A MULTI-SENSORIAL INTERFACE FOR DRIVING A MOTORIZED WHEELCHAIR

Bruno Carrilho †, Eduardo Ribeiro †, Tiago Martins †, Pedro Correia †, Gabriel Pires † ‡
email: *gppires@ipt.pt*

† Engenharia Electrotécnica e de Computadores - Departamento de Engenharias, Instituto Politécnico de Tomar, Tomar, Portugal
‡ Instituto de Sistemas e Robótica, Universidade de Coimbra, Coimbra, Portugal

IPT – Instituto Politécnico de Tomar

ISR – Instituto de Sistemas e Robótica

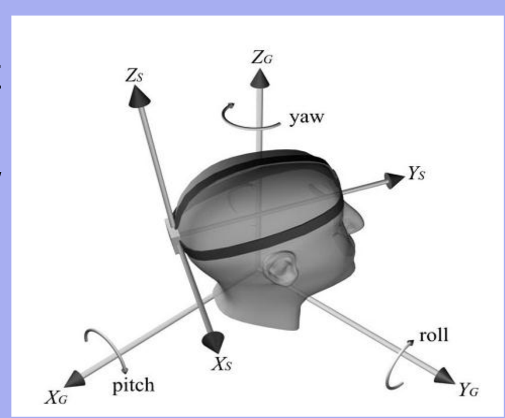
Abstract

This paper describes a multi-sensorial interface based on inertial sensors, infrared sensors and electrooculographic (EOG) signals for driving a motorized wheelchair and for controlling a mouse pointer on a computer screen. The wheelchair is steered through head movements which are detected by inertial sensors and infrared sensors. Using an head switch, the user can switch to the mouse pointer mode to control applications in a computer screen. The mouse click is emulated by eyes' blinks detected through EOG signals.
The inertial motion module uses an accelerometer which allows the decomposition of gravitational acceleration, thereby detecting the relative position of the sensor coupled to the user's head. Then, the head movements are translated into speed commands for the wheelchair or 2D positions for the mouse pointer [1].

Inertial Module

• From an initial reference from which we get the coordinates for the acceleration of gravity, we calculate the rotation angles with the new accelerometer readings.

• Inverse kinematics is applied to the rotation matrices based on the gravitational acceleration



$$\begin{bmatrix} G_X \\ G_Y \\ G_Z \end{bmatrix}_{XYZ} = \begin{bmatrix} -\sin\theta \\ \sin\Phi * \cos\theta \\ \cos\Phi * \cos\theta \end{bmatrix} \Rightarrow$$

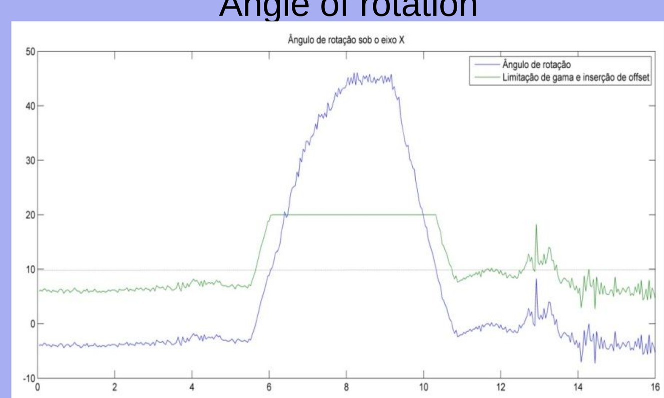
$$\theta = \arctan\left(\frac{-G_X}{G_Z}\right)$$

$$\Phi = \arctan\left(\frac{G_Y}{\sqrt{{G_X}^2 + {G_Z}^2}}\right)$$

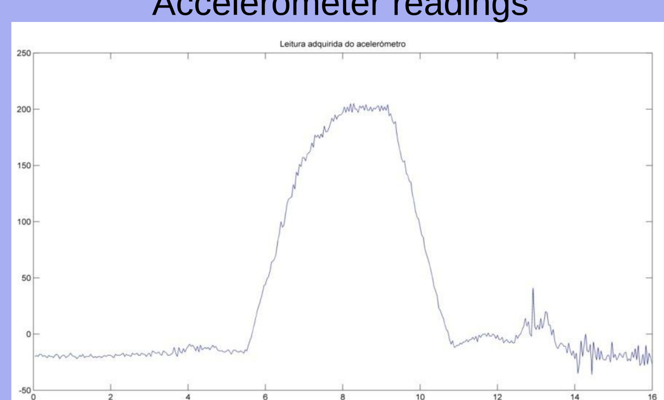
• Kinematic expressions are not independent from the sequence of movements. The expressions are analyzed for each sequence yielding a precision error not relevant at a range of 20 degrees.
• The operating range of the system is limited to 10 degrees of rotation and the mathematical expressions used for computation are the ones which entail lower cost for processing.

Prototype of the multi-sensorial interface

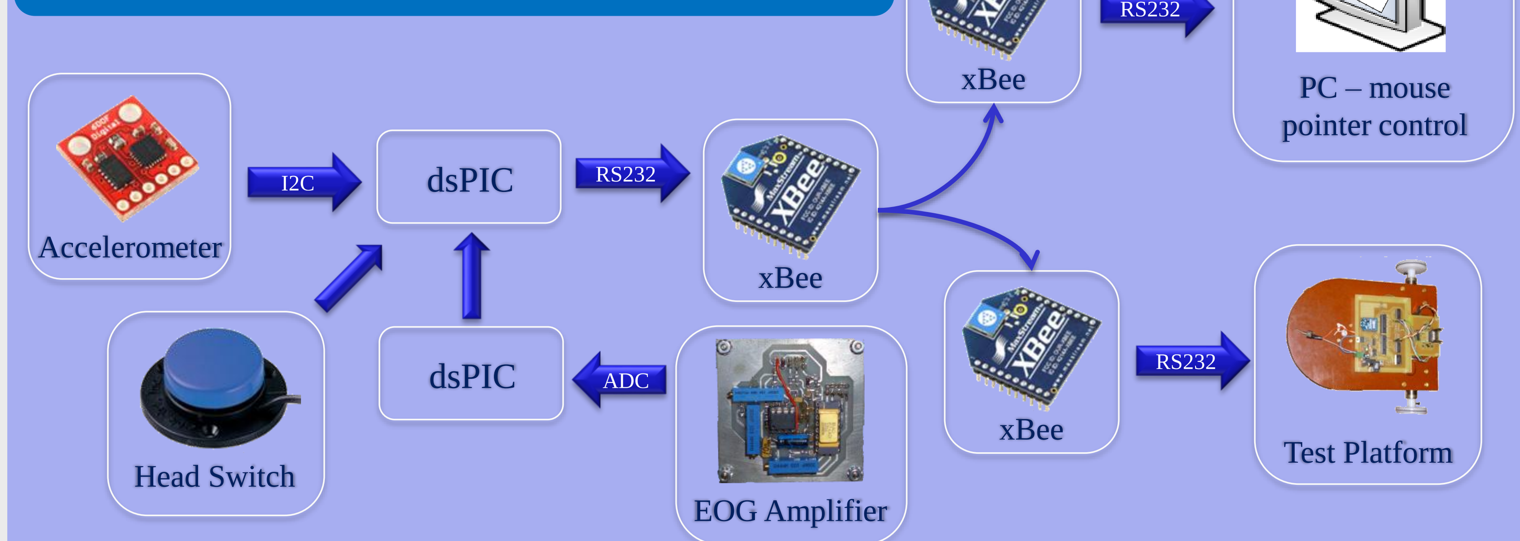
Angle of rotation



Accelerometer readings



Data Communication Diagram



• The accelerometer and infrared data are acquired through an I2C bus.
• Head movements data are sent to the test platform and to the PC through wireless communication (xBee modules).
• The connection between the two microcontrollers of the test platform was made with an I2C bus in a master slave configuration.
• RS232 communications uses a transparent protocol implemented with sync character to distinguish the message recipient.

Module Architecture

• **Inertial Interface - The sampling frequency of the accelerometer was set to 25Hz and the the signal bandwidth was limited to 250 mHz (DC component) through a digital filter implemented in the dsPIC microcontroller (dsPIC33FJ12GP202).**

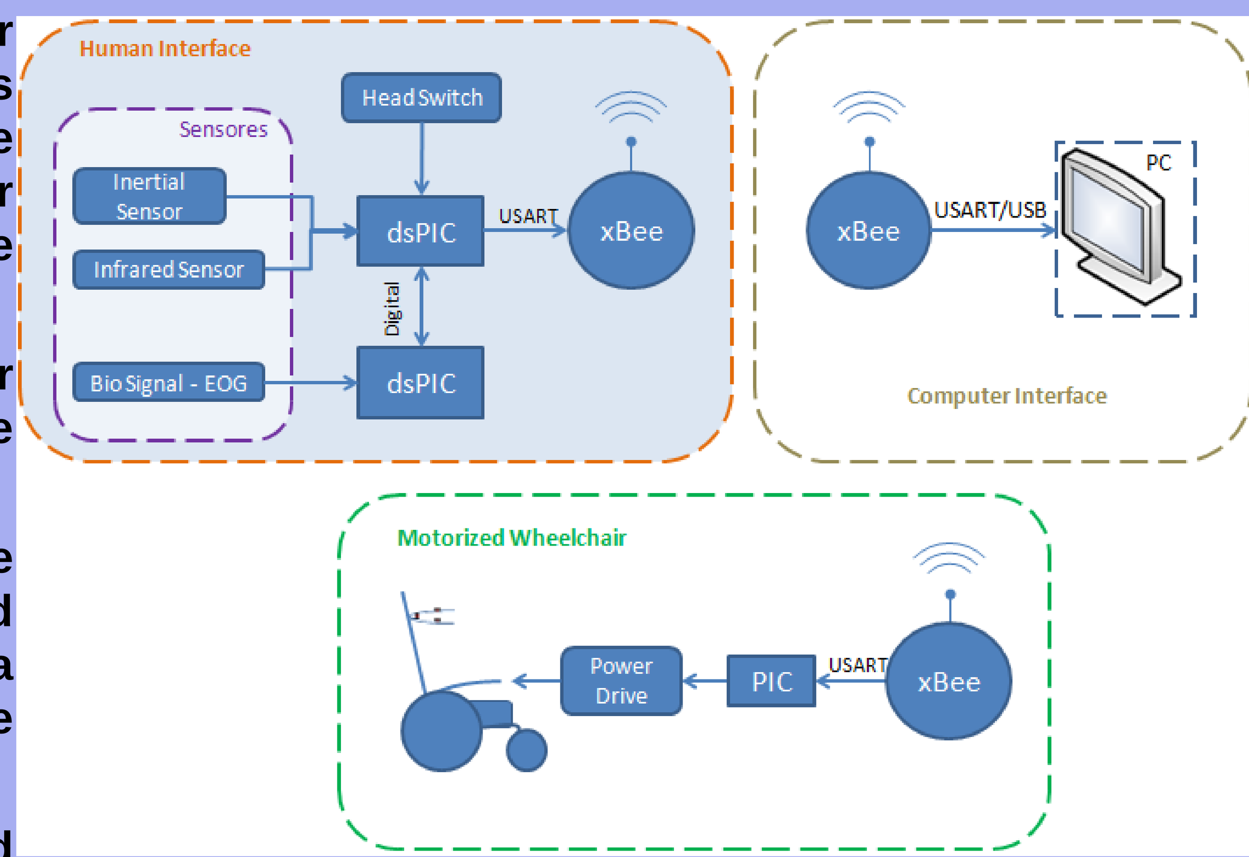
• **EOG Interface - The mouse click is emulated by eyes' blinks detected through EOG signals. The blink detection algorithm is implemented in its own dsPIC, allowing a modularity of the system. The resolution of the digital signal is 12bit and the sampling frequency was set to 200Hz.**

• **The control of the mouse pointer on the computer screen was developed in Java language. The driver consists of two threads for non-blocking mode and real-time operation of the mouse pointer.**

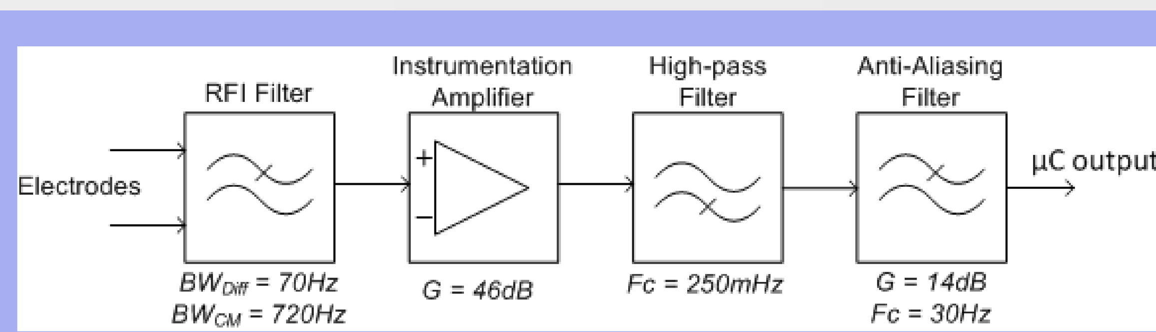
•Through an head switch the user can switch between the mouse control or wheelchair control.

• **A test platform, simulating the wheelchair, was developed integrating a mobile robot and a manual motion platform where the user sits**

•The modules are connected wirelessly through xBee.



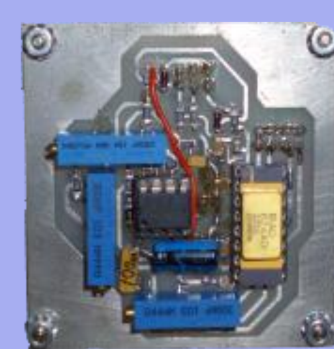
EOG Amplifier



EOG signals have very low amplitude values, typically in the range of 100-500 µV.

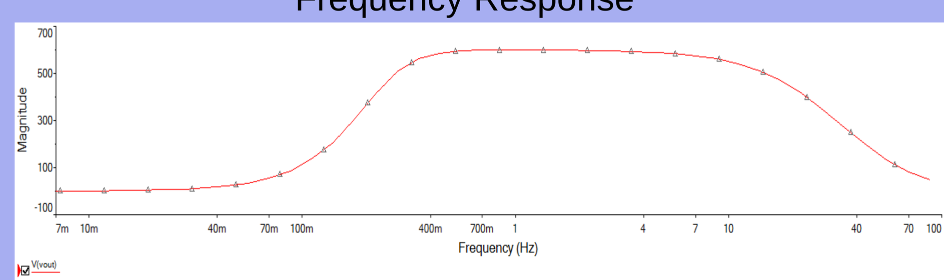
• **RFI Filter** – Radio frequency interference filter with differential and common mode bandwidth.
• **Instrumentation amplifier** - implemented with the AD624 circuit that is characterized by having low offset voltage, typically 25 µV, and high CMRR. The configurable gain is set to 46dB
• **High-pass filter** - second-order with cut-off frequency at 0.25 Hz. Rejects the DC component present in acquisition between active electrodes .
• **Anti-aliasing filter** - second-order lowpass filter with cut-off frequency of 30Hz and gain 14dB.

Channel resolution	12 bits
Input voltage full scale	500 µV
Min. input voltage step detect	895.18 nV
Min. input voltage step detect in AD converter	805.66 µV
Input frequency range	0,25-30Hz
Attenuation at sample frequency (fs=200Hz)	40dB
Common Mode Rejection Ratio (CMRR)	>130 dB
Min and Max Gain	46dB ~ 66dB

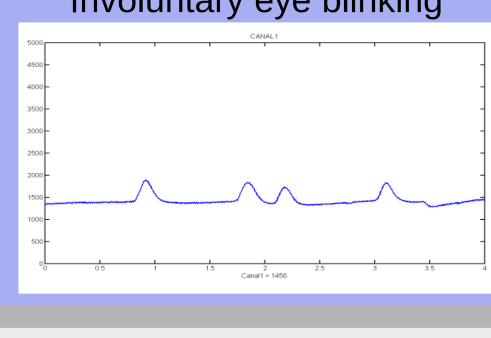


EOG amplifier

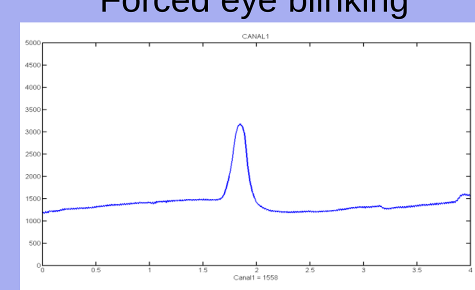
Frequency Response



Involuntary eye blinking



Forced eye blinking



Test Platform

• The motor control was implemented independently by two PIC18F258 µC, each one implementing PWM speed reference and incremental encoder processing.
• The head movements data are received and processed in the master µC and then transmitted via I2C to the slave µC.
• In case of communication failure the motor driver is disabled for user safety.

Conclusions

A multi-sensorial interface for wheelchair steering and mouse pointer control was here described. The results show that the inertial interface module provides a stable and reliable response. The EOG module effectively detects forced eye-blinks.
The experimental tests driving the robotic platform and controlling the mouse pointer show effective performance levels. The overall architecture is modular allowing real-time operation and high flexibility.

[1] – B. Carrilho, E. Ribeiro, T. Martins, "*Capacete multi-sensorial baseado em sensores inerciais, sensores de infra-vermelhos, e sensores EOG para condução de uma cadeira de rodas e controlo de um cursor no ecrã*", Tese de licenciatura, Instituto Politécnico de Tomar, LEEC-IPT, 2012

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