Prozessintegriertes autonomes Überwachungssystem für die Verfahrenstechnik auf Basis vernetzter, multifunktionaler MST-Funksensoren

(PAC4PT)

Ressourcen-effiziente, robuste Sensor- und Funksignalverarbeitung für autonome vernetzte Systeme in fluiden Medien

(ROSIG, Fkz. 16SV3604 )

ROSIG Project 2012/2013 Final Phase

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Motivation

- WSN becoming ubiquitous in Automation, Agriculture, AmI/AAL etc.
- Cyber-Physical-Systems and the Internet of things add momentum
- Limitation of existing implementations technologies require access to advanced packaging and MEMS technologies in addition to mainstream chip technologies (CMOS, BiCMOS, SOI etc.)

- ISE goal (project proposal) for research & exploitation: Get training in and access to packaging/MEMS technologies for inclusion in RLP research centers, e.g., Ambient Systems, Commercial Vehicles etc. and individual initiatives, e.g., Driver Assistance Systems (DeCaDrive) or SmartKitchen

- Important issues in WSN besides the communication and technology:
  - Localization
  - Synchronization
  - Self-X and Low-power

Sensor Node Prototype and Test Issues

- Coarse System Architecture (adapted from 2009):
  - Env.
  - Sensor(s) → Analog Electronics → Digital Core (Atxmega 256A3) → RF-Chip Antenna
  - Energy Supply/Management
  - Stationary, n > 4
  - Mobile, n < 100
  - Master (Gateway) (sim. by Matlab)
Sensor Node Prototype and Test Issues

Radio module (IMST)

Pressure sensor module (microTec)

AMR-Sensor module

Flipping-unit

MCU (ATmega 256A3)

Voltage controller (3.3V)

Accu (4.2V)

Charging module (UST)

Resonator (32kHz)

LED (2x)

EEPROM

T-Sensor module (UST)

2009-2010 prototype
Sensor Node Prototype and Test Issues

- First prototype wire-wrapped, thus ‘’cranky’’ and ‘’buggy’’
- Modular test of emerging 3D-CSP units difficult
- No back-up in case of defect/problems
- 3D-CSP complete sensor node unavailable, but needed for SW dev.
- Thus SoA modular PCB-system conceived (lot size 5)
- Numerous bugs found in design data base, e.g. pressure sensor, EEPROM etc.
- Shipped to partner (IMST) for better cooperation
Sensor Node Prototype and Test Issues

- PCB & 3D-CSP modules exchanged and tested
- SW development advanced
- Measurement became feasible
- Designed for small volume test of 3D-CSP

- Remaining problems:
  - Connectivity of 3D-CSP to PCB-Adapters ‘cranky’
  - Complete and functional 3D-CSP module set never available
  - ‘Lot size one policy’ created problems

Magnetic Localization

Sensors used for Localization (2009 survey)

- Radio base
- Light wave
- Magnetic Field
- Ultra Sound

- External Source
  - Quasi DC Field
  - AC Field

- Internal Source (ball magnet)
  - Magnetic Marker

- Magnetic Marker Technologies GmbH
  - http://www.acmeme.com/
Magnetic Localization

- **Triaxial Anisotropic Magnetoresistive (AMR) sensor for 3D localization**
- **Ternary quasi-DC coil switching** alleviate need for flipping of AMR

![Diagram of magnetic localization](image1)

**Conversion from Sensor Output to Distance Value**

- **AMR sensor**: Sensitec AFF755B

\[
V_i = \frac{V_F - V_e}{2}, \quad i = \{x, y, z\}
\]

\[
V_d = \left(\frac{V_x^3 + V_y^3 + V_z^3}{3}\right)^{1/3}
\]

\[
B_d = \left(\frac{B_x^3 + B_y^3 + B_z^3}{3}\right)^{1/3}
\]

\[
B_d = \frac{\mu_0}{2} \frac{n \cdot I \cdot R^3}{(R^2 + d^2)^{3/2}}
\]

\[
d = \left(\frac{\frac{\mu_0}{2} \frac{n \cdot I \cdot R^3}{(R^2 + d^2)^{3/2}}}{B_d}\right)^{1/3}
\]

where

- \(S\): sensitivity
- \(V_s\): bridge supply voltage
- \(G\): gain of amplifier
Magnetic Localization
Validation Scenario

- Warstein campaign (Carrella & Groben, Sept. 2011), front & backview of container in brewery ‘Technikum’ with TUKL/ISE coil system

- Reported measurements have not been made with the target hardware (atmel Xmega 256A3) but with analog 3D-AMR sensor & DT DAQ
- Field generation with both DAQ & Xmega 256A3 board

- Grid of investigated container volume (left), 3D-AMR sensor & board
Magnetic Localization
Validation Scenario

- First-Cut (Carrella & Groben, Sept. 2011) data acquisition & analysis
- 30 sensor positions with about 10 repetitions measured in center cube of tank
- Overall result: Mean err. 40.73 cm with standard dev. 16.79 cm!

- Reasons: imperfect ADC-use, inferior algorithms, missing calibration ....

Magnetic Synchronization
(a) Synchronous Starting (b) Periodic Resynchronization
Low Power and Self-x Issues
Self-x Extension of AD8290 in 3D-AMR

- InAmp AD8290, enable pin is available (for shut down), and gain is 50 V/V

![Functional Block Diagram of AD8290](image)

- Offset & gain programmable in differential ADC mode
- Offset read for each channel and compensated
- Gain set for full-scale: Zooming & self-x achieved!

Low Power and Self-x Issues
Additional Self-x Extension

- Alternative AMR sensor (reconfigurable) architectures studied
- MEMS switches application for reconfiguration/self-trimming
- Implicit temperature measurement and self-monitoring

- Emerging µC ADC characterization for DNL/INL, SNR, ENOB:
The volume used is 1.5m x 1.5m x 1.5m (coils rearranged to cylinder !)
Applying 6 (previous) coils with diameter of 13cm and 100 windings
WSN node has been tested (12 bit ADC, reduced sampling rate, triangulation)
The error is in the order of 10cm (depends on-center/off-center loc. !)
ADC/cal. problems and coil to sensor node angle require improvement !
Conclusions and Future Research & Exploitation

- Concept & PCB-implementation of sensor node with magnetic localization and magnetic synchronization
- First self-x features added
- Large scale scenario data acquisition (benchmark data)
- Efficient localization algorithms developed (synch. alg. in prep.)

- First-cut demonstrator of the measurement system achieved (2013)
  Baseline for follow-up research & exploitation/commercialization

- Miniaturized sensor node (swarm) implementation pursued by various accessible MEMS/3D printing technologies (prerequisite for cal. !)
- Mobile demonstrator in preparation

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