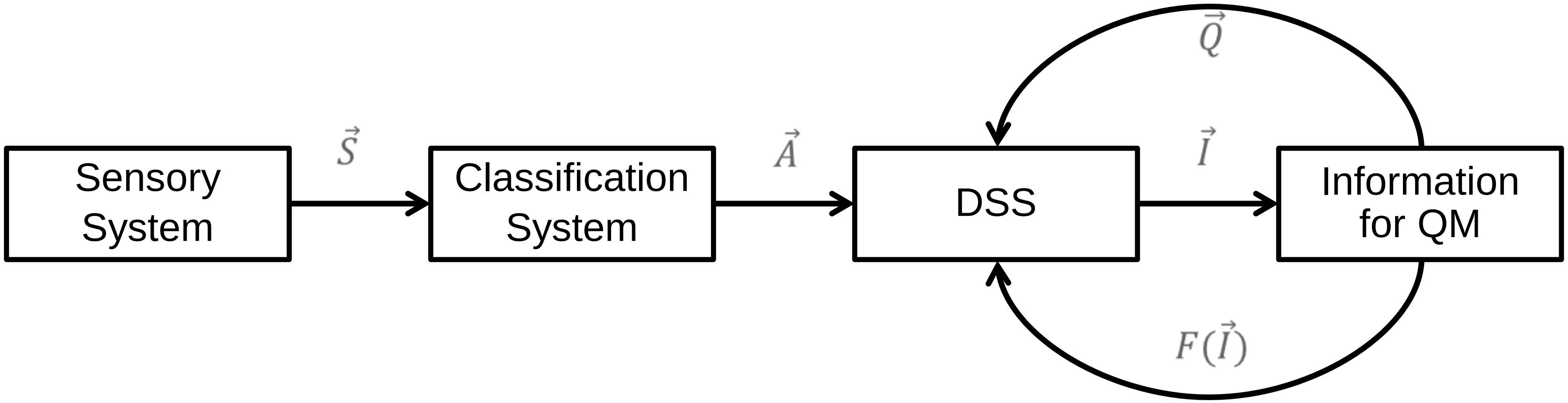
6 Individual Caretaking

Dementia – longterm and critical changes

- Dementia Symptoms[DGP 2009]
  - Depression, fear
  - Hyperactivity
  - Apathy
  - Sleep disturbances
  - Eating and drinking disorders
  - …
- Longtermn Changes in behavior[DGP 2009]
  - Hygiene
  - Usage of household appliances
  - Disorientation
- We need a system that detects changes in activities of daily living

7 Activity Detection



8 Detection of activities of Daily Living

State of the Art

- Many systems already implemented using different sensor setups
  - Motion detectors
  - Smart meters (NILM)
  - Door contacts
  - Body-worn sensors…
  - RFID tags
  - …
- No water usage detection sensor are used
  - Precision in typical measurement units in apartements is low and unaccesable
  - Expensive and intrusive installation of more complex sensors is necessary

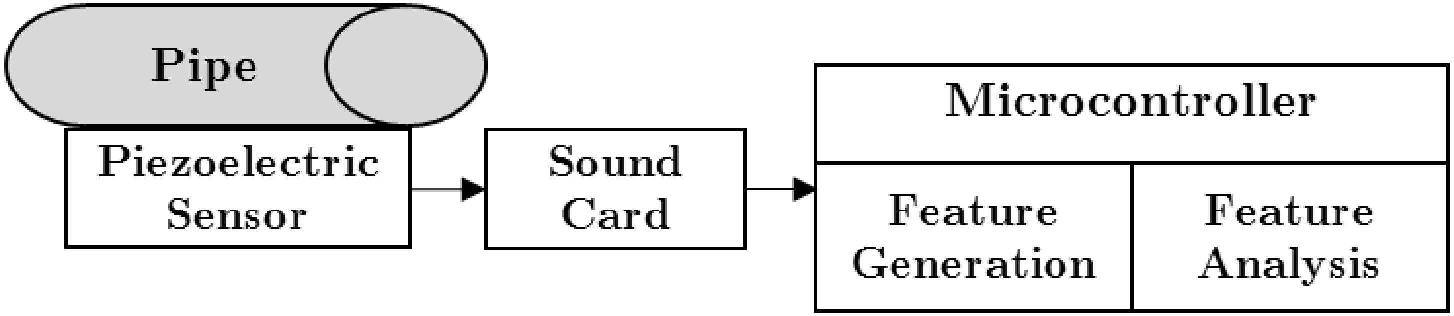
9 Measurement of water usage

State of the Art

- Industrial applications
  - Speed probes [Bleckmann 2014]
  - Ultrasonic : Doppler-shift and transit time flow meter [Morriss 1991, Iooss 2002, Simurda 2016]
- Identification of water consumers by their sound
  - Detection of leaks in water pipelines [Khulief 2011] [Hunaidi 2004]
- Sound of water in a pipe is Influenced by
  - Size of the leak
  - Bends of the pipe
  - Distance between sensor and leak

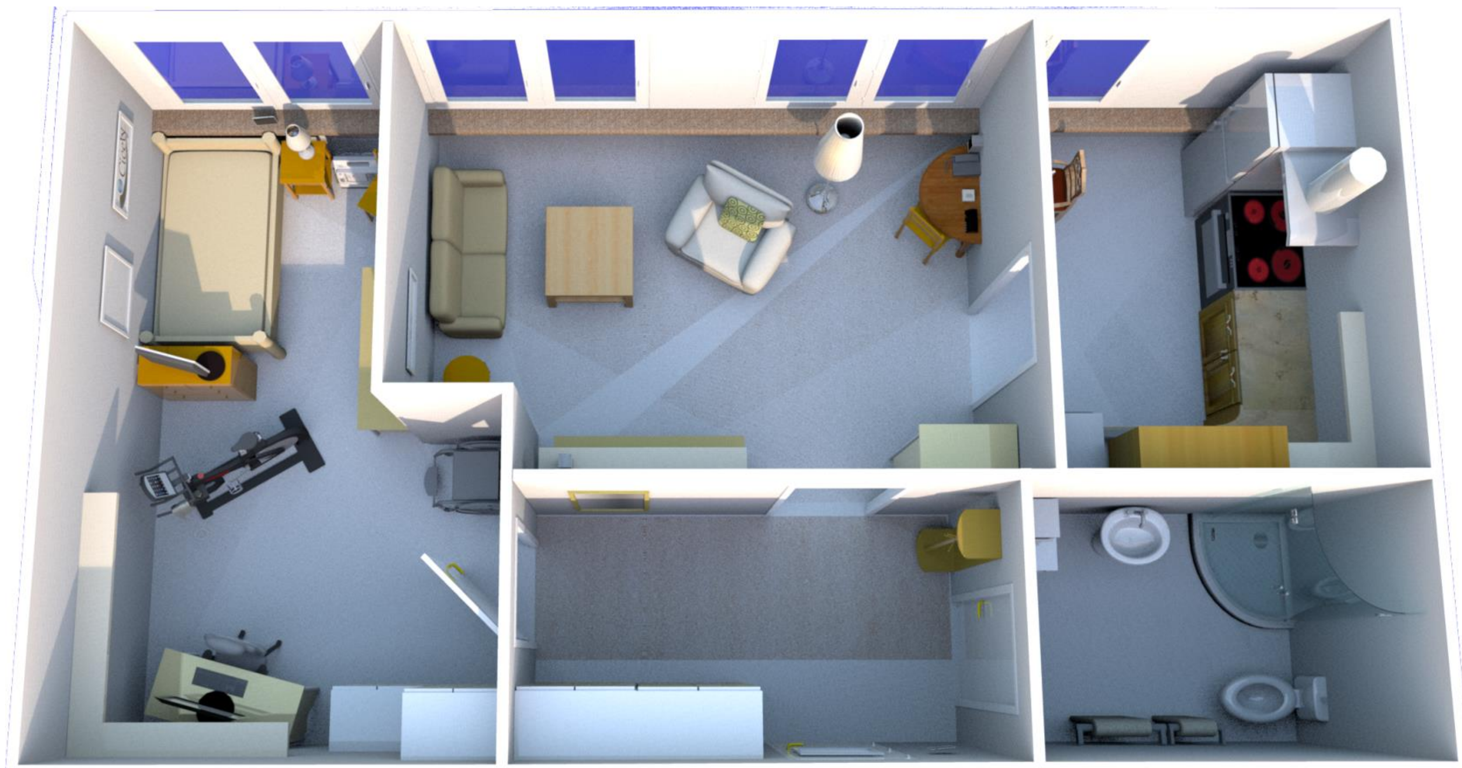
10 Water Usage Sensor

Test Setup



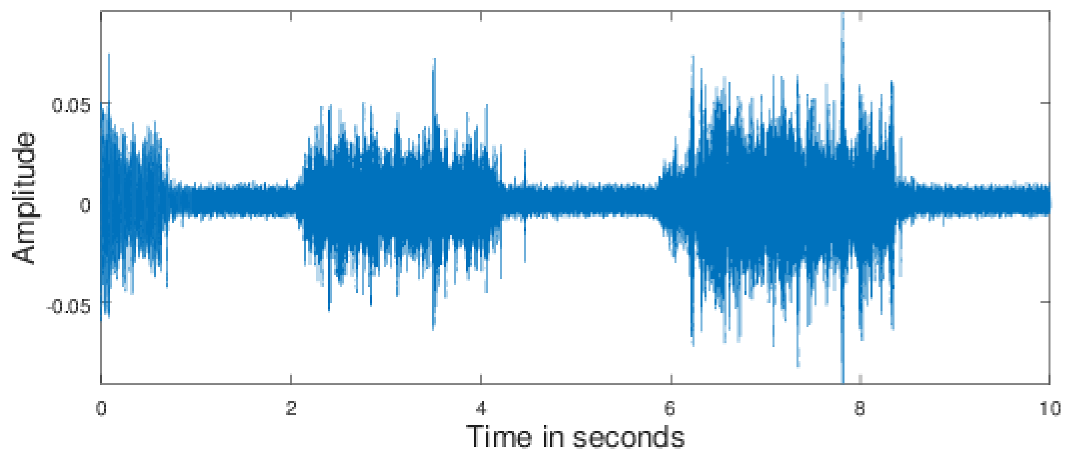
11 Feature Generation

Living Lab „IdeAAL“



12 Feature Generation

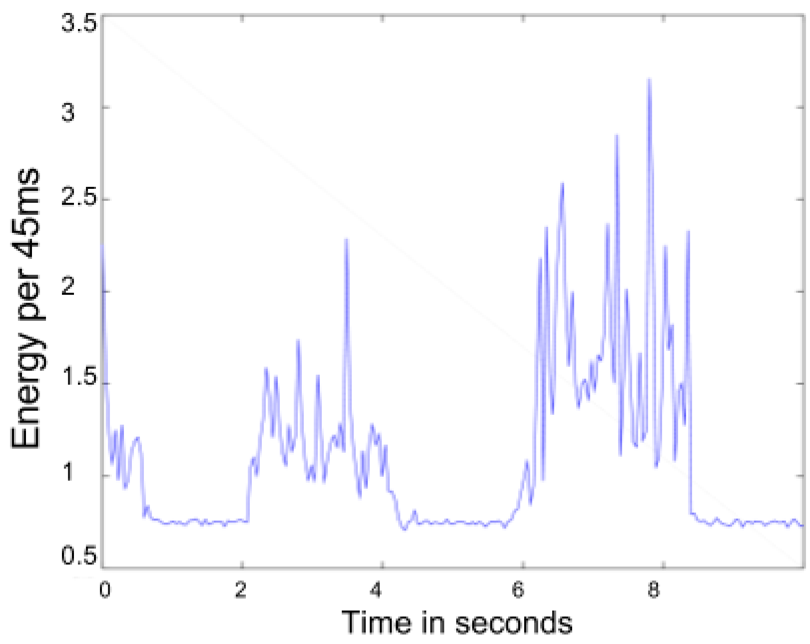
Pretest

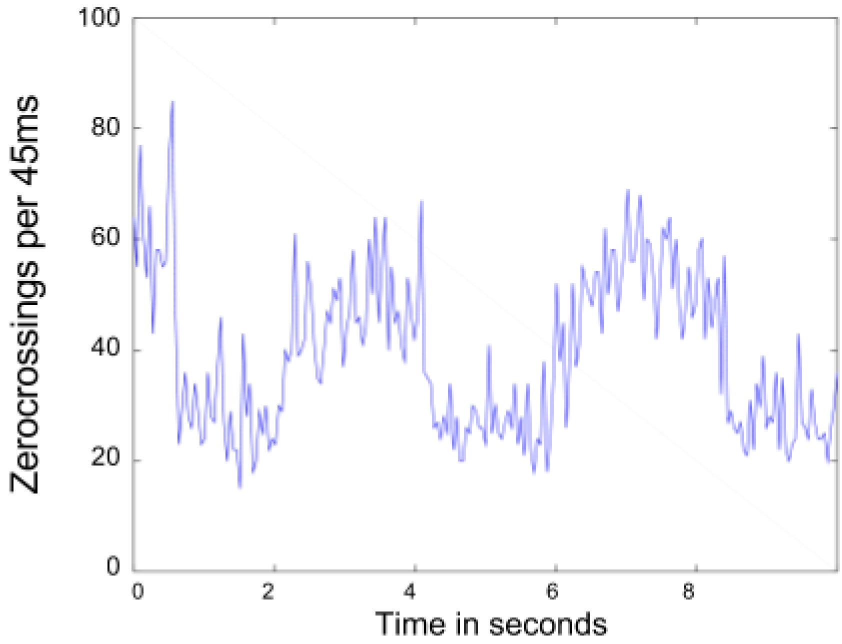


13 Feature Generation
Signal Energy and Zero-Crossing Rate

$$E = \sum_{k=0}^{N-1} x^2(k)$$ [Greenwood 1999]

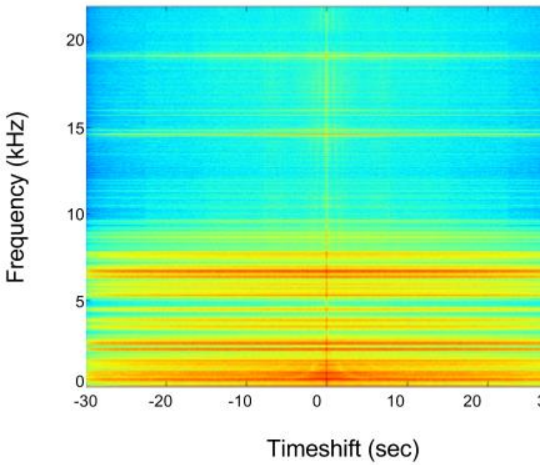
$$R_{ZC} = \sum_{k=0}^{N-1} |sgn(x(k)) - sgn(x(k-1))|$$ [Chen1988]

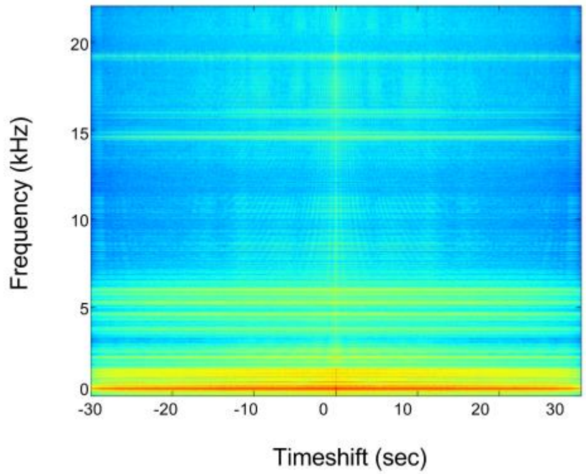


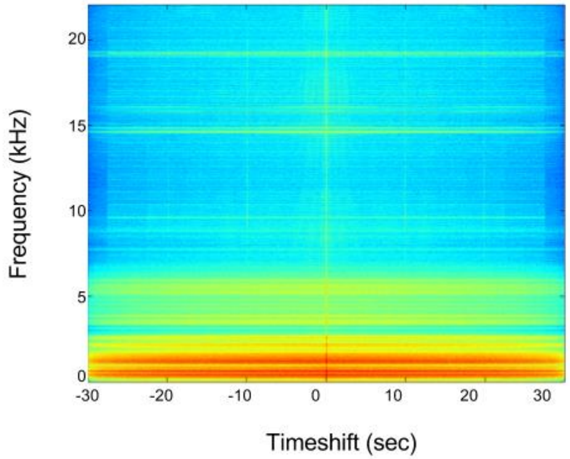


14 Feature Generation
Frequency Domain

- Signal energy in 33 frequency bands between 12.5 Hz and 20 kHz







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15 Feature Analysis

- Usage of machine learning tool „Weka“ [Hall 2009]

- Tested machine learning alghorithms
  - OneR [Holte 1993]
  - Naive Bayes [Murphy 2006, Rennie 2003]
  - C4.5 decision tree [Quinlan 2014]
  - One vs. One classifier based one logistic regression [Witten 2014]

- Test Methods
  - Measurement of 4 consumers in model apartment
  - Evaluation by cross validation and supplied test set

16 Test and Evaluation of the Prototype

Questions

- How does our system perform under stable and optimal conditions?
- How does the flow rate impact the detection rate?
- How does the water temperature impact the detection rate?
- How does simultaneous usage of different consumers affect the detection rate?
- What is the performance of the system if all environmental conditions vary at the same time?
- Which is the most suitable machine learning algorithm for our problem?

17 Test and Evaluation of the Prototype

Results

TABLE I

STABLE ENVIRONMENTAL CONDITIONS ($N_{Test} = 120$)

Classifier	Detection Rate	Correct Detections
OneR	96.67 %	116
NB	96.67 %	116
C4.5	94.17 %	113
One-vs-one	100.00 %	120

Test and Evaluation of the Prototype

Results

TABLE II
FLOW RATE TEST ($N_{Test} = 90$)

Classifier	Detection Rate	Correct Detections
OneR	30.00 %	27
NB	36.67 %	33
C4.5	28,89 %	26
One-vs-one	30.00 %	27

TABLE III
CROSS VALIDATION OF WATER FLOW TEST ($N_{Test} = 90$)

Classifier	Detection Rate	Correct Detections
OneR	80.00 %	72
NB	77.78 %	70
C4.5	82.22 %	74
One-vs-one	94.44 %	85

TABLE IV
WATER TEMPERATURE TEST ($N_{Test} = 60$)

Classifier	Detection Rate	Correct Detections
OneR	70.00 %	12
NB	15.00 %	9
C4.5	13.33 %	8
One-vs-one	46.67 %	28

TABLE V
CROSS CORRELATION OF TEMPERATURE TEST ($N_{Test} = 60$)

Classifier	Detection Rate	Correct Detections
OneR	100.00 %	60
NB	98.33 %	59
C4.5	98.33 %	59
One-vs-one	100.00 %	60

TABLE VI
MULTIPLE SIMULTANEOUS CONSUMERS ($N_{Test} = 300$)

Classifier	Detection Rate	Correct Detections
OneR	82.00 %	246
NB	94.33 %	283
C4.5	93.33 %	280
One-vs-one	98.33 %	295

Test and Evaluation of the Prototype

Results

TABLE VII

CROSS CORRELATION AGGREGATIVE TEST ($N_{Test} = 600$)

Classifier	Detection Rate	Correct Detections
OneR	35.33 %	212
NB	50.50 %	303
C4.5	75.83 %	455
One-vs-one	85.83 %	515

21 Discussion

Results

- Water consumers can be detected by their sounds
- The implemented features are useful
- The one-vs-one classifier achieved the best results
- External impacts have to be included in training data set
- Overall detection rate of 86 % is too low for AAL applications
  - Attachment of the sensor, building a sensor box
  - Digitization closer to the sensing element
  - Measurement of the water pipes temperature
  - Comparison with other sensing elements (vibration sensor)
  - Novelty/outlier detection for external sounds

22 Discussion

Outlook

- Field Study in the project QuoVadis 03/2017 – 12/2017
- 3 apartments equipped with
  - Smart meter (4.8 kHz sampling rate)
  - Motion detectors
  - Door contacts
- Monthly interviews with inhabitants by caregivers
- Goal: integration of water usage sensor in this field Study to obtain a very interesting database

Thank You!

www.quovadis-projekt.de

gefördert durch:
Spitzenverband
Die Johanniter
Aus Liebe zum Leben
Bauen & Wohnen in und um Oldenburg

24 Literature

[DGP 2009]	S3-Leitlinie "Demenzen"(Kurzversion), Deutsche Gesellschaft für Psychiatrie, Psychotherapie und Nervenheilkunde (DGPPN), Deutsche Gesellschaft für Neurologie (DGN), November 2009
[Bleckmann 2014]	Bleckmann, H. et al.: Flow Sensing in Air and Water, Springer, ISBN 978-3-642-414459, 2014.
[Morriss1991]	Morriss, S. L. and Hill, A. D.: Measurement of velocity profiles in upwards oil/water flow using ultrasonic Doppler velocimetry. SPE Annual Technical Conference and Exhibition. Society of Petroleum Engineers, 1991.
[Iooss2002]	Iooss, B et al.: Numerical simulation of transit-time ultrasonic flowme-ters: uncertainties due to flow profile and fluid turbulence. Ultrasonics,40(9), 2002, pp. 1009-1015.
[Simurda2016]	Simurda, M. et al.: Modelling of transit-time ultrasonic flow meters under multi-phase flow conditions. In Ultrasonics Symposium (IUS), 2016, pp. 1-6.
[Khulief2011]	Khulief, Y. A. et al.: Acoustic detection of leaks in water pipelines using measurements inside pipe. Journal of Pipeline Systems Engineering and Practice, 3(2), 2011, pp. 47-54.
[Hunaidi2004]	Hunaidi, O. et al.: Acoustic methods for locating leaks in municipal water pipe networks. International Conference on Water Demand Management, 2004, pp. 1-14..

25 Literature

[Hall2009]	Hall, M. et al.: The WEKA data mining software: an update ACM SIGKDD explorations newsletter, ACM, 2009, 11, pp. 10-18.
[Holte1993]	Holte, R. C.: Very simple classification rules perform well on most commonly used datasets, Machine learning, Springer, 1993, pp. 63-90.
[Murphy2006]	Murphy, K. P.: Naive bayes classifiers. University of British Columbia, 2006
[Rennie2003]	Rennie, J. D. et al.: Tackling the poor assumptions of naive bayes text classifiers ICML, 2003, pp. 616-623.
[Quinlan2014]	Quinlan, J. R. C4. 5: programs for machine learning Elsevier, 2014.
[Witten2005]	Witten, I. H., Frank, E. Data Mining: Practical machine learning tools and techniques Morgan Kaufmann, 2005 pp. 188f, 198f, 320, 397.
[Greenwood 1999]	Greenwood, M. and Kinghorn, A.: SUVing: automatic silence/unvoiced/voiced classication of speech. In: Undergraduate Coursework, Department of Computer Science, The University of Sheeld, UK, 1999.
[Chen 1988]	Chen, C. H., Signal processing handbook, Dekker, New York, 1988, pp.531