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The BITMAP exercise – a multi-laboratory performance assessment campaign of diffuse optical instrumentation

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ABSTRACT

Performance assessment of instruments is a growing demand in the diffuse optics community and there is a definite need to get together to address this issue. Within the EU Network BITMAP[1], we initiated a campaign for the performance evaluation of 10 diffuse optical instrumentation from 7 partner institutions adopting a set of 3 well accepted, standardized protocols. A preliminary analysis of the outcome along with future perspectives will be presented.

Keywords: performance assessment, standardization, diffuse optics, near infrared, absorption, phantom, scattering

1. INTRODUCTION

Diffuse optics (DO) or near infrared spectroscopy (NIRS) is the basis for different instrumentation in the field of biomedical diagnostics. To improve reliability in a clinical scenario, thorough performance assessment is a must. This is achieved using tissue mimicking phantoms implementing specific features of the clinical problems under study. Protocols with standardized guidelines for DO have been designed in the past by different networks[2–4]. One the other hand, multi-laboratory efforts to characterize and compare instruments with shared protocols could lead to a more reliable assessment and ultimately aid in the development of standardized figures of merit for the community at large.

In the framework of the EU Network BITMAP, we undertook a large exercise aiming at fostering the culture of performance assessments in biophotonics, as highlighted also recently in the framework of an EU workshop on Performance Assessment and Standardization held at European Commission premises[5]. The whole exercise is divided into 3 actions. Firstly, a set of tests from 3 well accepted protocols, namely, the MEDPHOT[2], the BIP[3] and the nEUROPt[4] protocol, along with the phantoms necessary for their implementation were circulated to the different labs enrolled in the study and the instruments were assessed using the tests. The second action is aimed at deploying all data collected during this exercise into an open data repository. Finally, the third action aims at cross analyzing all the collected data using the different algorithms and techniques available in DO. This would help understand the effect of the data analysis on the overall performance of the instrument. At this level, the first action has been successfully completed and some of the initial results will be presented here.

2. INSTRUMENTATION

Ten instruments belonging to seven institutions in Europe were enrolled for this exercise. Instruments varied widely in terms of technological readiness level, application and technique (CW- continuous wave, TR – time resolved and FD – Frequency Domain). A brief description of the instruments and institutions involved has been presented in Table 1.

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Table 1. Instruments enrolled. #det = number of parallel detector channels and TRL = Technology Readiness Level of the instrument under test (e.g. TRL3 = component/subsystem, TRL4 = laboratory prototype, TRL5 = clinical prototype, TRL6 = clinical system already demonstrated in clinics, TRL8 = commercial clinical device)

No.	Institution	Instrument	Technique	Application	TRL	λ[nm]	#det
1	POLIMI[a]	clinical spectrometer	TR	spectrometer	5	600-1100	1
2	POLIMI[a]	large area detector stage	TR	oximeter	3	670,830	1
3	PTB[b]	laboratory system	TR	spectrometer	4	670,750,830	2
4	UHB[c]/UoB[d]	NIRO 200NX	CW	oximeter	8	735,810,850	2
5	UHB[c]/UoB[d]	ISS OXIPLEX-TS	FD	oximeter	8	690,830	4
6	UHB[c]/UoB[d]	ISS IMAGENT	FD	oximeter	8	690,830	4
7	IBIB[e]	laboratory system	TR	spectrometer	5/6	680-868	2
8	IBIB[e]	laboratory system	TR-DCS	perfusion	4	760	1
9	UCL[f]	laboratory system	CW	spectrometer	6	704-911	8
10	ICFO[g]	clinical system	TR	oximeter	7	690,830	1

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3. IMPLEMENTATION

3.1 Protocols

Table 2 shows a synopsis of the adopted protocols, which were elaborated, defined, and agreed among many EU Institutions in the course of the last decade.

Table 2. Brief synopsis of the Protocols

Protocol	Tests	Phantoms	Measurable	Characterizes
MEDPHOT	Accuracy, Linearity, Uncertainty, Stability, Reproducibility	Matrix of 32 homogeneous phantoms	Absolute absorption and reduced scattering coefficients	Ability to accurately retrieve absolute optical properties
BIP	General performance, Responsivity, DNL	Responsivity	Multiple	General characteristics of sources and detectors
nEUROPt	Depth selectivity, lateral resolution	Solid switchable	Contrast, Contrast to noise ratio	Ability of the instrument to detect an inhomogeneity

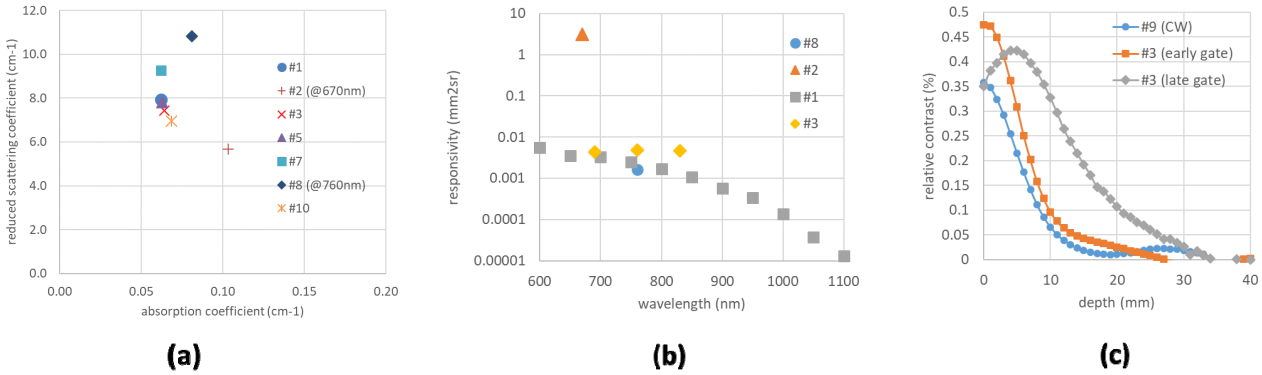
3.2 Phantoms

A set of well calibrated phantoms necessary to perform all the tests was circulated to all the institutions. A matrix of 32 resin phantoms covering a wide range of optical properties (μ_a - (0.05:0.05:0.4cm^{-1}); and μ'_s - (0.05:0.05:0.4cm^{-1})) was considered for the MEDPHOT protocol. The BIP protocol used a responsivity phantom to measure the light harvesting capabilities of the detector. A solid switchable phantom[6] with a dynamic inhomogeneity contained in a homogenous phantom was used for the nUEROPt protocol.

3.3 Other Parameters

To have a standardized set of data from each instrument all the data were obtained as 20 repetitions of 1s acquisitions. With regards to the other parameters like the source detector separation, count rate (for TR systems) etc. the standard operating conditions of the instruments were considered.

4. RESUTS, CONCLUSION AND FUTURE PERSPECTIVES



(a) **(b)** **(c)**

Figure 1. Comparison of the results from the different instruments on the different tests. **(a)**absolute optical properties of one of the phantom from the MEDPHOT kit, all data shown at 830nm unless specified otherwise in the legend. The number on the legend corresponds to the serial number of the instrument (refer Table 1) **(b)** Responsivity or light harvesting capability of the instruments tested for in the BIP protocol and **(c)** depth sensitivity to localized optical perturbations tested on a CW (#9) and TR (#3) instruments using the nEUROPt protocol

Preliminary results, based on the first level analysis performed by each institution are presented here. Not all tests could be applied to every system. Therefore, for each device only the applicable tests were adopted. Figure 1 shows the result of one of the tests from each protocol. The mean discrepancy of instruments operating at 830 nm (data at 670 and 760 nm excluded) is 4% and 10% of the average value for absorption and reduced scattering, respectively. The responsivity test shows System #2 is based on a large area solid-state detector apt to be directly placed in contact for maximum light harvesting shows a significantly higher responsivity than the others. Figure 1, (c) shows the relative contrast detected as a function of the depth z of the buried object for a source-detector separation of 3 cm and different time-windows ("gates") for a TR system and a CW system.

In conclusion, a multi-laboratory campaign aimed at facilitating a shared culture of performance assessment in DO based instrumentation was conducted. 10 diverse set of instruments were enrolled and tested against a set of well-established, standardized protocols. A preliminary data analysis was also performed. Future perspectives include, enrolling more instruments from other institutions to promote the culture of shared performance assessment procedures, open data deployment and cross-analysis of the data.

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