New Wheelchair Control Interface Systems

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Outline

- SYSIASS Project
- Wheel chair interface:
  - Resistopalatography
  - RFID
  - Epidermal Electronics
  - Tongue Proximity Sensor
Passive Assistive Technology with Dignity

Assisted Living (SYSIASS project)

The intention is to produce wheelchair control assistive technology that is not obtrusive or functional looking.

This work involves Kent, Essex & Lille Universities together with East Kent Hospitals University NHS Foundation Trust and Groupe Hospitalier de l'Insitut Catholique de Lille.
Resistopalatography:

- Utilises tongue pressure against the hard palate to control either a computer or a wheelchair.
- Consists of a force sensing resistor array that can be mounted onto a standard dental retainer plate.
- Capable of measuring light pressure impacts and full force swipes.
  - The large range between full and no pressure offers opportunity to cater for widely differing user strengths.
  - Sensed output is amplified & digitized.
  - The array of values is processed to calculate required \((x, y)\) control input.
  - Desired speed can be derived from the force applied.
Resistopalatography Measurements:

• The control system has been implemented and tested on a powered chair.

• Position measurements were obtained using an optical motion capture system.

  • Currently 64/128 sensors are implemented in the array.

  • More sensors could be activated to improve resolution.

• Other uses for the system include:

  • Diagnostic Tool for Speech and Language Therapy allowing for tongue palatal contact to be observed.

  • Diagnostic analysis of dysphagia by measuring tongue force during swallowing.
Body-Centric RFID Tagging and Sensing

RFID is conventionally used in asset tracking, but it is finding new applications.

- Stock control
- Transport
- Anti-theft
- Anti-counterfeiting
- HCI for:
  - Healthcare
  - Assisted Living

Most people are familiar with RFID as near field (smart card or contactless payment) technology at 13.56MHz.
UHF RFID

This work involves UHF RFID (860-920MHz)

- Works like RADAR
- Energised by reader signal
- Tag reflects modulated information back to reader
- No battery needed at the tag (Passive System)

In favourable conditions (no people around) read ranges of 7m+ can be achieved.
Eye Blink Sensing as Human-Computer Interface

E-make up has been demonstrated to control interfaces including a wheelchair.

The first temporary transfer tattoo RFID tag:

Temporary On-Skin Passive UHF RFID Transfer Tag

Mohamed Ali Ziai and John C. Batchelor, Senior Member, IEEE

Abstract—A passive UHF RFID tag design is presented in the form of a transfer patch similar to a temporary tattoo that is mountable directly onto the skin surface. The transfer tag is suitable for monitoring of people over time in mission critical and secure environments. The antenna reactance is first calculated to conjugate match the measured RFID chip reactance and then full wave simulation is used to design the tag with good performance on a human flesh model. Finally, the tag read range is measured on different parts of a volunteer’s body and compared to simulated read range values for the entire RFID bands.

Index Terms—Body centric communications, conducting ink, RFID.

I. INTRODUCTION

With the emergence of distributed and wireless sensor technologies readable tags will be able to collect a vast sea of data that can be processed to provide new information. Such information could be extremely important in mission critical environments such as power plants, airports, military bases and depots, refineries, oil rigs, and access restricted areas to provide the highest quality of security to record trends and take immediate required actions. In these environments as well as healthcare, monitoring and identifying people is vital to interface different services to create a more resilient system.

Passive RFID is emerging as particularly useful in monitoring, identifying and tracking people in work environments [1]-[3]. For example, employees or visitors could be located and their action monitored in defined environments over a moderate distance without requiring a deliberate read action from the tagged person [4]. This would allow convenient fast access to restricted areas and a safer working environment for

<table>
<thead>
<tr>
<th>TABLE 1</th>
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<tbody>
<tr>
<td><strong>LF, HF AND UHF RFID SYSTEM CHARACTERISTICS [5], [6]</strong></td>
</tr>
<tr>
<td><strong>LF</strong></td>
</tr>
<tr>
<td>Typical RFID Frequency</td>
</tr>
<tr>
<td>Approximate read distance</td>
</tr>
<tr>
<td>Typical data transfer rate</td>
</tr>
</tbody>
</table>

of up to 10 m. The long interrogation range, along with low cost tags and relatively high data rate as shown in Table 1 make UHF RFID systems suitable for human monitoring. [5], [6].

II. RFID TAGS FOR HUMAN MONITORING

Human tagging, external to the body, is usually based on wrist bands or ID badges which could be removed and given to other people. There is little work reported on skin mounted RFID tags that cannot be removed without destroying the tag, and [7]-[11] describe work which requires a substantial gap of several millimeters between the tag and the skin to provide an acceptable read range. These designs are also complicated by multiple layers either with or without cross layer connections, and therefore they are not suitable for ultra low profile tags which can be directly mounted on skin.

Being a passive system, the power collected by the tag antenna is used to activate the tag IC. The transmitted read power available to the tag antenna is constrained by electromagnetic compatibility regulations and thus it is essential that the maximum possible power is transferred to the tag IC in order to be able to read the tag.
Inkjet printing of transfer tattoo tags

Research grant money has developed flexible conducting transfers:
The slot provides an impedance transformation between the antenna terminals and the complex impedance of the transponder chip.

The tag becomes mis-matched when the slot conditions change (the energy entering the tag is reduced).

This means more power is required at the reader to activate the tag.
Efficient tag operation is highly dependent on the impedance match between the transponder electronics and the antenna input.

This is done using a nested slotline input transformer with dimensions $l$ and $w$. 
Predicted Read Range

Tag maximum read range

\[ R_{\text{max}}(\theta,\phi) = \frac{c}{4\pi \cdot f} \sqrt{\frac{\text{EIRP}}{P_{IC}}} \cdot \tau \cdot G_{\text{tag}}(\theta,\phi) \]

where \( \text{EIRP} \) is reader power and \( \tau \) depends on the tag impedance match

\[ \tau = \frac{4R_{IC}R_a}{|Z_{IC} + Z_a|^2} \]

\( P_{IC} \) is the transponder activation power.
An RFID Switch to Control Wheelchairs

The in-mouth technology is intended to be disposable and straightforward to fit onto a dental plate.

There is one small chip and no battery required inside the mouth.

A tag was tested to work:

- on the tongue
- Inside the mouth
- With the mouth closed
Reduced Size Mouth Mounted RFID Switch Design

Read range for in mouth tag = 1m

<table>
<thead>
<tr>
<th>Slot Width</th>
<th>a</th>
<th>1.5 mm</th>
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<tbody>
<tr>
<td>Slot Length</td>
<td>b</td>
<td>20 mm</td>
</tr>
<tr>
<td>Tag Width</td>
<td>c</td>
<td>20 mm</td>
</tr>
<tr>
<td>Tag Length</td>
<td>d</td>
<td>50 mm</td>
</tr>
</tbody>
</table>
Measurements with mouth open:

Transmitted Power (dBm) at 900MHz vs. Tongue / tag separation (mm)

Proximity sensing range

5dB range isolation between ON and OFF
Reduced Size Mouth Mounted RFID Switch Simulation

A simple homogeneous flesh model of the hard palate and tongue was created. $\varepsilon_r = 55$ and conductivity $\sigma = 0.94$ S/m.

The effective tongue capacitance was simulated for various tongue-tag separations.

![Simulation graph showing tag power response vs. tongue-tag separation distance.](image)
Improved Modelling

A more accurate 3D mouth model was used for the simulation.

Measured results averaged over 3 users.
User Improvements with Practice

The 3 users were asked to hit all 5 targets and were given 7 attempts at each.

The average for all 3 users for all 5 targets was individually found for attempts 1 to 7.

The percentage error $|E|$ was calculated for each attempt:

$$|E| = \left| \frac{\text{Target}_{\text{measured}} - \text{Target}_{\text{expected}}}{\text{Target}_{\text{expected}}} \right| \times 100\%$$

The average errors were observed to halve after 5 attempts, and to drop to about 1% by 7 attempts.
Hitting Random Targets

Finally, the 3 users were asked to hit the 5 targets in a random sequence of 25 attempts.

The graphs show the distribution around the required target when (a) all 25 attempts are included and (b) when only the final 13 attempts are considered.

Overlap is observed in (a) meaning there is confusion between the targets. However, by allowing some practice time and only considering the second half of the measurement, in (b) each target is now clearly discriminated.
The Next Stage

A target selection algorithm will be developed. The extent of confusion between targets must be investigated.
An interface to the chair control must be implemented. A second direction control should be added.
Summary

- Future work will establish if multi-vector switches can be fitted for joystick/mouse control.

- Integrated sensing function has been demonstrated for tongue control.

- Skin mountable RFID/Antennas have been developed for muscle twitch control.