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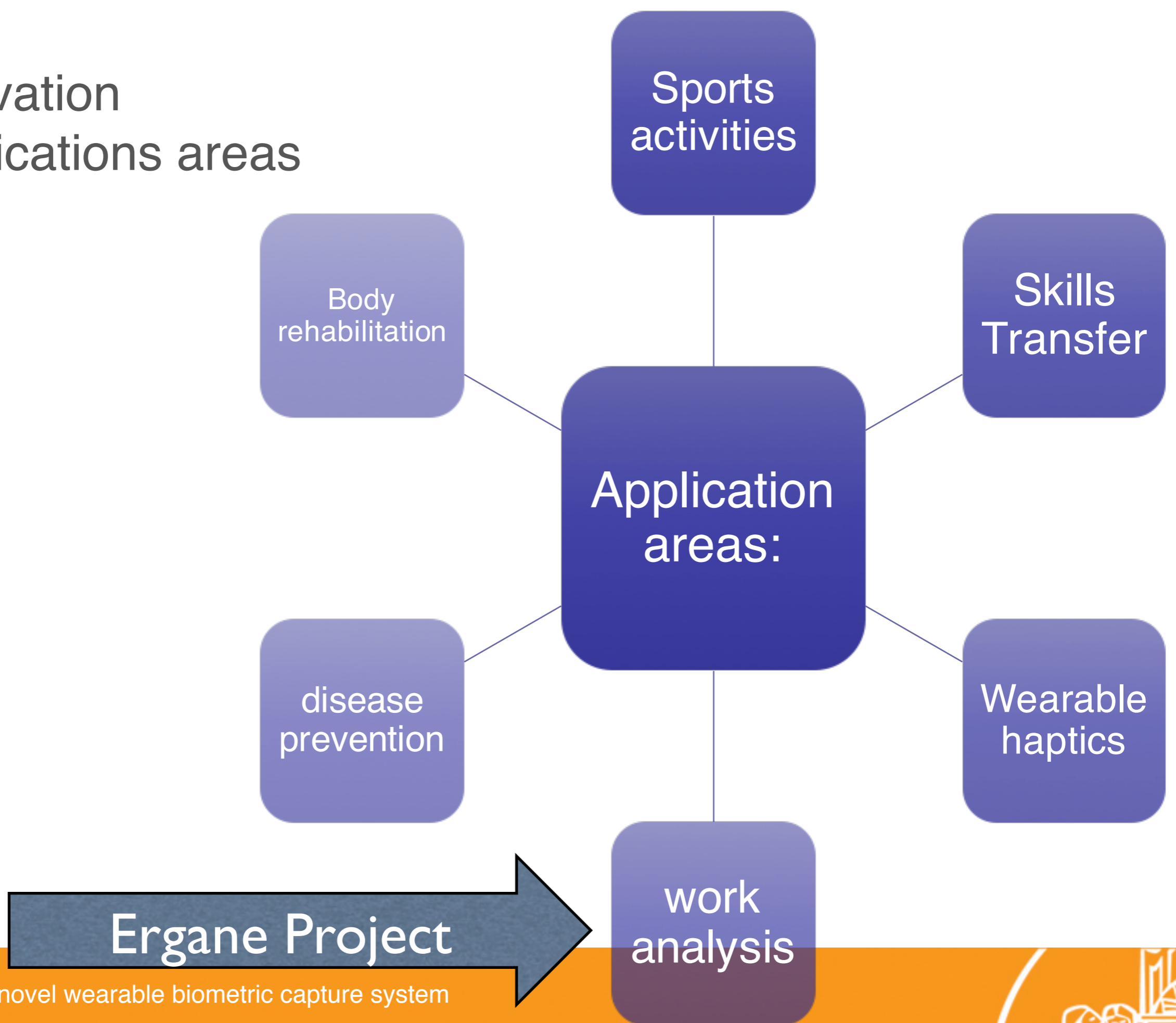
A novel wearable biometric capture system

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Motivation Applications areas



A novel wearable biometric capture system



Pre existing multichannel wireless EMG boards (No available solution)

Name	Com Proto	Com Speed	Year	SPS	Sensors	CMRR	Gain	Chan	Bits	Low Pass	High Pass	Filter Type
Free EMG 300	802.15.4	250Kbps	2012	<4000	Analog	85		<16	16	N/A	N/A	N/A
Vampire BAT [6]	ZigBee	250kbps	2012	<1000	-	51	51-73dB	1	14	500Hz	16Hz	3rd
FioBOARD [7]	ZigBee	250ksps	2012	<1500	-	51		<6	10	N/A	N/A	N/A
Vavrinsky [8]	RF	N/A	2012	<13330	-	100	60-80dB	<3	16	1Hz	1000Hz	2nd
Shimmer [3]	802.15.4	250ksps	2009	1024	-	85		1	16	5Hz	332Hz	4th
TeleMyo2400T	802.15.4	250ksps	N/A	1500/3000	-	85		16,8	16	3Hz	1000Hz	
Villaneuva [4]	ZigBee	250kbps	2013	160	IMU	N/A	N/A	-	16	N/A	N/A	N/A
Aurion ZeroWire	802.15.4	250ksps	2008	4000 Each	ANA Int.	90	1000	1-32	16	10Hz	500,100Hz	Type I
Chang [9]	BT	115.2ksps	2012	2000	NO	60	100x	1	12	30Hz	100Hz	N/A
Youn [10]	BT	115.2ksps	2009	1024	-	N/A	1000	1	16	10Hz	500Hz	
Pluto [11]	802.15.4	250ksps	2005	1000, 100	IMU	85	N/A	1	16	N/A	N/A	N/A
Zhu [12]	ZigBee	250ksps	2011	1024	NO	92		1	16	5Hz	500Hz	N/A
Magno [13]	BT, 802.15.4	256kbps	2013	100	-	N/A	N/A	2	12	Absent	338Hz	N/A
Duan [14]	BLE	115.2ksps	2012	500-32K	-	115		8	24		250Hz	



Previous work assess scenario: Imu + gTEC

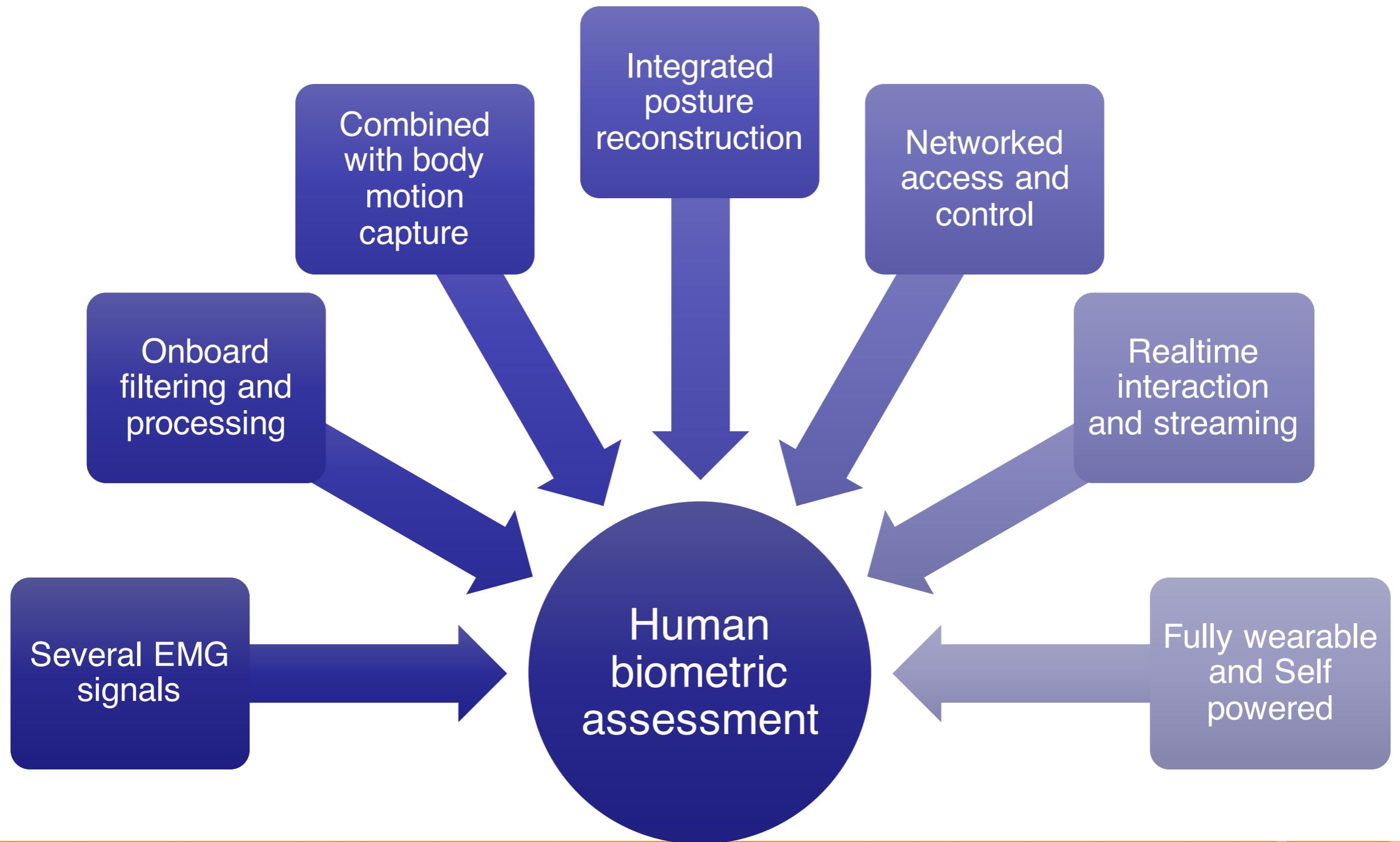


Limitations:

- No sync with IMUs
- Electric anchor
- Reduced number of EMG channels
- Post process analysis
- Non realtime or interactive applications
- Not embeddable or portable to dynamic environment/scenarios



Applications requirements



Design Goal

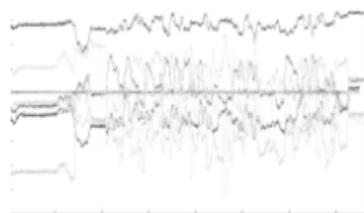
- A novel biometric capture system (BCS) for capture and analysis of motion and EMG signals.
- The system is composed of:
 - An embedded wearable device
 - A modular server



Acquisition board architecture



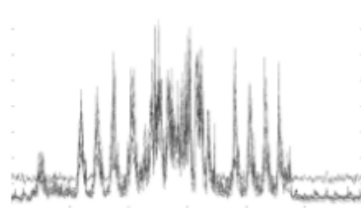
IMU
Signal



EMG
Signal



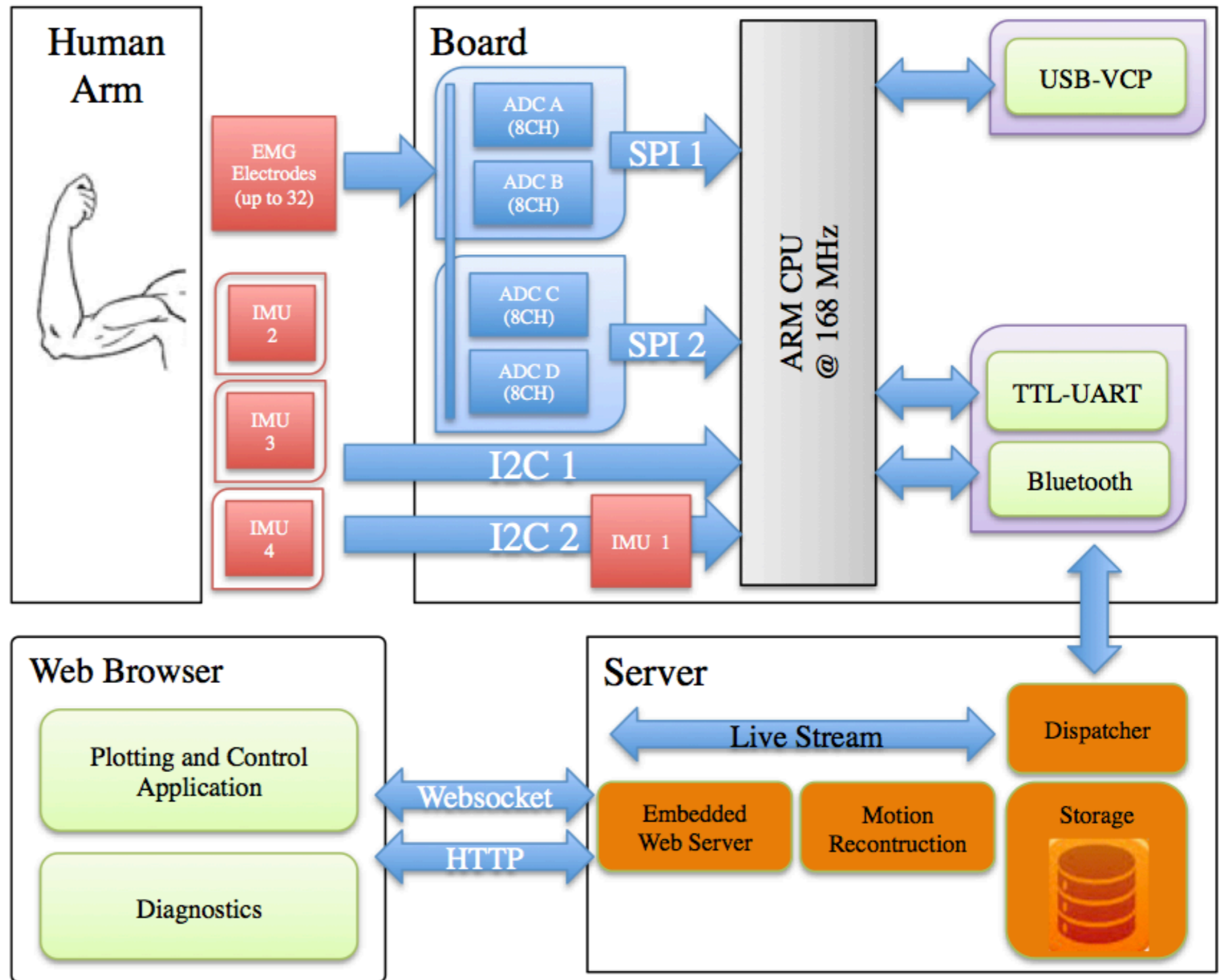
EMG
Features



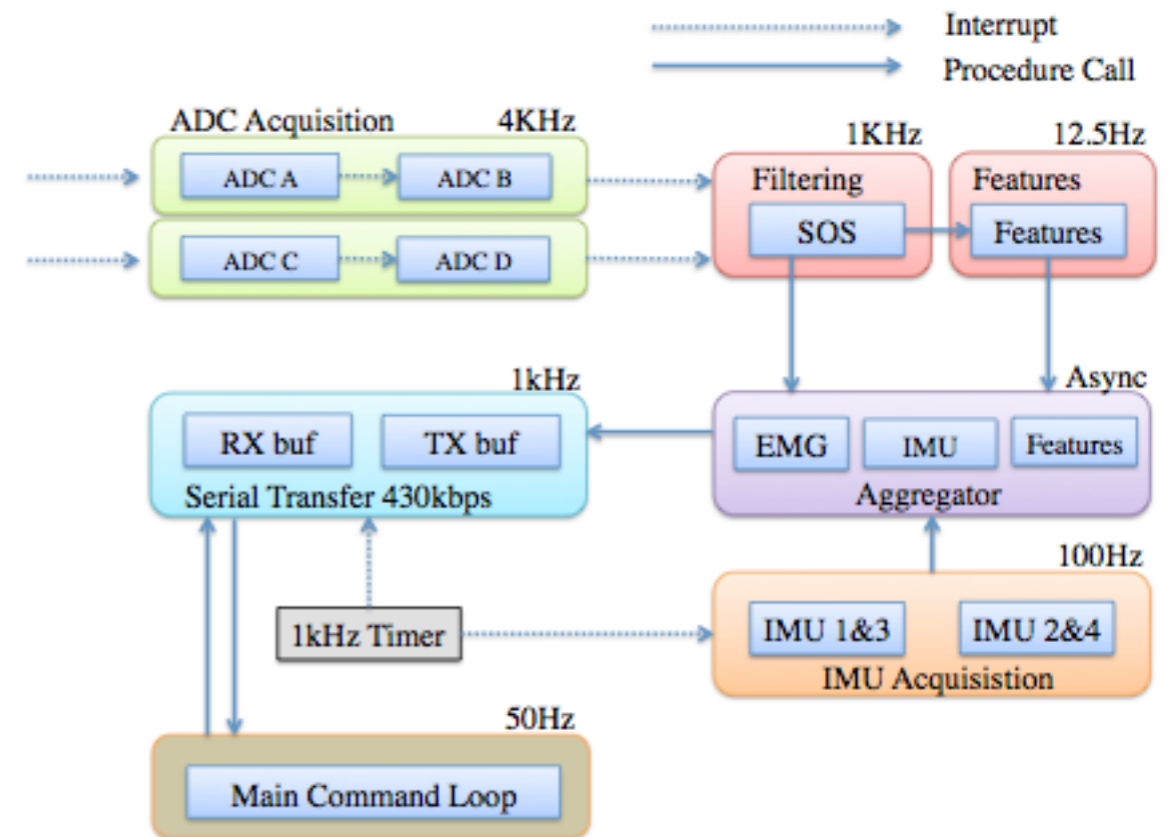
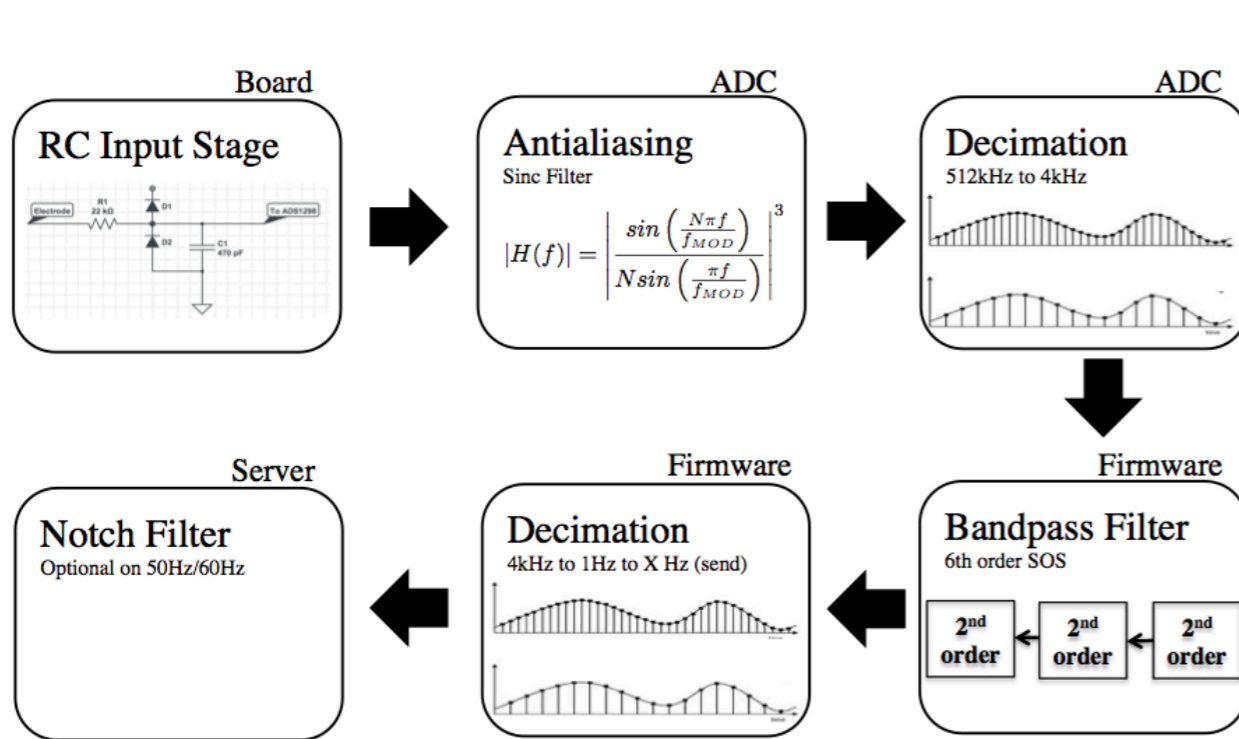
- Dimensions: 5 inches mobile phone
- Processor: STM32F407 (168MHz)
- Nine-axis inertial sensors: 4 (mpu9150)
- EMG: 32 channels (ADSI298)
- Bluetooth (HiSpeed UART transceiver)



Acquisition architecture



Computing architecture



- EMG interface: 32 channels @ 4KHz
- IMU: 100 Hz constant rate (I2C)
- Shared Timestamp for data alignment
- When possible communication is done through DMA

- Internal software filter allow to manage the EMG information accordingly to the common practice in bio-medical application



The featuring subsystem

- The device provides the parallel computation of a wide set of features that can be broadcasted at lower frequencies:

- Mean Square

$$F_{RMS}(K) = \sum_{i=1}^{64} \frac{EMG_{chan}(K * 64 + i)^2}{64}$$

- Average Rectified Value

$$F_{ARV}(K) = \frac{1}{64} \sum_{i=1}^{64} |EMG_{chan}(K * 64 + i)|$$

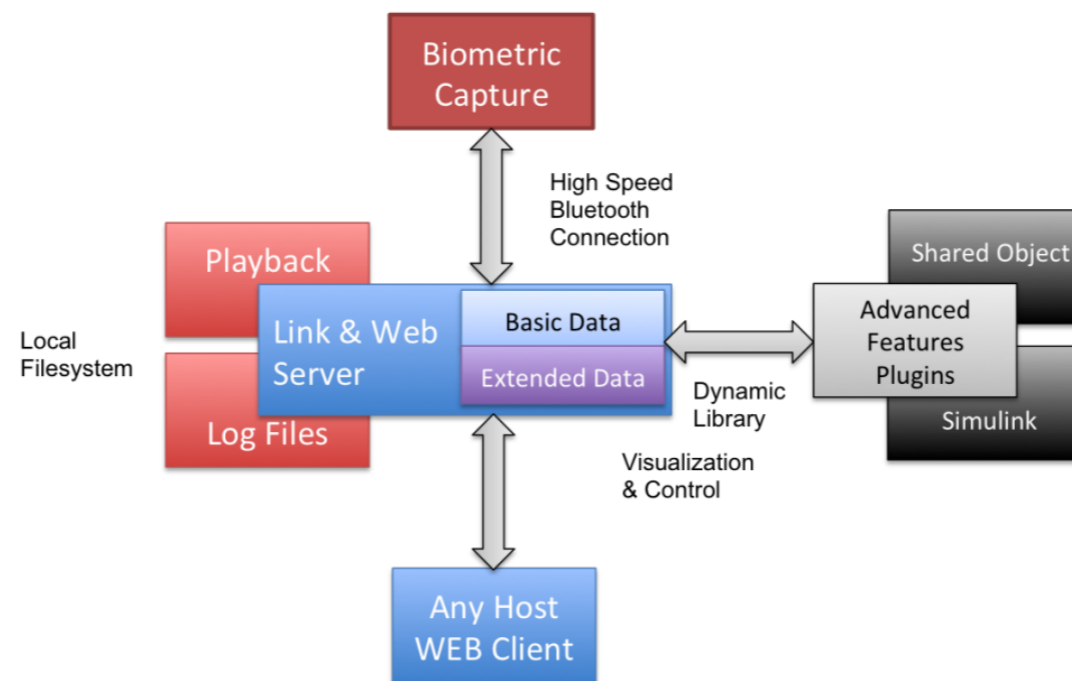
- Number of Zero Crossing

- Number of Peaks



The server software architecture

- The web server serves the incoming Bluetooth connection, decode the data into several streams and make them available as websocket services
- Supports real-time file recording of the received data
- The host server support loading at startup for external plugins.



The web server interface

Completely interoperable among different Oses (OSX, Linux, Android, iOS, Windows)

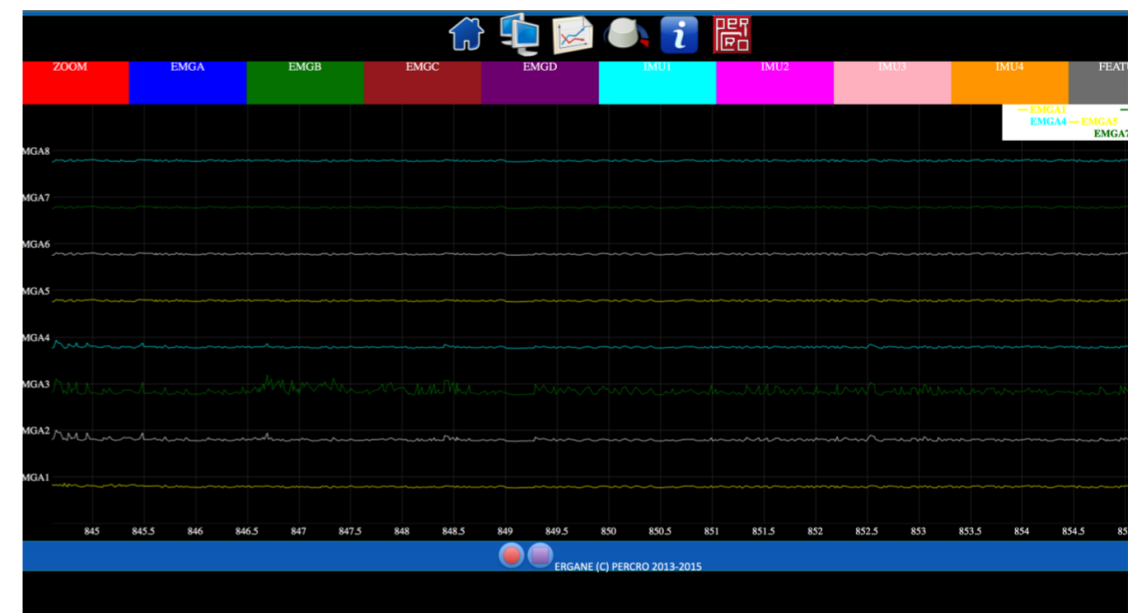
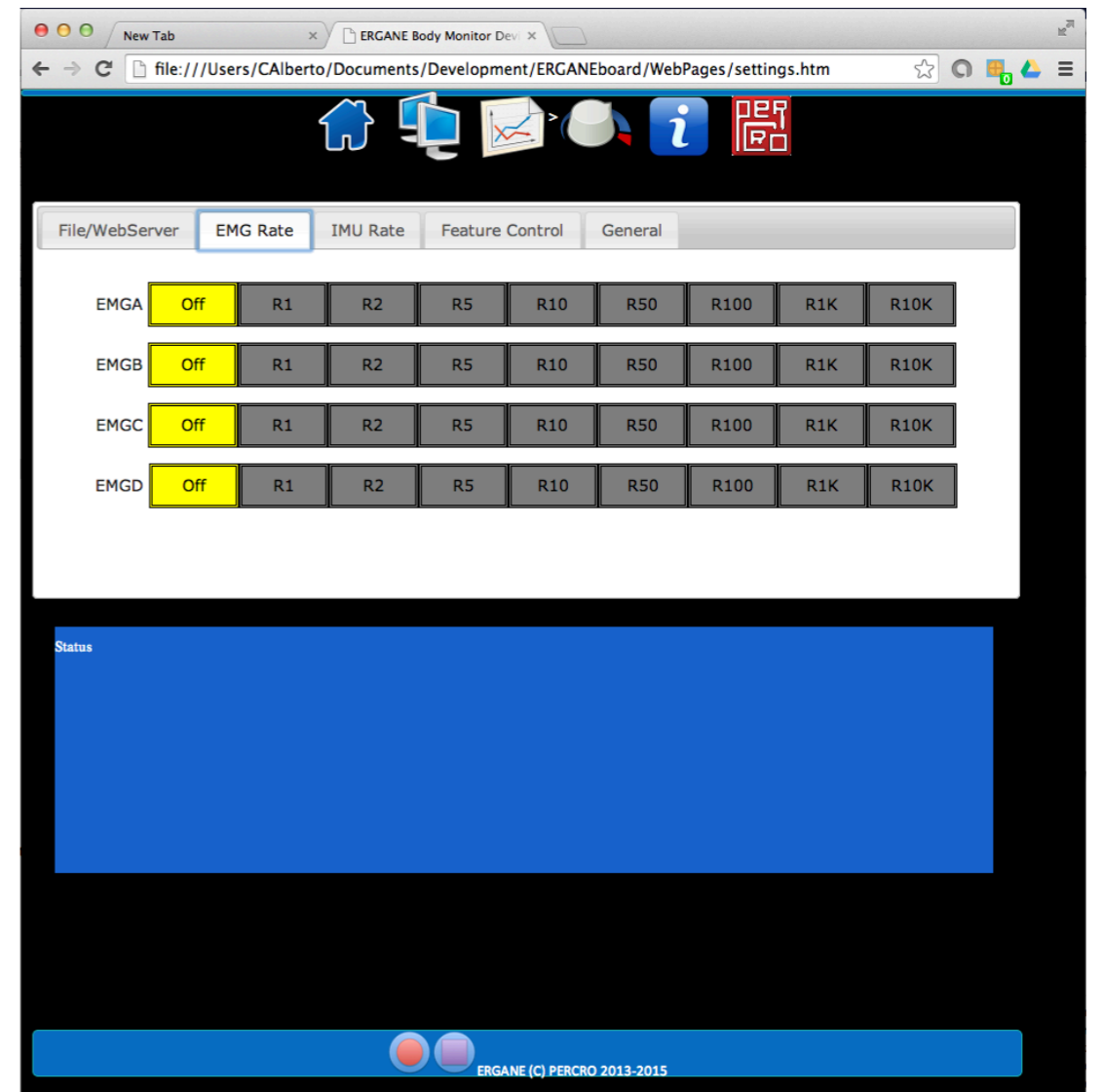
The webserver uses data sharing standards and visualization such as Websockets, WebGL, jQuery and dygraphs JS library (dygraphs.com)

Access and control all data in the board Save and recall experiments.

The device provides a variety of additional information (rapid plots and access to plugin architecture)

IMUs (3D information about linear acceleration, angular velocities and Earth magnetic field)

EMG channels.



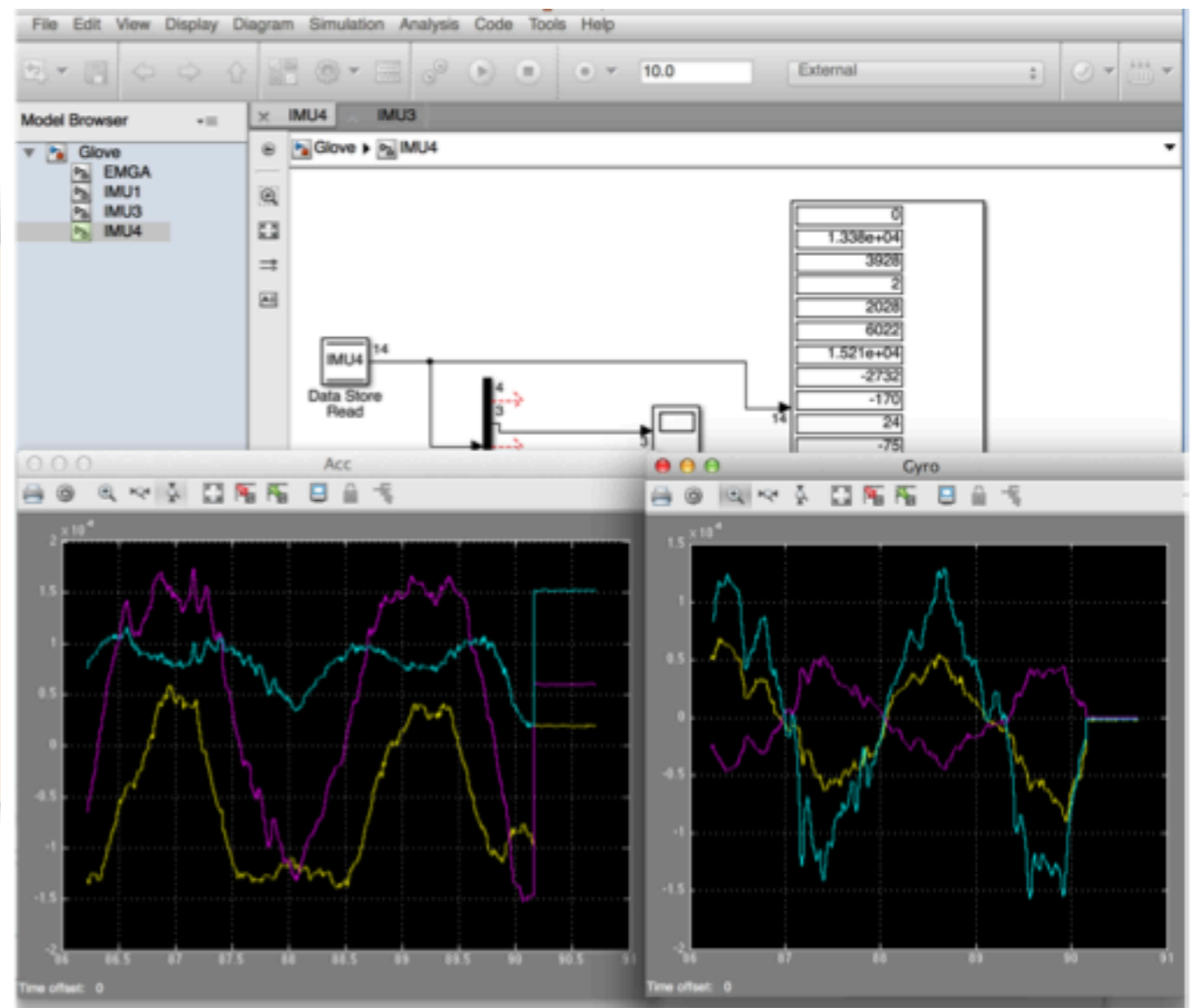
External plugin interface

```
# SET is used to initialize data values
# SET TYPE val
# TYPE can be one of the following (char, uint, ushort, ulong, float)
# The command set can be used to initialize parameters and values
# before plugin starts

# LOAD loads a plugin file extension not required for portability
LOAD mplug/Glove
#LOAD mplug/MatPlug_win64

# CONNECT attach a plugin function to data
# CONNECT demo([inputlist],[outputlist],[paramlist])
#CONNECT Standalone([IMU1, Glove],[Result],[[]])
CONNECT ExtMode([IMU1,IMU3, IMU4, EMGA, Glove],[Result],[[]])

# TRIGGER sets the data update which triggers the plugin hierarchy
# TRIGGER IMU1 (all plugin are called when IMU1 is updated)
TRIGGER IMU1
```



plugins architecture

Initialized through a configuration file with a specific syntax. Load execute external libs with shared data

Define server VS external lib I/O relationships (a lightweight data sharing environment).

Plugins for Matlab-Simulink RTW target:

Simulink can connect to the server in external mode

Simulink can be used to generate standalone models compatible with the server

Any sort of filter plugins may interact:

to further expand the system capabilities with higher level functionalities

skeleton reconstruction, muscular activity, force analysis, complementary or Kalman filters, sensors calibrations, ...



Performance assessment

- The performance of the system are limited by three concurrent factors:
 1. the internal capabilities of the embedded acquisition board
 2. the bandwidth limitation of the wireless communication link
 3. the local capabilities of the server host.
- The processor load is close to 85% with all services running
- We use a recent Bluetooth module which can support transfers up to 760Kbit/s.

Rate (Hz)	Number of Float To Send (4 bytes each)						
	1F	2F	4F	8F	16F	24F	32F
10	400	800	1600	3200	6400	9600	12800
50	2000	4000	8000	16000	32000	48000	64000
64	2560	5120	10240	20480	40960	61440	81920
100	4000	8000	16000	32000	64000	96000	128000
128	5120	10240	20480	40960	81920	122880	163840
200	8000	16000	32000	64000	128000	192000	256000
250	10000	20000	40000	80000	160000	240000	320000
256	10240	20480	40960	81920	163840	245760	327680
500	20000	40000	80000	160000	320000	480000	640000
512	20480	40960	81920	163840	327680	491520	655360
1000	40000	80000	160000	320000	640000	960000	1280000



Integrated system



Conclusions

- We discuss the software architecture and the characteristics of a novel wireless biometric system that aims at providing integrated force and motion capabilities.
- The system is capable of acquiring, filtering and processing:
 - 32 channels EMG signals (4 KHz)
 - 4 IMUs signals (100 Hz)
- The system can be interfaced with a server which exposes a web interface and a plugin architecture to expand system capabilities
- The system is currently being tested in a variety of sectors:
 - Assessment of work injuries performed in ecological conditions [7].
 - Assessing rowers technical capability in indoor and outdoor conditions [8].



thank you!

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References

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