Innovative Mobile Smart Photonic Dimensional, Color and Spectral Measurement Engineering

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Abstract. Aim of the paper is the demonstration of a paradigm shift in dimensional, color and spectral measurements in industry, biology/medicine, farming/environmental protection and security, as well as in education and training: Measurement engineering and quality assurance become mobile, modular and smart. Smartpads, smartphones and smartwatches (smartcomps) in combination with innovative hardware apps (hwapps) and conventional software apps (swapps) are fundamental enablers for the transformation from conventional stationary working places towards innovative mobile working places with in-field measurements and point-of-care (POC) diagnostics. Furthermore mobile open online courses (MOOCs) are transforming the study habits. Practical examples for the application of innovative photonic micro dimensiometers, colorimeters and spectrometers will be given. The innovative approach opens so far untapped enormous markets for measurement science, engineering, applications, education and training. These innovative working conditions will be fast accepted due to their convenience, reliability and affordability. A highly visible advantage of smartcomps is the huge number of their real distribution, their worldwide connectivity via Internet and cloud services, the standardized interfaces like USB and HDMI and the experienced capabilities of their users for practical operations, obtained with their private smartcomps.

1. Mobilization of Computers

The computer market is changing. Miniaturization and mass production of smartcomps are in progress. The special advantages of smartcomps are their mobility and their multitouch user interfaces. Market leaders are Apple with iOS operation system and Google with Android operation system. Microsoft with Windows 8 operation system is a late but powerful and experienced follower (Figure 1a) [1]. Windows 8 smartcomps combine the typical Windows working style with the leisure look and feel of iOS and Android life style. The innovative computers are equipped with consumerized interfaces for wired and/or wireless communications (Figure 1b) [1]. Smartcomps are additional equipped with powerful hardware apps for image acquisition as for example light sources, cameras, camcorders and scanners and with software apps for image processings. Smartcomps are mobile because they are light weight and battery powered. In addition, the number, quality and diversity of external hardware apps for smartcomps are increasing (Figure 1c) [1]. They are applicable for industrial measurements, biological/medical diagnostics, farming/environmental protection and security as well as for scientific investigations or mobile education and training purposes.

Figure 1a. Innovative Windows mobile computers

Figure 1b. Innovative mobile interfaces

Figure 1c. Consumerized measurement systems

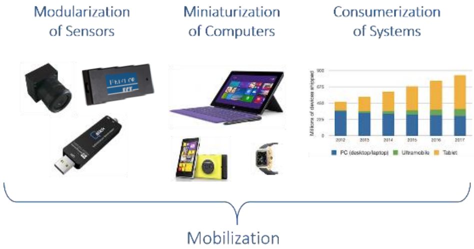


Figure 1d. Multi-hybrid measurement systems

Figure 1. Mobilization and standardization of computers and measurement systems

The Ozcan Group at the University of California, Los Angeles (UCLA) is working since years successfully on this topic. Their research results recently has been summarized in a very informative overview [2]. A fundamental purpose of the present paper is to show that many innovative mobile smart solutions can be designed with already existing functional modules according to the LEGO principle. Due to smartcomps with the quasi standardized industrial operation system Microsoft Windows 8 (see Figure 1a) and standardized interfaces (see Figure 1b) the existing consumerized hardware modules and software modules (see Figure 1c) must not be modified in their original structures and functionalities. A disadvantage of the shown multi-hybrid solutions might sometimes be that they are more complex in its structures and in its functionalities than specialized solutions. But the advantages of these multi-hybrid solutions are their fast availability because they are composed of commercially available components supplemented by mass-produced consumer goods (see Figure 1d) [1].

2. Mobile Smart Photonic Measurement Systems

Mobile smart photonic measurement systems are a combination of smartphones, smartpads and smart wearables (smartcomps) with additional task specific hardware apps (hwapps) and software apps (swapps). Dimensional measurements are the analysis of geometric shapes in 1, 2, 2.5, 3 and n dimensions (Figure 2a). Color measurements are the analysis of light and body colors in accordance with the human color perception (Figure 2b). Spectral measurements are the analysis of unknown spectra in comparison with evaluated terms of known spectra (Figure 2c).

Figure 2a. Dimensional measurement systems

Figure 2b. Color measurement systems

Figure 2c. Spectral measurement systems

Figure 2. Mobile smart photonic measurement systems

3. Mobile Smart Photonic Measurement Hardware Apps

Typical photonic dimensional measurement hardware apps are digital miniature cameras and microscopes with standardized CMOS sensors, USB interfaces and flexible S-Mount lenses (Figure 3a) [3] [4]. Typical photonic color measurement hardware apps are digital miniature colorimeters or photometers with standardized True Color sensors, USB interfaces and SMA-Connectors (Figure 3b) [5]. Typical photonic spectral measurement hardware apps are digital miniature spectrometers preferably with standardized linear CCD sensors, USB interfaces and SMA-Connectors (Figure 3c) [6].

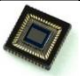
			
CMOS sensors	Hardware modules	USB interfaces	S-Mount lenses
	Sensor: CMOS RGB Bayer Matrix, 5 MP 2592x1944 pixels, 1/2.5 Digital interface and power requirements: 5V USB 2.0, typ. 0.6W Dimensions and Weight WxHxD: 15 x 15 x 8 mm, 5 g		
Figure 3a. Dimensional hardware apps			
			
True Color sensors	Hardware modules	USB interfaces	SMA-Connectors
	Sensor: Tri-stimulus value function, DIN 5033, digital resolution (ADC) 16 bit Digital interface and power requirements: 5V USB 2.0 Dimensions and Weight WxHxD: 89 x 32 x 27 mm, 20 g		
Figure 3b. Color hardware apps			
			
Linear CCD sensors	Hardware modules	USB interfaces	SMA-Connectors
	Sensor: 2500 pixel linear CCD detector, 360 - 740 nm, 1.2 nm FWHM Digital interface and power requirements: 5V USB 2.0, 150 mA Dimensions and Weight WxHxD: 85.7 × 22.0 × 10.0 mm, 10 g		
Figure 3c. Spectral hardware apps			

Figure 3. Mobile smart photonic measurement hardware apps

4. Mobile Smart Photonic Measurement Software Apps

To design consistent measurement systems with smartcomp compatible specialized software apps must be available. Due to the longstanding successful implementation of specialized software tools for photonic measurements on computers with Microsoft Windows operation systems XP, Vista, 7 and 8 a big number of excellent software tools commercially are applied. Under the influence of modern speaking habits these software tools may be understood as software apps, if they are compatible with the Microsoft Windows 8 operation system. Normally Windows 8 is downwards compatible to Windows XP, Vista and 7. Therefore a remarkable variety of photonic measurement software apps for photonic dimensional (Figure 4a), color (Figure 4b) and spectral (Figure 4c) measurements are already traded.

		
Figure 4a. Dimensional software apps	Figure 4b. Color software apps	Figure 4c. Spectral software apps

Figure 4. Mobile smart photonic measurement software apps

5. Calibration tools for mobile smart photonic measurement systems

Calibration is an operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication (VIM 2.39) (6.11) [7]. **Mobile** calibration tools are designed to enhance capabilities, performance, and ease-of-use of the mobile smart photonic measurement systems. There are various kinds of mobile calibration tools for photonic dimensional (Figure 5a) [8], color (Figure 5b) [9] [10] [11] [12] [13] and spectral (Figure 5c) [14] [15] measurements.

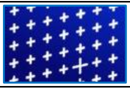
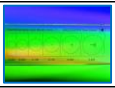
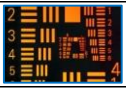
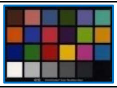
				
Holes/dots/pattern	Glass scales	Surface detect pattern	USAF Testchart	Siemens Star
Figure 5a. Dimensional calibration tools				
				
Calibration LED	X-Rite Colorchecker	RAL Color Fan	VIS color liquids	VIS color glasses
Figure 5b. Color calibration tools				
				
Radiometic sources	Wavelength sources	Reflectance standards	UV-VIS-NIR liquids	UV-VIS-NIR glasses
Figure 5c. Spectral calibration tools				

Figure 5. Calibration tools for mobile smart photonic measurement systems

6. Examples for Mobile Smart Further Educations and Shared Hands-on Trainings

Manufacturers and system integrators of hardware and software for photonic image acquisition and digital image processing are on the way to reduce the significant qualification deficits of potential users. Two efficient methods are promising:

1. Imaging specific multilingual digital text books (ebooks) and videos for end users on smartcomps,
2. Imaging specific hands-on trainings in industry and/or shared between universities and industry.

6.1. Mobile imaging specific ebooks and videos on smartcomps for end users

To increase the efficiency of individual education and training processes, about 2000 digital papers and 1000 videos, dealing with recent developments in mobile smart photonic dimensional, color and spectral measurements are open accessible on the cluster-platform spectronet.de (Figure 6.1). The search box in spectronet.de enables the users to identify experts, institutions and enterprises as well as professional contents, selectable by professional keywords.

Figure 6.1. Digital papers, videos, experts, institutions and enterprises on spectronet.de

Highly visible and recognized contributions to the current education and training in image processing are provided by AIA (visiononline.org), SPIE (spie.org), EMVA (emva.org), VDMA-Industrielle

Bildverarbeitung (vdma.org) and Fraunhofer-Allianz Vision (vision.fraunhofer.de). Today any educational organization is affected by the transition of analogue paper books, paper pictures and film videos to their digital versions on smartcomps. This transition is irreversible due to their convenience, reliability and affordability for an efficient and flexible individual use at work and at home. A convenient, reliable and affordable conversion of .pdf-papers to ebooks is done for example by Yumpu (yumpu.com/de/browse/user/spectronet.de). Furthermore, clusterpartners of SpectroNet elaborated their own educational material (Figure 6.2).

analytikjena	AMA	Baumer Passion for Sensors	INSPECT	KONICA MINOLTA
1	2	3	4	5
Mahr	MAZeT	Ocean Optics	OMRON	Pool-i.d.™
6	7	8	9	10
pyramid building IT	STEMMER® IMAGING	Vision Components® The Smart Camera People	ximea	ZEISS
11	12	13	14	15

1. analytik-jena.de/de/life-science/service-support/downloads.html
2. ama-weiterbildung.de
3. baumer.com/de-de/services/anwenderwissen
4. inspect-online.com/whitepaper
5. konicaminolta.eu/de/measuring-instruments/lernzentrum
6. mahr.de/de/Know-how/Know-how
7. mazet.de/de/downloads/produkt-und-kundeninformationen/white-paper#.U1YQKfl_s00
8. spectroscopytv.com
9. ns.europe.omron.com
10. pool-id.com/html/index.php?option=com_content&view=article&id=84&Itemid=4&lang=de
11. polytouch.de/de/pr-media.html#section-bilder
12. stemmer-imaging.co.uk/en/handbook
13. vision-components.com/service-support/wissensdatenbankfaq
14. ximea.com/support/wiki/allprod/Knowledge_Base
15. zeiss-campus.magnet.fsu.edu

Figure 6.2. Imaging specific ebooks for mobile smart photonic dimensional, color and spectral measurements

6.2. *Imaging specific hands-on trainings in universities and industry*

To streamline the enormous qualification deficits in imaging, several up-to-date manufacturers and system integrators increasingly are taking the qualification of their employees and customers into their own hands. Since many years an efficient collaboration between the Ernst-Abbe-University of Applied Sciences Jena and the Mahr Company Jena is performed. The Ernst-Abbe-University of Applied Sciences Jena is increasingly defined by interdisciplinary collaboration [16]. The Mahr Group is the world's third largest manufacturer of a complete range in dimensional measuring products from calipers to optical coordinate measuring systems [17]. Imaging specific hands-on trainings with students of the Ernst-Abbe-University of Applied Sciences Jena since many years are successfully shared with Mahr Company Jena to increase the efficiency of resources by the application of current hardware apps and software apps for qualification purposes (Figure 6.3.).

EUROPEAN IMAGING ACADEMY	Mahr	Ocean Optics	st w	ZEISS
				
1	2	3	4	5

1. stemmer-imaging.de/de/support/schulungen
2. spectronet.de/de?t=/contentManager/onStory&ParentID=1310139565449&StoryID=1294424405064&lang=1&active=no
3. oceanoptics.com/Products/education_new.asp
4. spectronet.de/de/vortraege_bilder/vortraege_2014/steinbeis-spectronet-collaboration-forum-2014-ilme_htfjcn4k.html
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Figure 6.3. Imaging specific hands-on trainings

7. Conclusions

Smartcomps became global mass products with great convenience, high reliability and affordable prices. These market developments enable a paradigm shift in photonic measurement engineering, automation and quality assurance for industrial and non-industrial applications. With modular hardware apps and software apps new classes of hybrid instruments can be created. Modular hardware apps and software apps are reducing development time, cost and risk. Smartcomps are already revolutionary game changers in lifestyle. Now they are also penetrating into the workstyle. Miniaturization and consumerization inspire each other with increasing speed. Field instrumentations will be based on re-invented laboratory instrumentations. First steps on innovative routes are already gone successfully. An interesting convergence of measurements, diagnostics and quality control in industry, biology/medicine and environmental protection can be expected. In summary, it should be noted that the recently available mobile smartcomps and hardware apps in conjunction with proven software apps for Microsoft Windows operation systems are stimulating the re-invention of conventional solutions in measurement engineering, automation and quality assurance preferably for photonic image acquisition and digital image processing. This situation is also an enormous challenge for further education and shared hands-on trainings in these fields. Approaches to practical solutions have been explained in detail.

References

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[6] http://www.rgb-laser.com/content_products/product_qstick.html
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[10] http://xritephoto.com/ph_product_overview.aspx?id=1192
[11] http://en.wikipedia.org/wiki/RAL_colour_standard
[12] http://www.lovibondcolour.com/liquid-standards
[13] http://www.lovibondcolour.com/glass-standards
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[16] http://www.fh-jena.de/fhj/fhjena/en/Seiten/default.aspx
[17] http://www.mahr.com/index.php?Language=enus