



SAPIENZA
UNIVERSITÀ DI ROMA

Wearable Sensors:

*Smart Autonomous Systems as a **convergence** of multiple
electronic functions and different ICT technologies*

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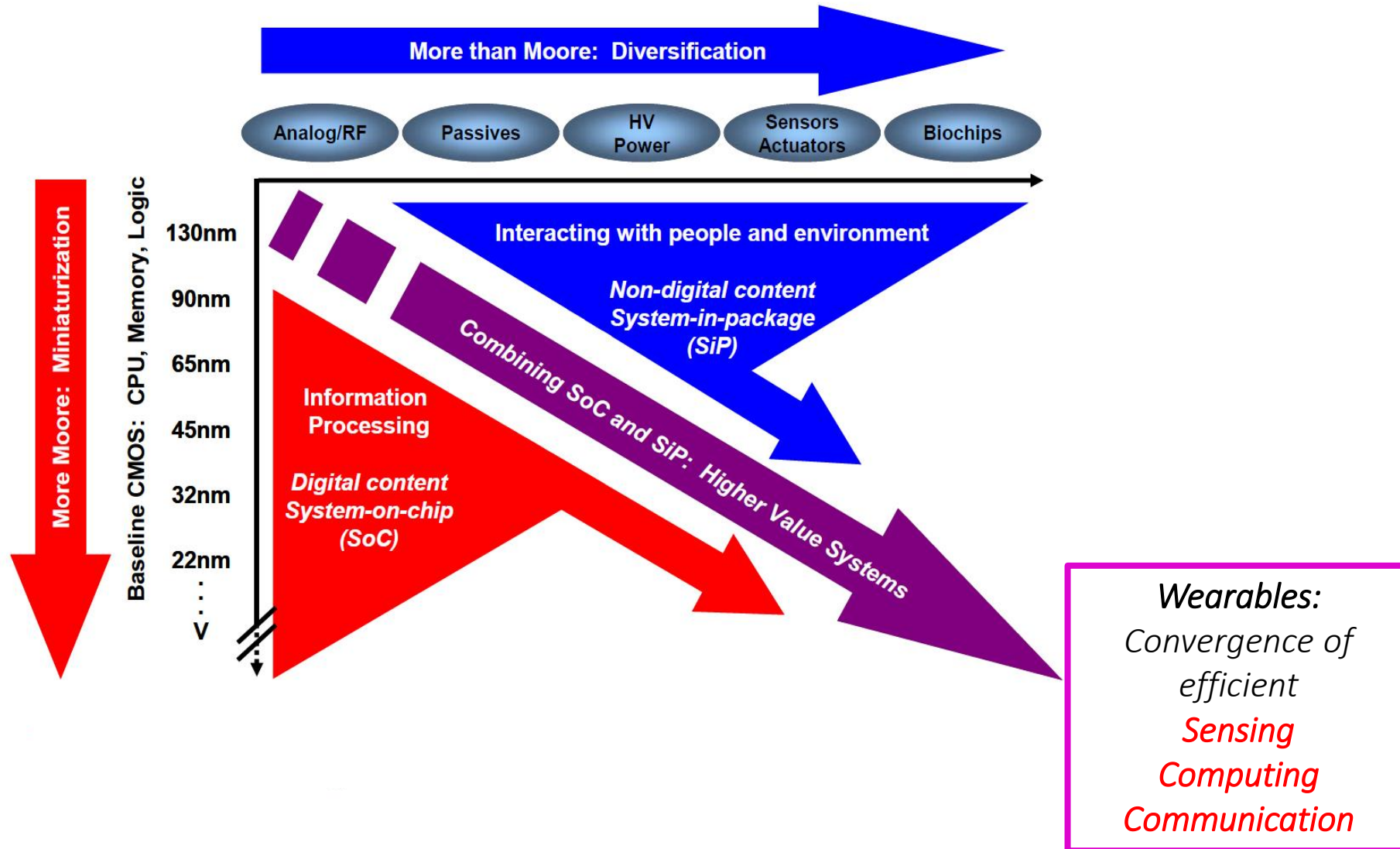


Summary

- Context
- We4PD
- Signal processing
- Results
- Conclusion



The evolution of electronics and the evolution of IUNET





Topic	Acronym and title	Coord.	Countries
High-Efficiency Sensor Networks	CONVERGENCE: Frictionless Energy Efficient Convergent Wearables For Healthcare and Lifestyle Applications	A. IONESCU	CH, BE, EE, FR, IT, LV, TR

		Udine	Bologna	Ferrara	Roma1	
IUNET	Device & Interface modeling	WP1 Modelling and	WP2 simulation			The components
	IC evaluation IC design	WP1 , WP3 Energy management				Power consumption
	Signal Processing Architecture		WP3, WP5 Signal processing, architecture			Computing
	System Test				WP7 Body sensor networks	The whole system
	Networking Dissemination	WP8 Networking and dissemination				

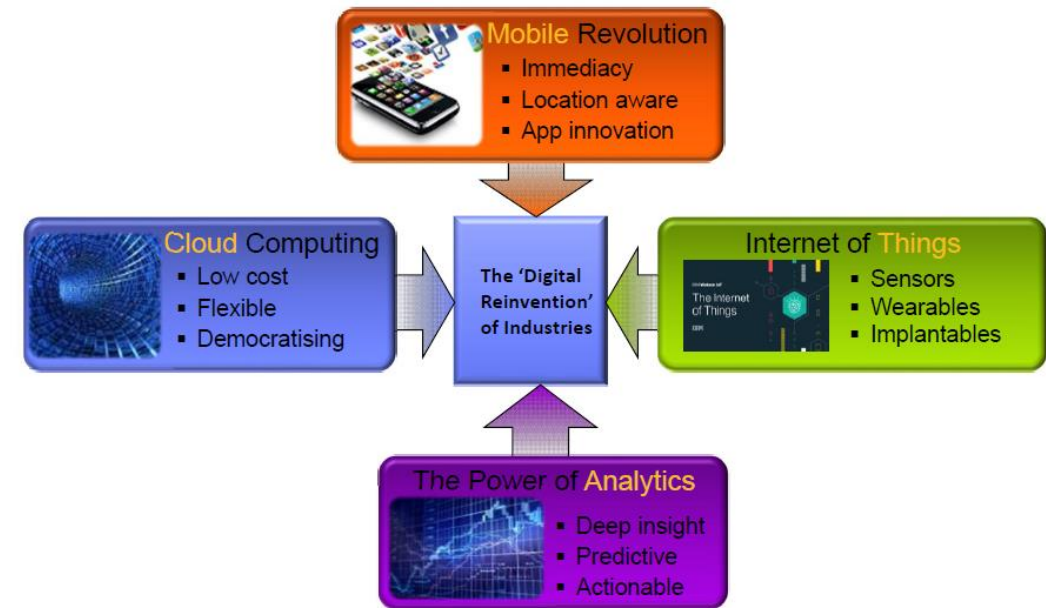
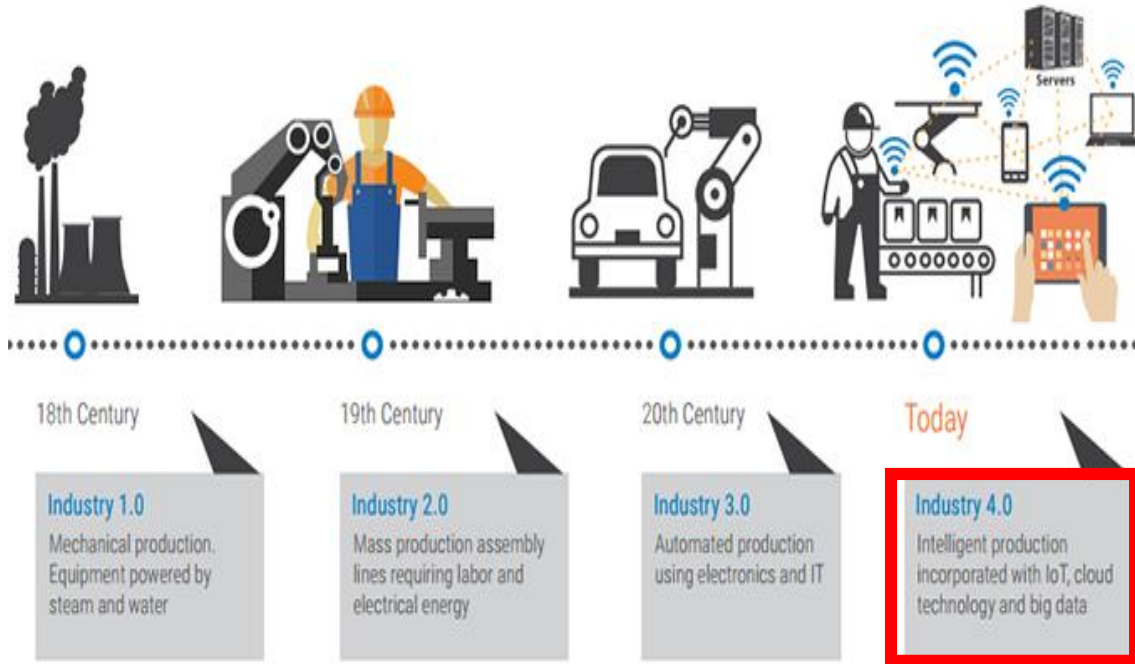
INDUSTRY 4.0 ASSUMPTION

A *hyper-connected Society* where the *Internet of Everything* will generate indefinite *growth and prosperity* by unleashing *digital technological progress*



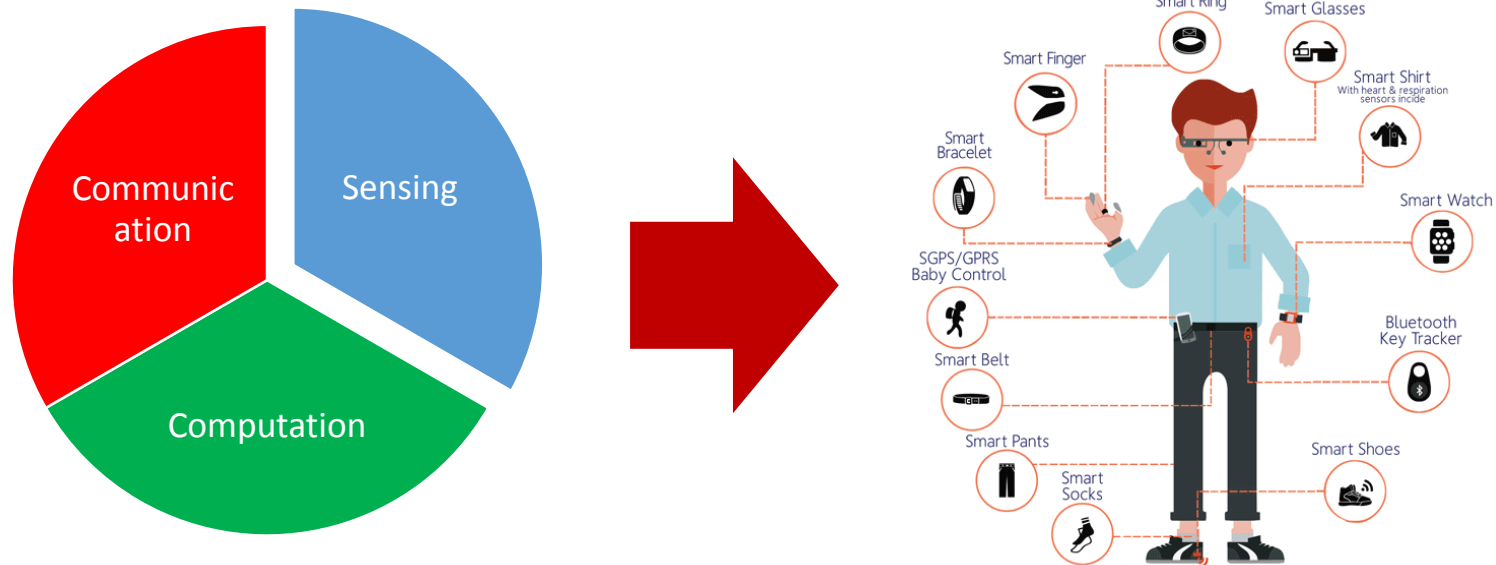
HEALTH 4.0 ASSUMPTION

Distributed, virtual services based on *embedded* and *cyber-physical systems*



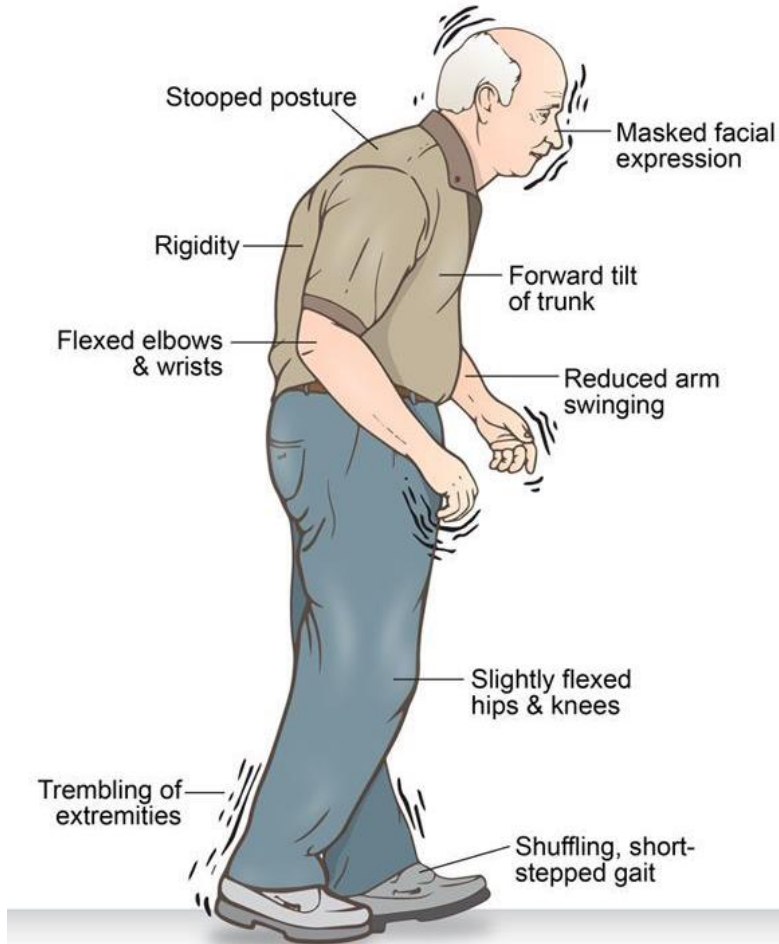
Wearables for healthcare

Smart autonomous systems sensing bio-, physical-, physiological-, environmental- parameters



Wearables for healthcare can represent the solution in all those situations where the *conventional methods* of the National Health Service *cannot be effective*

Parkinson's Disease (PD) - what is it?



©UWorld

It is a progressive disease characterized by a **low level of dopamine**. Dopamine is a neurotransmitter **controlling motion** (and more...)

Motion Symptoms

- Joints rigidity, involuntary movements, tremor, dyskinesia, bradykinesia, akinesia, **freezing of gait (FoG)**, ...
- FoG is a gait disturbance with a transient nature, **interrupting walking**
- FoG increases the **risk of falls**
- **Rhythmic Sensorial Stimulation** may help releasing FoG

Parkinson's Disease (PD) – drug therapy

- Levodopa (L-dopa)



- L-dopa therapy can be very effective if closely customized.

- The not customized drug therapy has severe side effects, worse than the symptoms themselves.

- Long-time monitoring is necessary



We4PD

We4PD: what is it?

It is a smart autonomous sensing system aiming to :

- ✓ Long-time home monitoring (**therapy customization**)
- ✓ Rhythmic Auditory Stimulation (**falls prevention**)



IMU:
3 axis-Accelerometers
3 axis-Gyroscopes
Microcontroller
BT comm. module
Power supply circuits
Li Battery



**Just two sensors
on the shins**

It can be recharged during the night



Summary

- Context
- We4PD
 - ✓ Outdoor use
 - ✓ Indoor use
- Signal processing
- Results
- Conclusion

We4PD: outdoor

Headset



On the shins



Portable receiver

We4PD: outdoor

- Operates in Real Time.
- *We4PD* recognizes FoG and provides a **rhythmic auditory-feedback** to the patient at FoG onset. **It may send a message** to caregivers.

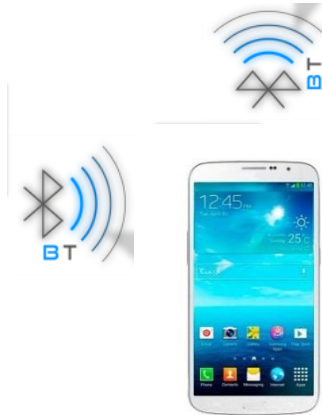


We4PD: indoor

Headset



On the shins



Portable receiver

Lan-Wifi



Wifi



Home PC

We4PD: indoor

- Operates as an Electronic Diary.
- We4PD collects **lots of informations along the day**, makes off-line processing, statistics, (creates an avatar), connects **remotely** doctors, caregivers, relatives in a cloud.

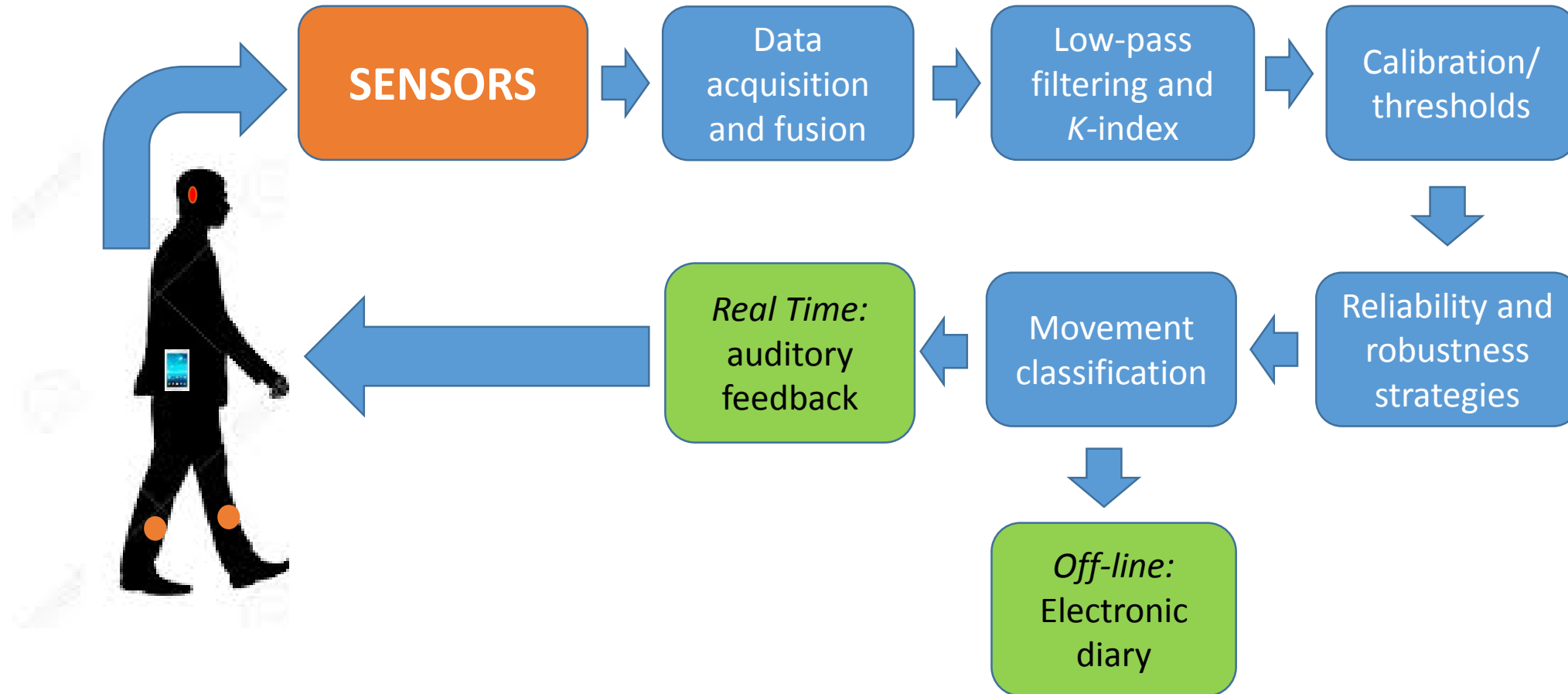




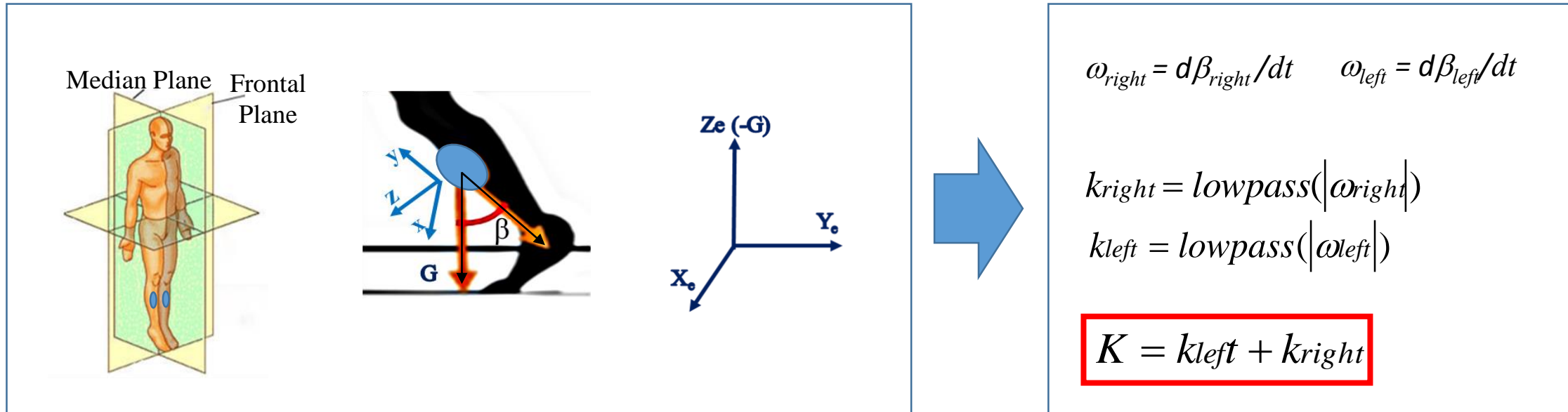
Summary

- Context
- We4PD
- **Signal processing**
- Results
- Conclusion

Signal processing

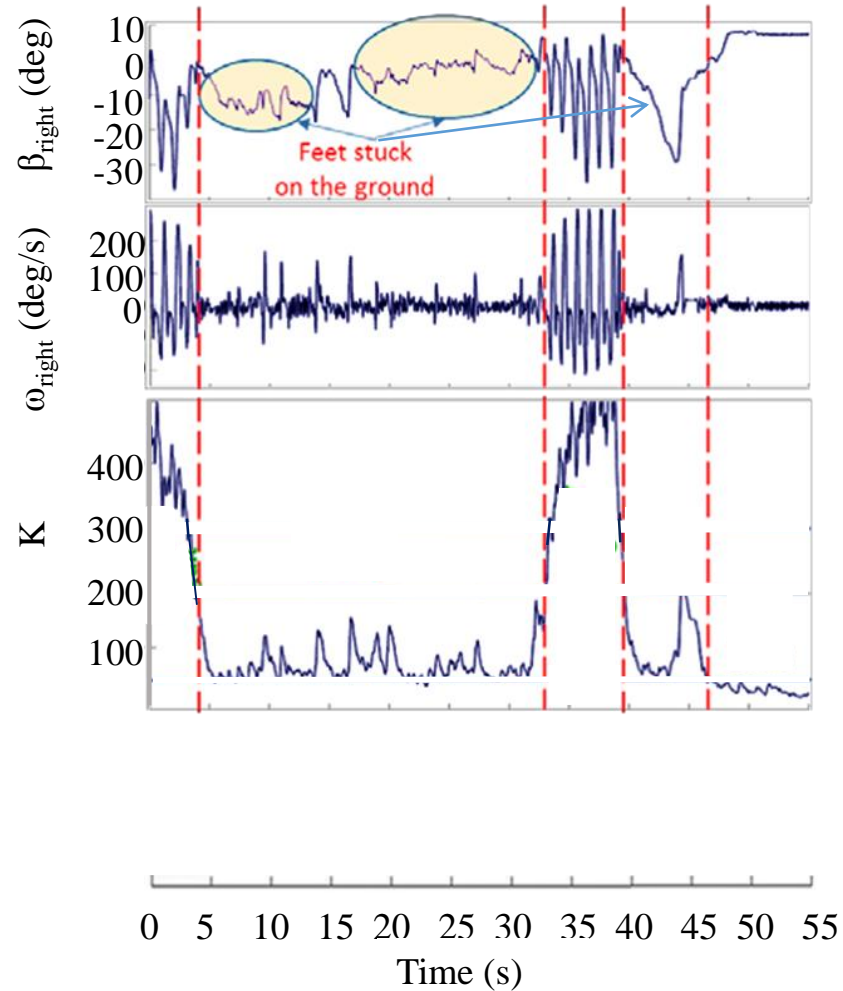
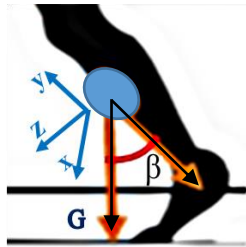


Data acquisition and fusion: The framework

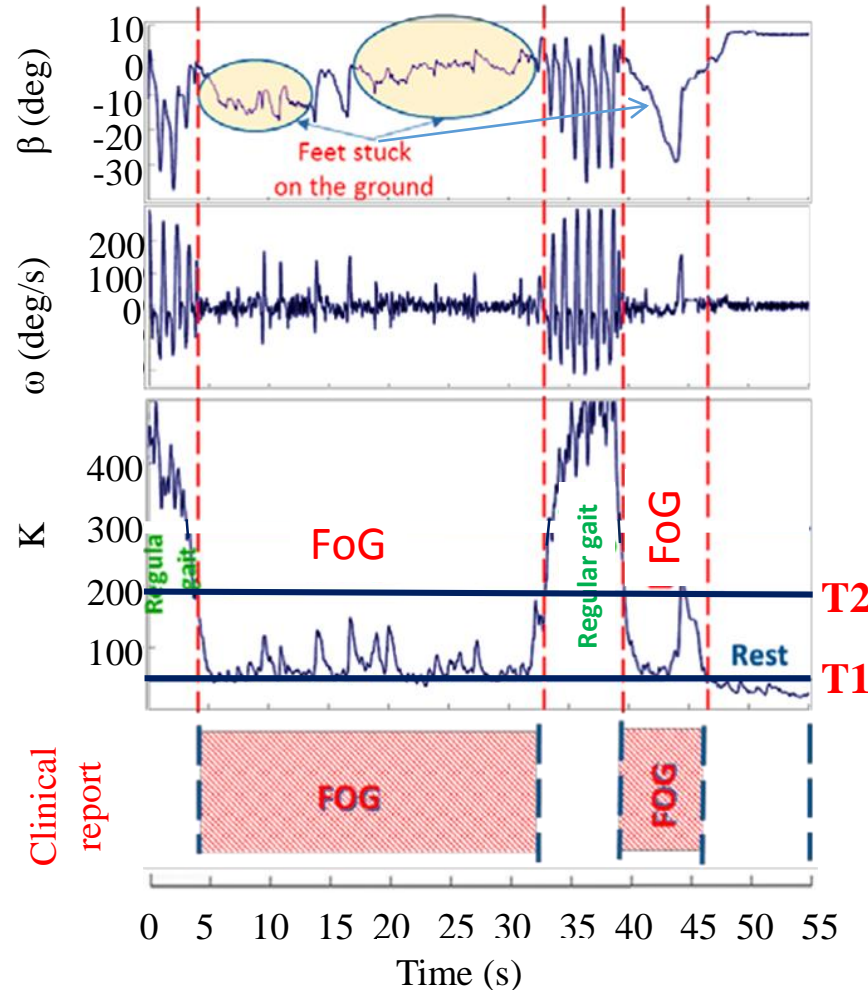


The sensor reference system x - y - z rotates in the earth system X_e - Y_e - Z_e
The *fusion* between accelerometer and gyroscope allows to calculate β

Low-Pass filtering and K index: Typical traces



Classification of 3 states with 2 thresholds



Thresholds are defined by comparison with the clinical report



Summary

- Context
- We.SensPD
- Signal processing
- **Results**
 - The trial
 - FoG detection
 - The electronic diary
- Conclusion



The trial

- 45 PD patients between 50 and 80, male and female, 290' recording time
- After L-dopa: **ON**
- Before L-dopa: **OFF**
- Time=0 and Time= + 6 months
- 9 healthy control group



FoG detection: performance

Our system	Sensitivity %	Specificity %
average values over 45 patients & 290' rec. time	93.3	98.4
average values over 9 healthy control group		98.4

Performance evaluated on the episode *duration*, not on the episode *occurrence*



FoG detection: performance

Our system	Sensitivity %	Specificity %
average values over 45 patients & 290' rec. time	93.3	98.4
average values over 9 healthy control group		98.4

6.7% false negative

1.3% false positive

- Best performance in FoG detection published in literature to date

Performance evaluated on the episode *duration*, not on the episode *occurrence*



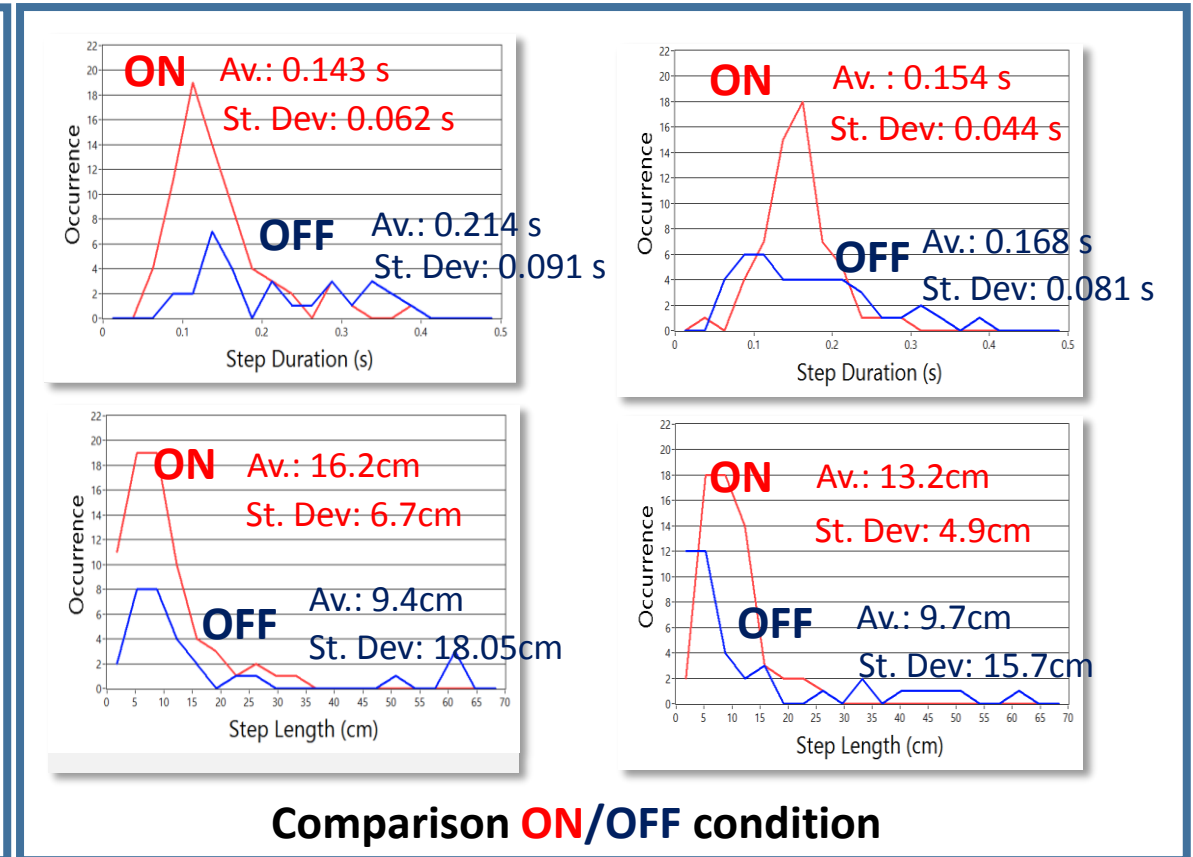
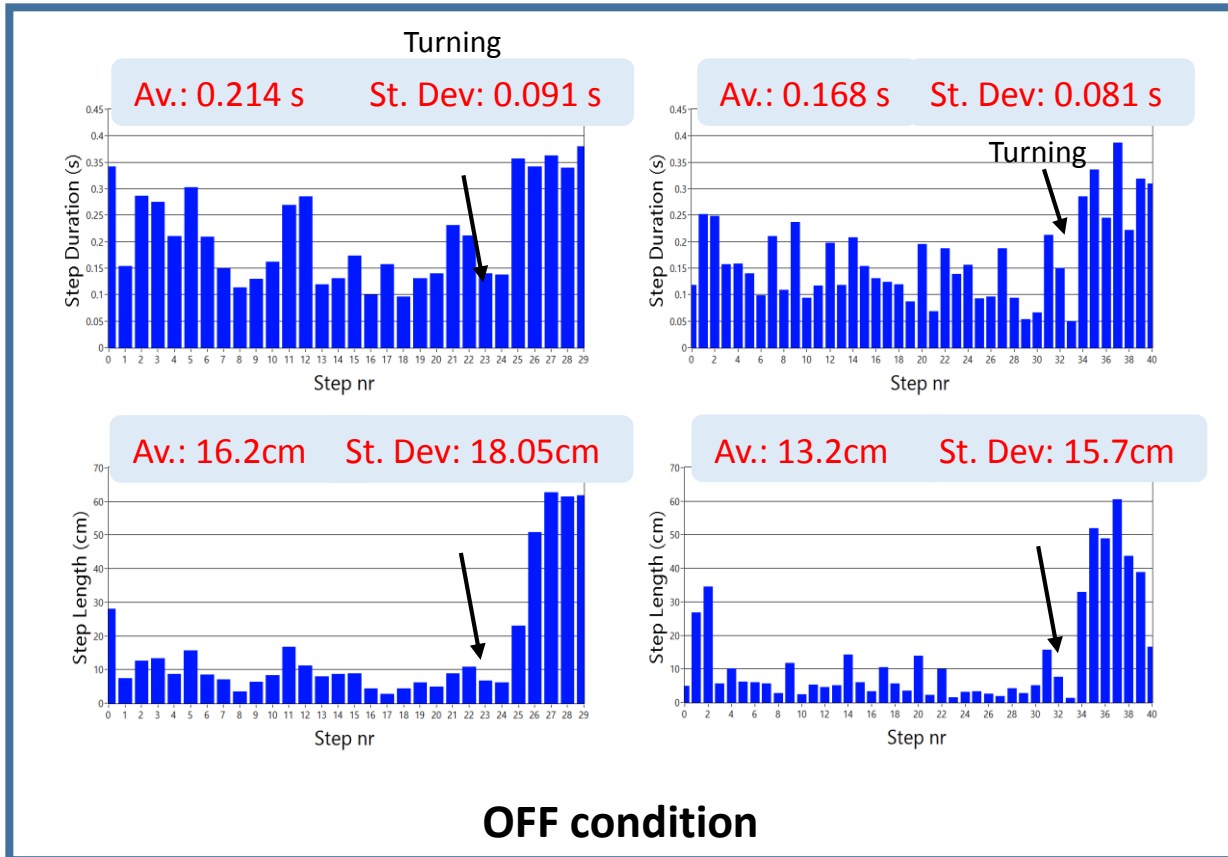
The electronic diary: statistics on pace features (patient C.B.)

Left Leg

Right Leg

Left Leg

Right Leg





The electronic diary: effect of drug in time (patient C.B.)

time=0	Average step length	ST. Dev. step length	Average step duration	ST. Dev. step duration
Ratio ON/OFF	1.72	0.37	0.67	0.68

6 months later	Average step length	ST. Dev. step length	Average step duration	ST. Dev. step duration
Ratio ON/OFF	1.56	0.48	0.76	0.87



Conclusions

- We4PD: a smart autonomous sensing system for long-time assistance of PD patients
- Just two IMU on the shins
- Operates in real time and activates an auditory feedback in the case of involuntary block
- Realizes an electronic diary of the patient and a database for any purpose

Special thanks to the patients

