XVIII BrainStorming day
Catania - Istituto Nazionale di Geofisica e Vulcanologia, 05/06/2009

Dottorato di Ricerca in Ingegneria Elettronica, Automatica e del Controllo di Sistemi Complessi – XIV Ciclo

Human oriented sensing systems and methodologies

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Human oriented sensing systems and methodologies

**Sensors**
- Design, realization and characterization
- Multi-sensor systems
- Distributed sensor networks
- Wireless sensor networks
  - Autonomous sensor nodes

**Methodologies**
- Stochastic resonance & Dithering
- Non-linear dynamics
- Multi-sensor data fusion
- Advanced algorithms for signal processing

**Applications**
- Environmental measurements (B-Field)
- AAL & Assistive technologies
- Energy Harvesting
- ...

**PhD research activities**
1. PhD research activities
2. RTD Fluxgate
3. Ambient assisted living
4. Publications & courses

**Topic**
- Sensors
- Methodologies
- Applications
RTD Fluxgate magnetometers

Suitable for measuring static or quasi-static magnetic field intensities, in the range of nT at room temperature.

Why research on RTD Fluxgate?
RTD Fluxgate is an alternative to the traditional 2nd harmonic Fluxgate. The benefits are:

- Intrinsically digital form of the output signal (time domain readout)
- Reduced complexity in the conditioning and readout electronics that traduces in less noise and less power consumption

Possible applications
- Magnetic Immunoassay [health-care]
- Natural hazards detection (Volcanic ash fall monitoring) [safety]
- Accurate monitoring of geomagnetic field
**RTD Fluxgate Magnetometers**

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**Introduction**

- Operating principle
- Prototypes
- Characterization
- Perming effect

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**Operating principle**

**Fluxgate RTD**

**Time domain readout strategy**

\[
U(x) = \frac{x^2}{2} - \frac{1}{c} \ln \cosh[c(x + H_e(t) + H_x)]
\]

\[
\tau \frac{dx}{dt} = -x + \tanh\left[\frac{x + H_e(t) + H_x}{K}\right] = -\frac{\partial U(x,t)}{\partial x}
\]
Operating principle

Introduction

Operating principle

Prototypes

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\[ H_e(t) \]

\[ +H_c \]

\[ -H_c \]

\[ t_1 \]

\[ t_2 \]

\[ t_3 \]

\[ t^+ \]

\[ t^- \]

\[ H_x = 0 \]

\[ RTD = T^+ - T^- = 0 \]

Excitation waveform

Fluxgate output

Schmitt Trigger output

\[ H_x > 0 \]

\[ RTD = T^+ - T^- > 0 \]

Excitation waveform

Fluxgate output

Schmitt Trigger output
**Experimental setup**

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**Experimental setup components**

- Functions Generator (Agilent 33120A)
- Tension/Current converter
- FluxGate Primary Coil
- FluxGate Secondary Coil
- Schmitt’s Trigger
- GPIB Interface
- DAQmx NI 6221 Analog Output
- Instrumentation Amplifier (INA114)
- DAQmx NI 6221 Counter 32bit 80 MHz

**Equations and parameters**

- $A_{bias} =$?
- $f_{bias} =$?
- Offset =$?$
- Waveform =$?$
- $T_{bias} =$?
- $I_{dc} =$?
- $L = 30\text{mm}$
- $\varnothing = 63\text{mm}$
- $N/L = 5000 \text{[n°spire/m]}$
- $\text{Wire width} = 0.2\text{mm}$
- $R = 144.82 \Omega$
microWire characterization

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Operating principle
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Graphs showing characteristics of microWire:
- Resolution vs Observation Time
- Sensitivity vs Excitation current
- Resolution vs Observation Time
- Magnetic Field vs DRTD
The perming effect can affect the output signal of the device (by an offset) after a magnetic shock. It is similar to hysteresis, but the applied field must be much higher than the full-scale range.

All the sensors containing ferromagnetic material are susceptible to perming.

The only solution is the periodic remagnetization of the core; in the case of fluxgate sensors, the re-magnetization is performed by forcing a current through the primary coil.

Anyway, it must be considered that no significant perming is observed if the device is polarized by a high current value.
Perming effect
Experimental procedure

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### Steps

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<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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</thead>
<tbody>
<tr>
<td>Applied Magnetic field (mT)</td>
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<tr>
<td>Excitation Current Amplitude (mApp)</td>
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<tr>
<td>Raw RTD (µs)</td>
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</table>

ΔRTD
The figure below shows the typical trend in the RTD signal, before (red) and after (blue) the magnetic shock. The quite constant values for the red curve means that the reset procedure (step B) worked properly. Data refer to μWire prototype with a triangular driving current amplitude of 2 mApp @ 80 Hz.
Experimental results show that the $\Delta$RTD consequent to the magnetic shock increases quite linearly with the field intensity. Moreover, this effect is less evident when excitation current amplitude increases. This is quite reasonable because an higher driving current produces a better saturation of the ferromagnetic core that hence becomes less susceptible to perming.
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05/06/2009

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phD research activity outline

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Topic
- Sensors
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- Applications

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Main Research areas involved in AAL:

- New materials
- Microelectronics and Microsystems
- Sensors & Embedded systems
- Power management and scavenging
- Communication technologies
- Software, web & network technologies
- Domotics and Smart houses
- Human-machine interaction
- Smart textiles
- Robotics
- Sociology

\[ ... \]

\[ ... \]

**Why research on AAL & Assistive technologies?**

**Social problem**

Disabled people represent 50 million persons in the EU (about 10% of the entire population)

According to ISTAT (2004-2005), 4.8% of the Italian population (2,800,000 persons) suffer from some kind of disability, the 75% of which are over-65 years old.

*New innovative solutions can have a major effect on quality of life, thus easing the pressure of increasing costs in European social and care systems*

**Attractive potential market**
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- Human-machine interaction
- Smart textiles
- Robotics
- Sociology
- ...
- ...

Why research on AAL & Assistive technologies?

AAL Joint Program
The AAL JP is a new joint research and development (R&D) funding activity implemented by actual 20 European Member States and 3 Associated States with the financial support of the European Community.

Call AAL 2008 1
Call AAL 2009 1
...

FP7-ICT-2009.7.2
Accessible and Assistive ICT,
Embedded Accessibility of Future ICT
A wireless sensor network for indoor user localization.

Embedded US transducer, with RF transceiver (battery-powered)

- Analog signal conditioning circuitry
- Microcontroller (PIC18F2520)
- Piezoceramic Capsule (RX)
- RF 433 MHz Transceiver
- USART

40 kHz
A wireless sensor network for indoor user localization.

User (visually impaired)

- Bluetooth earphone
- Compass
- Accelerometer
- Microcontroller (PIC18F2520)
- RF 433 MHz Transceiver
- 40 kHz
- Analog signal conditioning circuitry
- Piezoceramic Capsule (TX)
- USART
A wireless sensor network for indoor user localization.

Master (sink) node.

- GUI for the system administrator (LabVIEW)
- Algorithms:
  - trilateration
  - routing
  - object interaction
  - odometry
  - multi-sensor data fusion
  - ...

Microcontroller (PIC18F24J11)

RF 433 MHz Transceiver
A wireless sensor network for indoor user localization.

Transmits through the RF trainsceiver a “start” sequence. We can say that each network node, including the user module, will receive the start signal at the same time.

Start their timers
Generate a short ultrasonic wave
Receives and stop its timer
Receive and stop their timers
Receive and stop its timer

Queries each node for their elapsed time (polling) and computes the distance between the user and each network node (time of flight). Finally, user module is queried too for retrieving data from the compass and the accelerometer. This raw data is then transferred to the PC running LabVIEW for further processing, through a USART connection.
A wireless sensor network for indoor user localization.

Within the white area the user can be successfully localized thanks to the **MTA**.

In gray areas most of the US capsules won’t receive the acoustic wave. To ensure localization within shadow areas an alternative localization strategy, that does not rely on the ultrasonic wave, must be adopted.

This can be achieved by the use of **odometry** starting from data retrieved from embedded compass (that give us user orientation) and accelerometer (that give us an idea about the number of user’s steps).

Moreover, when the user is inside white areas, the system can perform an **automatic calibration of the odometric subsystem** (i.e. determine the average measure of a step).

When should I trust odometry? When trilateration?: **Multisensor data fusion** approach.
N = number of US sensor nodes  
M = number of users

After we gain a reliable and accurate estimation of user location within the environment, we can provide the impaired user with a useful kind of assistance, on the basis of his impairment typology and his skills. A general purpose assistance strategy could start from: obstacles avoidance, services notification, routing features through an auditory and/or haptic feedback.
A wireless sensor network for indoor user localization.

**Fully accomplished**
- ✔ Design of the US sensor node
- ✔ Design of the user and master node
- ✔ Implementation and testing of the MTA
- ✔ Preliminary GUI for the system administrator
- ✔ Stand-alone odometric subsystem
- ✔ Audio feedback subsystem

**Partially accomplished:**
- ▪ Routing algorithms
- ▪ Improved PCBs for the sensor nodes, user and master modules
- ▪ Set-up of wireless communication (CAN-BUS → Xbee → RF 433 MHz)
- ▪ Improved GUI for the system administrator

**To do:**
- ❇ Integration between MTA and odometry
- ❇ Metrological characterization of the whole system
- ❇ Power budget minimization through firmware optimization
- ❇ Test with end-users
- ❇ …
Journals:


Conferences

2) B. Andò, A. Beninato, S. La Malfa, N. Pitrone, Didactic tool assisting visually impaired students during laboratori sessions, the 7th WSEAS International Conference on Education and Educational Technology (EDU08), pp. 190-193, 2008.

3) B. Andò, A. Ascia, S. Baglio, A. Beninato, S. La Malfa, N. Pitrone, Sensing a physical movement with a ferrofluidic device, the 4th WSEAS International Conference on Remote Sensing (REMOTE08), pp. 99-102, 2008.

4) B. Andò, S. Baglio, S. La Malfa, V. Marletta, N. Savalli, A Distributed Sensor Network Approach for Orientation Tasks, IMTC2009.


7) B. Andò, S. Baglio, S. La Malfa, V. Marletta, A “Multisensor Guide System” To Assist Visually Impaired In Unfamiliar Environments, ASME, IDETC/CIE 2009

8) B. Andò, S. Baglio, S. La Malfa, N. Pitrone , A Remote Monitoring System to Improve Educational Activities of Visually Impaired Students, XIX IMEKO World Congress, 2009

Courses:
- Modelli Matematici I (prof. O. Muscato - cdl Matematica)
- Elaborazione Numerica dei Segnali (prof. A. La Corte – cdl Ing. Microelettronica)