A Surface Electromyography-Based Platform for the Evaluation of Sarcopenia

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Information about the author

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Andrea Caroppo received the Master's Degree in Computer Science Engineering in 2004 from the University of Lecce. From 2004 to 2006 he was researcher fellow at the Italian National Research Council (CNR), Institute of Study of Intelligent Systems for Automation (ISSIA) in Bari (Italy). His research interests were in the area of image and video processing/coding, neural networks, motion estimation in video sequences and multi-dimensional signal processing.

From 2012 to 2017 he was researcher fellow at the Italian National Research Council (CNR), Institute for Microelectronics and Microsystems (IMM) in Lecce (Italy). Since 2018 he is researcher in the same Institute. He is interested in signal and image processing, pattern recognition, computer vision and development of enabling technologies for healthcare with particular focus on the new Ambient Assisted Living (AAL) technologies.

He is author of more than 40 papers in national and international journals and conference proceedings.

Introduction and Motivation (1/3)

WHY: Sarcopenia is a disorder characterized by a loss of muscle mass and muscle strength → Long term monitoring of patients at risk of developing sarcopenia to detect early its onset or progression through objective and specific indicators

OBJECTIVES: Design and implementation of an integrated platform that includes a sEMG based wearable device and interfacing with a processing software for clinical monitoring and management of the pathology

Introduction and Motivation (2/3)

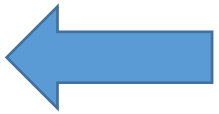
- A serious change associated with aging is the progressive decline in muscle mass
- In 1989 Rosenberg proposed the term 'sarcopenia' to describe this age-related reduction in muscle mass **[1]**
- Sarcopenia produces a deterioration in physical functions and means postural instability, alterations of thermoregulation, worse bone trophism, modification of glucose homeostasis, reduction of basal energy production

Sarcopenia is very difficult to treat because it is not easy to evaluate the temporal trend of its three fundamental components:

1) muscle strength
2) muscle mass
3) physical performance such as walking speed

different non-invasive gold standard techniques

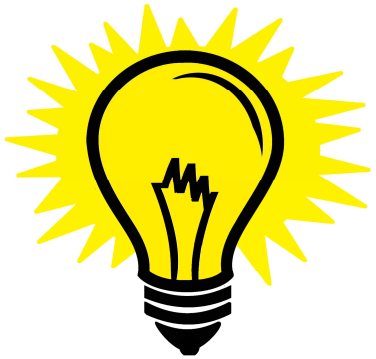
- Dual Energy X-ray Absorptiometry
- Magnetic Resonance Imaging
- Computed Tomography



rarely used in practice due to:
- lack of portability
- high equipment costs
- highly trained medical personnel for the use

[1] Rosenberg, I. H. (1989). Summary comments: epidemiological and methodological problems in determining nutritional status of older persons. The American journal of clinical nutrition, 50(5), 1231-1233.

Introduction and Motivation (3/3)



Creation of innovative and unobtrusive systems supporting diagnosis and monitoring of patients affected by sarcopenia

SMART TECHNOLOGIES (HEALTHCARE FIELD)

Wearable Devices

Mobile Apps

Embedded systems

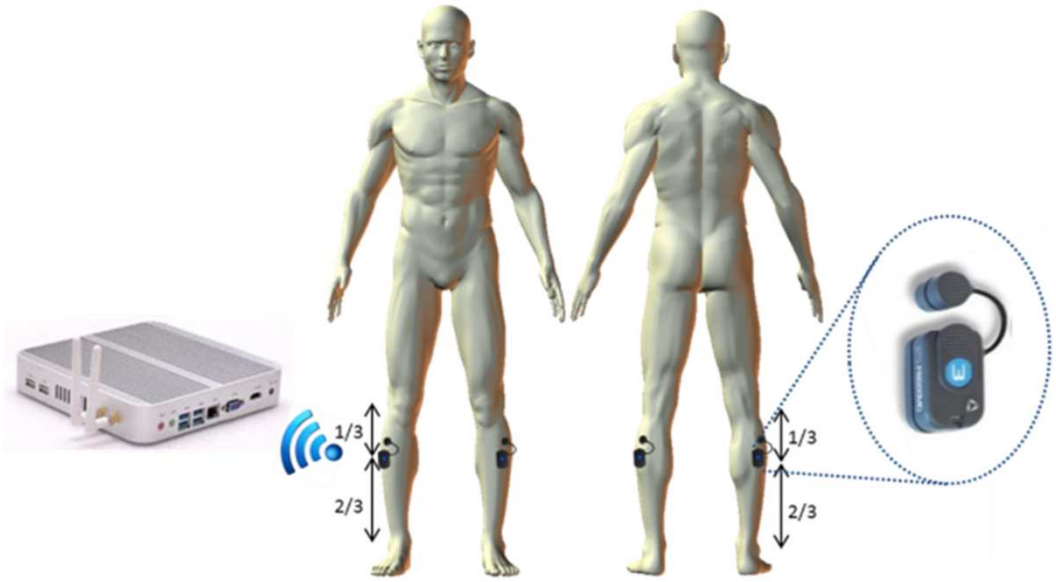
Use of surface EMG (**sEMG**) as non-invasive measurement for monitoring muscle fatigue among the physiological measurement systems

Widely used for the analysis of specific pathologies, but very few works in literature have focused their attention on the use of sEMG for monitoring/evaluating sarcopenia

Overview of the proposed EMG-based platform for the measurement and management of sarcopenia (1/3)

Overall system based on two main components:

1) hardware able to detect all sarcopenia-related parameters
2) software able to process data coming from the hardware component (sEMG), storing them and making them available to the end user

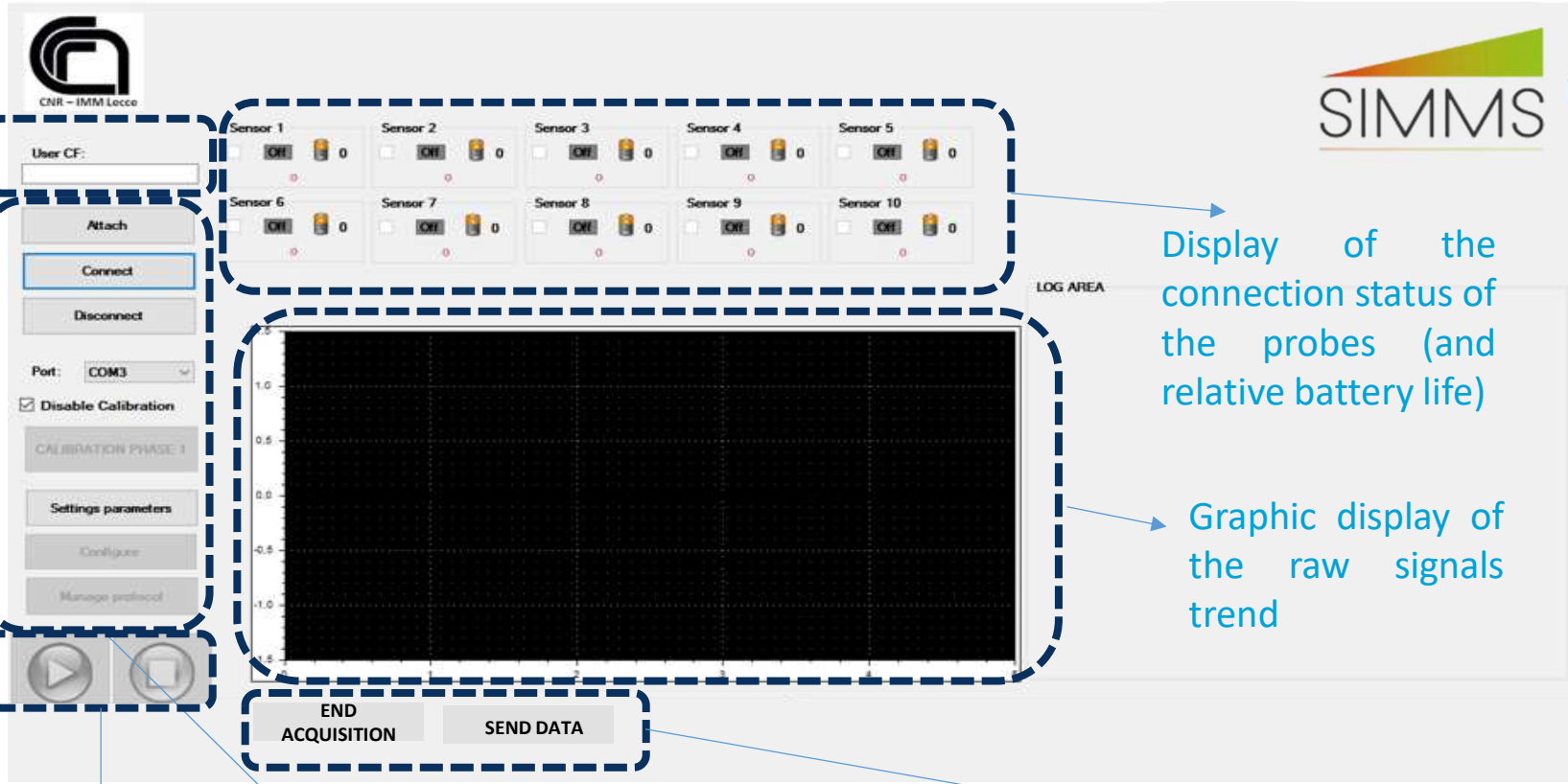


Overview of the proposed EMG-based platform for the measurement and management of sarcopenia (2/3)

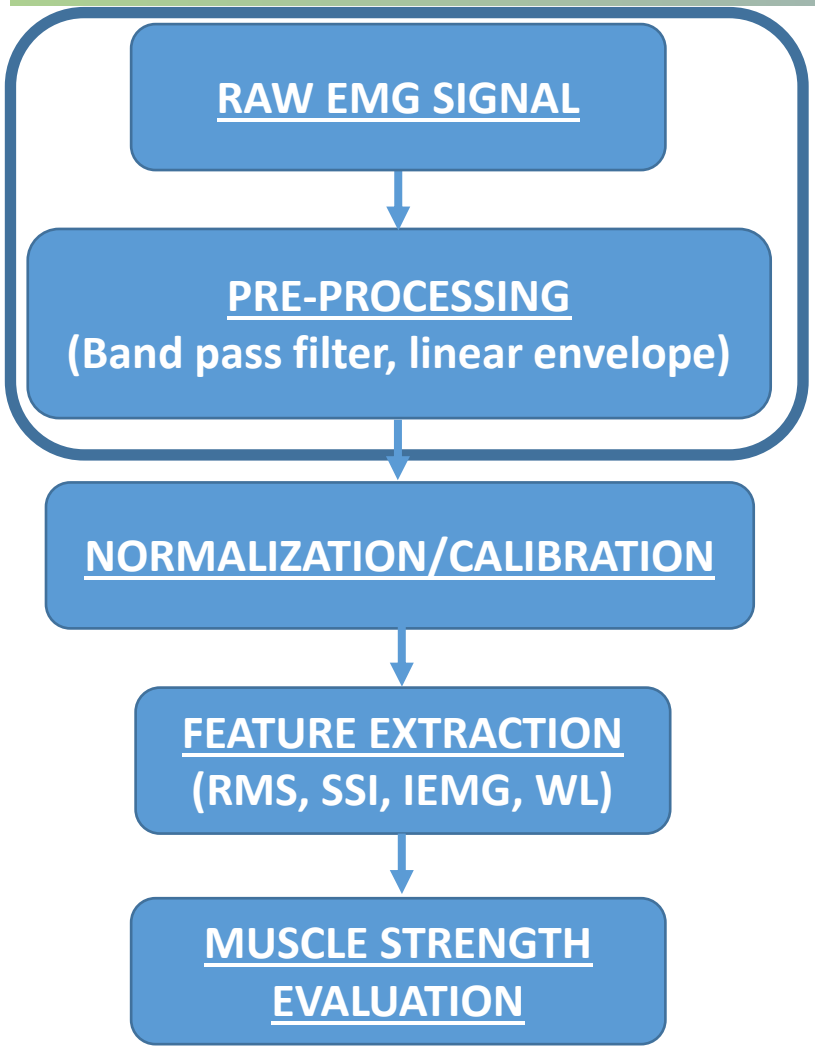
EMG probes main features

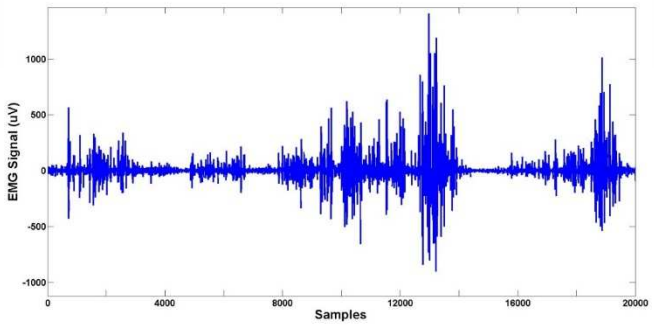
Surface Electrodes	Variable geometry electrodes with snap connectors
Resolution	16bit
Acquisition Frequency	1kHz
Data Transmission	Wireless IEEE 802.15.4
Battery	LiPo battery, rechargeable with proprietary charger
Battery Life	Over 6 hours of continuous acquisition
On-board Memory	Solid-state memory - up to 2 hours
Weight	About 13 grams - battery included
Dimensions	41,5×24,8x14mm mother electrode – Ø 16x12mm satellite electrode
Certification	CE Class IIa, FDA registration

Overview of the proposed EMG-based platform for the measurement and management of sarcopenia (3/3)

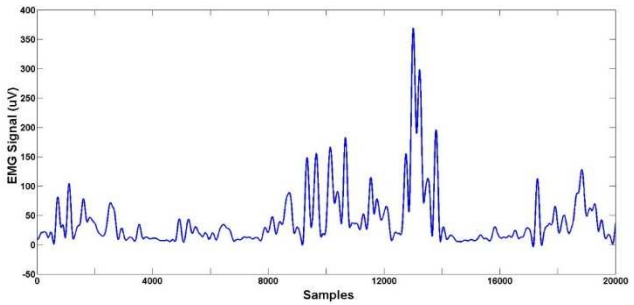


Algorithmic pipeline for the evaluation of sarcopenia (1/2)

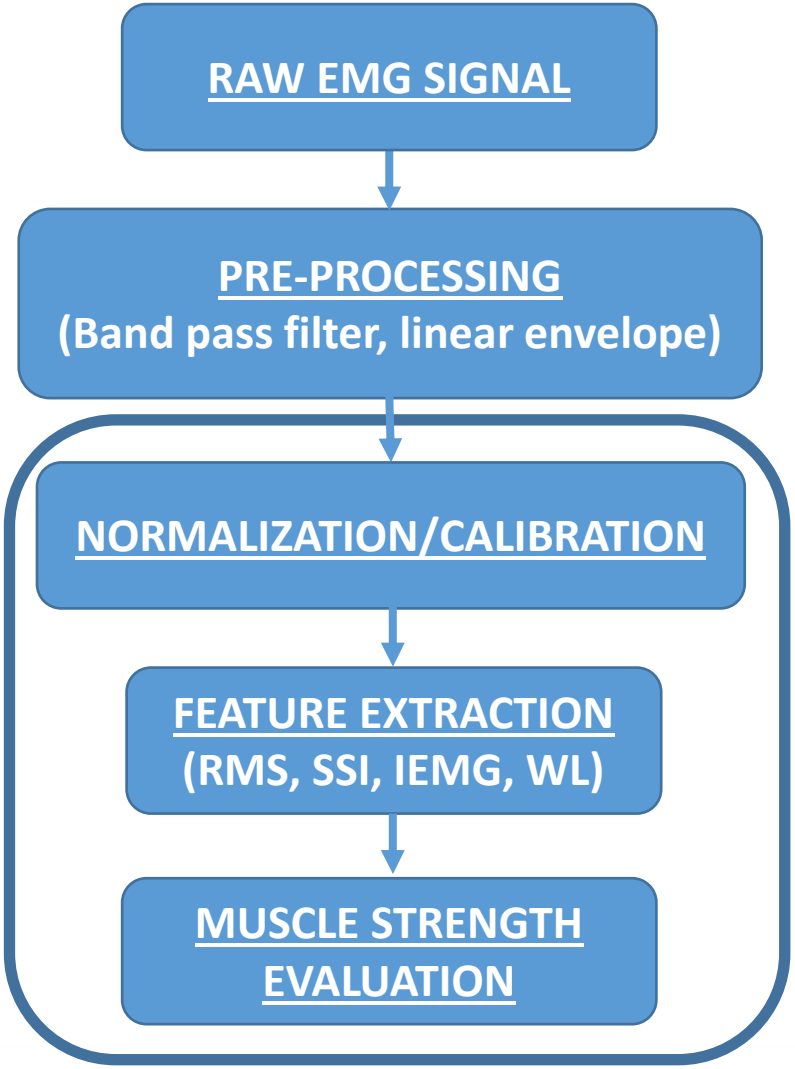




- application of a bandpass filter within 20–450 Hz
- full wave rectification and linear envelope
- 10th order low-pass Butterworth filter



Algorithmic pipeline for the evaluation of sarcopenia (2/2)



3 stages normalization:

1) the user is required to remain in idle condition for 5 seconds
2) the user executes the ankle plantar flexion against a fixed resistance and holds for 5 seconds
3) the user executes the ankle dorsi flexion against a fixed resistance and holds for 5 seconds

Extraction of low-cost time-domain features

$$WL = \sum_{i=1}^{N-1} |EMG_{i+1} - EMG_i| \qquad IEMG = \sum_{i=1}^{N} |EMG_i|$$

$$SSI = \sum_{i=1}^{N} |EMG_i|^2 \qquad RMS = \sqrt{\frac{\sum_{i=1}^{N} EMG_i^2}{N}}$$

Results (1/2)

The hw/sw platform has been implemented within the SIMMS project (Sarcopenia Integrated Measurement and Management System)

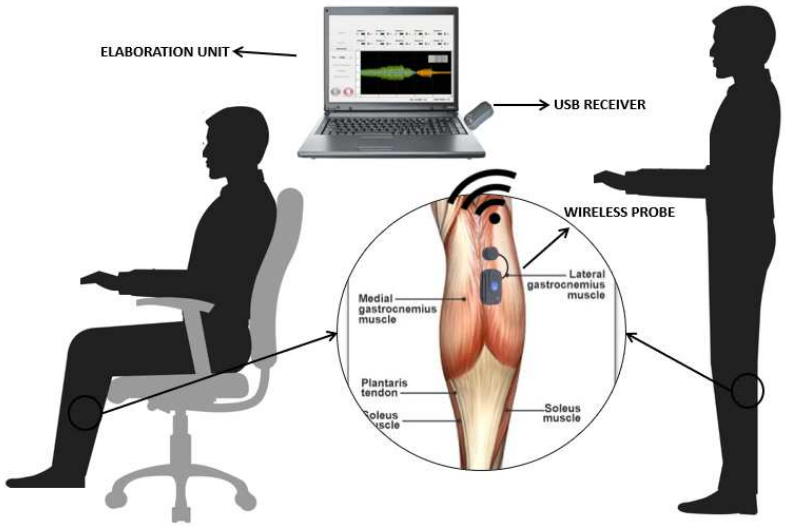
Validation in controlled environment (laboratory @ CNR-IMM in Lecce)

Gender	Age (years)			
	(29-47)	(48-64)	(> 65)	Total (29-73)
Male	4	3	2	9
Female	2	2	2	6
Total	6	5	4	15

Two tests:

1) walking test
2) sit-to-stand test

The walking test consisted of the user being monitored in the execution of a 5-meter journey, whereas sit-to-stand is commonly used in clinical context for evaluating lower limb muscle function



Results (2/2)

First experiment: mean and variance evaluation of the extracted features with different sample rates

WALKING TEST

Sampling Rate	Feature			
	RMS	SSI	IEMG	WL
250Hz	0.36 (0.07)	13.01 (3.88)	36.05 (5.23)	0.12 (0.06)
500Hz	0.56 (0.04)	31.57 (2.90)	56.18 (2.52)	0.26 (0.03)
1000Hz	0.58 (0.03)	35.33 (2.78)	59.43 (2.38)	0.28 (0.02)

SIT-TO-STAND TEST

Sampling Rate	Feature			
	RMS	SSI	IEMG	WL
250Hz	0.87 (0.11)	22.09 (5.78)	52.18 (6.55)	0.86 (0.10)
500Hz	1.16 (0.07)	43.12 (4.19)	71.34 (4.11)	1.33 (0.08)
1000Hz	1.19 (0.05)	49.19 (3.53)	76.21 (3.78)	1.47 (0.05)

Second experiment: evaluation of the time interval required to extract the features with different sample rate and as the duration of the exercise changes

Sampling Rate	Walking test duration			
	30 sec	60 sec	90 sec	120 sec
250Hz	0.848 s	1.345 s	1.786 s	2.124 s
500Hz	1.112 s	1.732 s	2.203 s	2.568 s
1000Hz	1.121 s	1.918 s	2.413 s	2.834 s

Clinical protocol for validation

The initial 6-month test phase was reduced to approximately 2 months and will be performed at Casa Sollievo della Sofferenza Hospital in San Giovanni Rotondo (Lecce, Italy)

- randomized cohort of 100 patients aged ≥ 65 years and at risk or suffering from sarcopenia (i.e., ADL ≥ 4 and SARC-F ≥ 4), either admitted to the Geriatrics Operational Unit or evaluated at the Geriatrics clinic.

- The assessment of sarcopenia will be carried out according to the EWGSOP2 guidelines **[2]**

Muscle strength, Muscle mass and functional status will be determined

EMG PLATFORM

TOTAL BODY SKELETAL MUSCLE MASS (SMM)
APPENDICULAR SKELETAL MUSCLE MASS (ASM)

[2] Cruz-Jentoft, A. J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., ... & Zamboni, M. (2019). Sarcopenia: revised European consensus on definition and diagnosis. Age and ageing, 48(1), 16-31

Conclusions

- First tentative to evaluate sarcopenia-related parameters using EMG as wearable devices
- Development of a novel sEMG platform to provide phisician or caregivers with a decision support tool to evaluate in an innovative way the temporal evolution of sarcopenia
- Possibility to send all collected information to a third-party software platform through an app developed on smartphones for patients and/or caregivers

FUTURE WORKS

- Validation of the platform and evaluation of other sarcopenia-related parameters
- Extrapolation of possible correlation on time series of the extracted features
- Statistical analysis on time series with the aim to try to implement an intelligent and automatic tool for early diagnosis of the considered pathology

THANK YOU

for the attention