An inertial haptic interface for robotic applications

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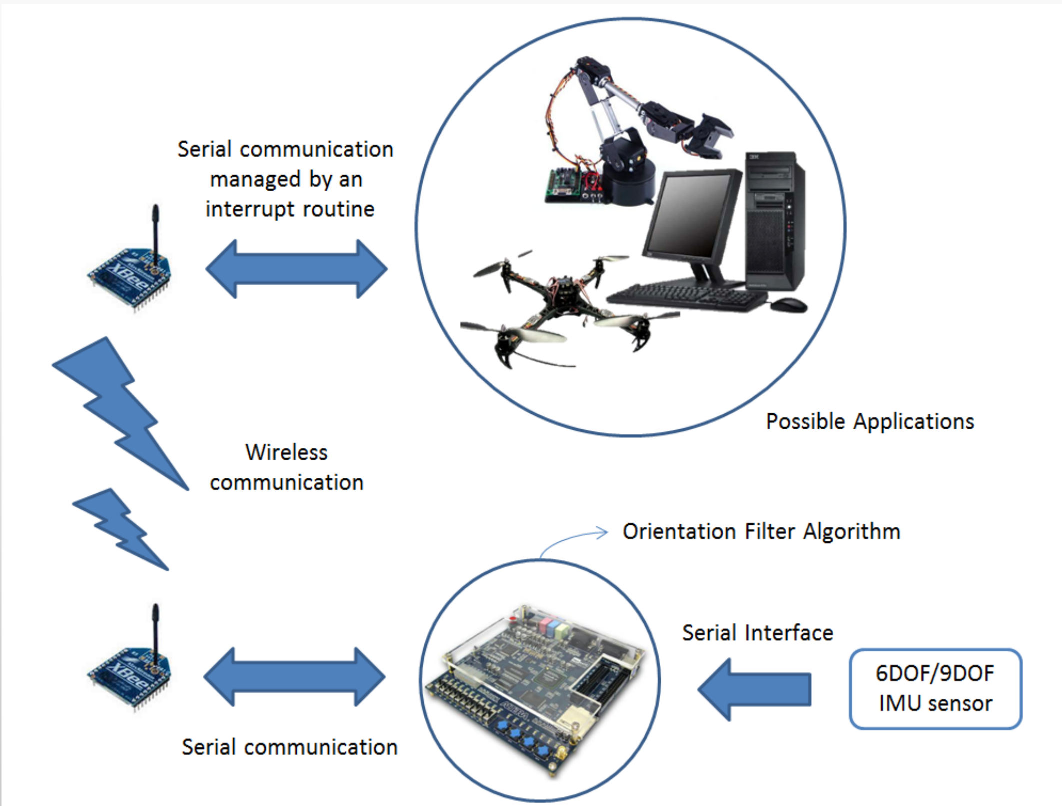
Objective

- Build a Low Cost Interface to acquire rich data about human movements and gestures
- An Inertial Measurement Units (IMU) can be used to measure accelerations, angular velocities (6 Degree of Freedom) and magnetic field (9 Degree of Freedom) in order to collect reach data
- The collected data can be used to reconstruct euler angles using an Attitude and Heading Reference System (AHRS) algorithm

Some Applications:

- Interfacing the IMU sensor to a software application in order to reconstruct the sensor rotations
- Build a real time haptic interface (IMU based) to drive advanced robotic or videoludic systems throught human gestures (such as Sony and Nintendo consoles gamepad)

Proposed System Architecture

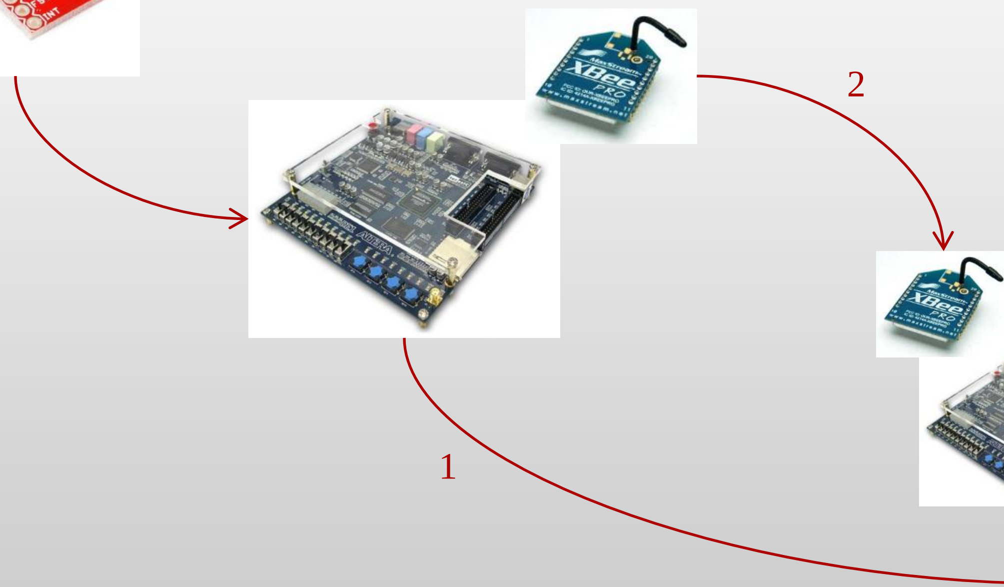


General Scheme

- An Altera DE1 board
- Two Xbee Modules
- An IMU (6DOF or 9DOF)
- Your imagination as possible application

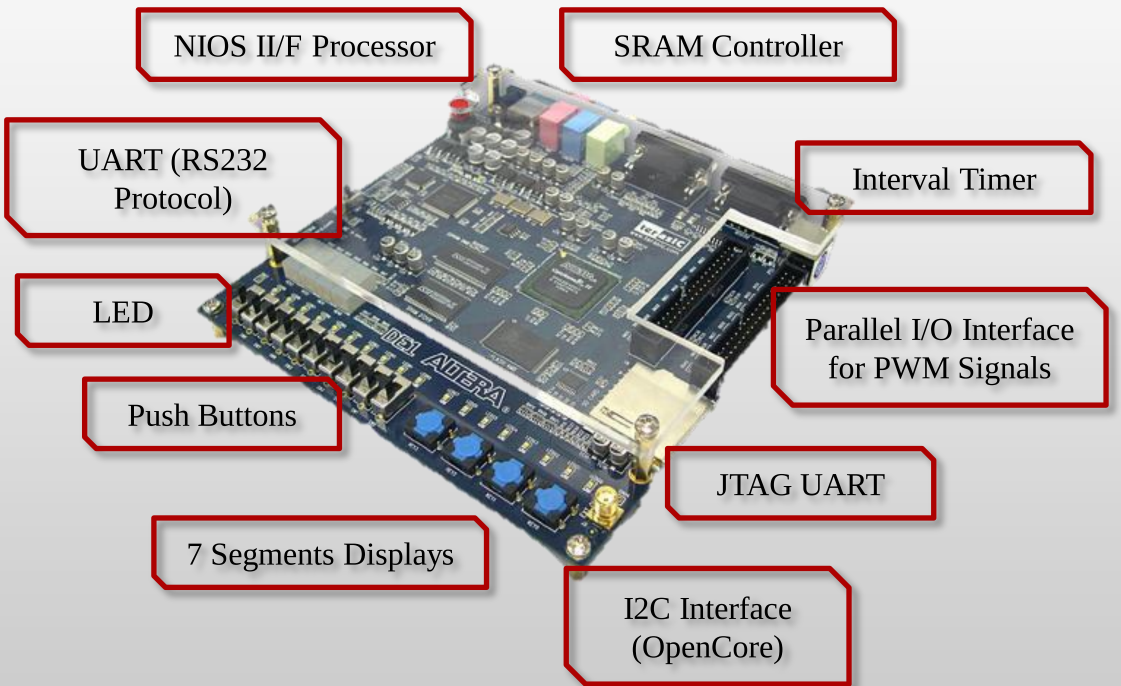
Functioning

- The DE1 Board acquires data from the IMU (MPU9150) via I2C interface
- It elaborates the information, gives the estimated orientation of the sensor frame as result using the AHRS algorithm



The data are sent on a wireless communication channel (i.e. xbee – zigbee protocol) or on a wired bus to the controlled system

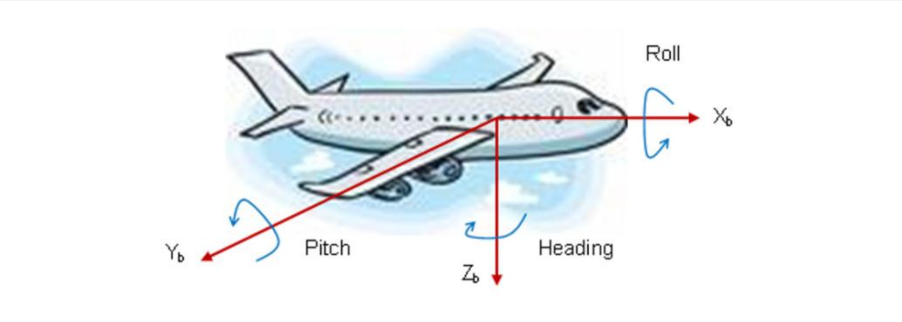
NIOSII Soft-Core



Conn...	Name	Description
	⊟ **cpu_0**	Nios II Processor
	instruction_master	Avalon Memory Mapped Master
	data_master	Avalon Memory Mapped Master
	jtag_debug_module	Avalon Memory Mapped Slave
	⊟ **sram_0**	SRAM/SSRAM Controller
	avalon_sram_slave	Avalon Memory Mapped Slave
	⊟ **opencores_i2c_0**	OpenCores I2C
	avalon_slave_0	Avalon Memory Mapped Slave
	⊟ **jtag_uart_0**	JTAG UART
	avalon_jtag_slave	Avalon Memory Mapped Slave
	⊟ **uart_0**	UART (RS-232 Serial Port)
	s1	Avalon Memory Mapped Slave
	⊟ **led_green**	PIO (Parallel I/O)
	s1	Avalon Memory Mapped Slave
	⊟ **timer_0**	Interval Timer
	s1	Avalon Memory Mapped Slave
	⊟ **pwm**	PIO (Parallel I/O)
	s1	Avalon Memory Mapped Slave
	⊟ **led_red**	PIO (Parallel I/O)
	s1	Avalon Memory Mapped Slave
	⊟ **hex0**	PIO (Parallel I/O)
	s1	Avalon Memory Mapped Slave
	⊟ **hex1**	PIO (Parallel I/O)
	s1	Avalon Memory Mapped Slave
	⊟ **hex2**	PIO (Parallel I/O)
	s1	Avalon Memory Mapped Slave
	⊟ **hex3**	PIO (Parallel I/O)
	s1	Avalon Memory Mapped Slave
	⊟ **pushbutton**	PIO (Parallel I/O)
	s1	Avalon Memory Mapped Slave

The AHRS Algorithm

- In applications that require the calculation of the orientation of a rigid body with respect to an earth reference frame, an algorithm to estimate the sensor frame orientation is required
- An AHRS Algorithm allow to estimate the sensor frame orientation in term of a quaternion or the three Euler Angles ZYX or better kwon as Yaw (Heading), Pitch and Roll angles



- Yaw is defined as the angle between the axis Xb and magnetic north on the plane horizontal to the earth's surface measured counterclockwise when the device (rigid body) is viewed from above
- Pitch is defined as the angle between the axis Xb and the horizontal plane when the device is rotated around the axis Yb
- Roll is defined as the angle between the axis Yb and the horizontal plane when the device is rotated around the axis Xb

The AHRS Algorithm - Implementation

- The Madgwick AHRS algorithm requires 109 (in the case of a 6DOF IMU sensor) or 277 (9DOF IMU sensor) scalar arithmetic operations on float variable:

  "An efficient orientation filter for inertial and inertial/magnetic sensor arrays" of Sebastian O.H. Madgwick

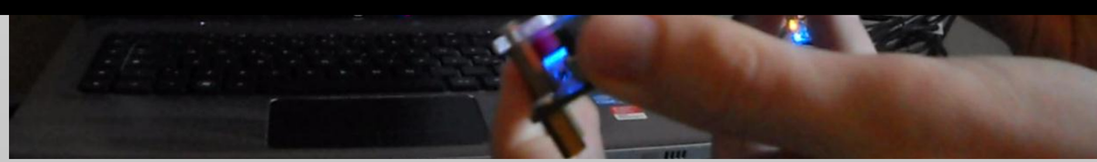
- The filter update must be executed as fast as possible in order to improve the performance of the control system
- A Floating Point Unit with a Floating Point Division Hardware has been considered in the soft-core definition

- The AHRS algorithm is computed with a frequency of 50 Hz
- Two AHRS algorithms have been developed using:
  - 6 DOF IMU sensor (gyroscope and accelerometer)
  - 9 DOF IMU sensor (gyroscope, accelerometer and magnetometer)

Application 1

AHRS Algorithm test

- Th[redacted]n an[redacted] int[redacted]
- A [redacted]sed to[redacted]



Application 2

Ball Maze

- Th [redacted]
- A [redacted] on a [redacted] of [redacted]
- The inertial interface computes the calculation of the Euler angles and generates a PWM signals used to control the two servomotors

Application 3

Anthropomorphic Robotic Arm Control

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- Th[redacted]
  ine[redacted]
  - [redacted]
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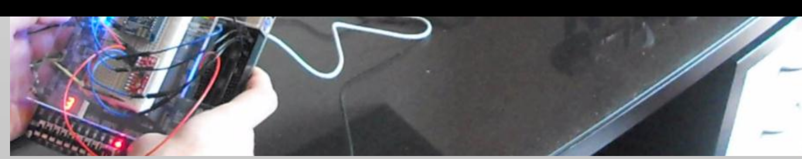
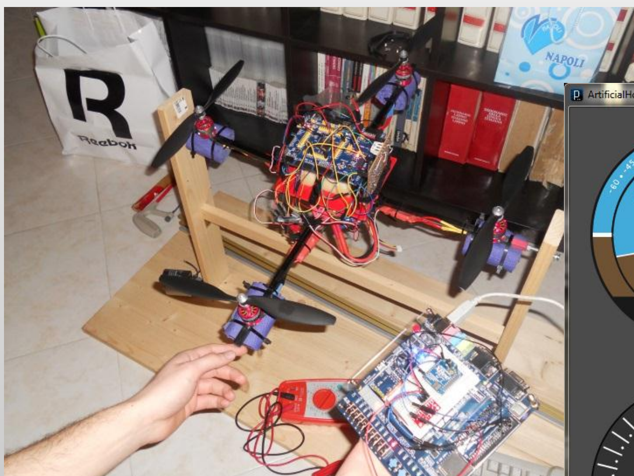


Application 4

Quadcopter control

- The inertial interface can be easily interfaced with an UAV such as a quadcopter
- An FPGA could be used also to support the develop of a telemetry system for an UAV: it could be used to acquire the sensor information, to elaborate them and to communicate with an host PC the orientation of the vehicle and other information such as the motors speed, battery voltage, altitude, GPS position, etc.



Thanks for your attention