BYOD, gamification & high definition innovations for telemedicine

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***Abstract*—We cover every year the innovations in Telemedicine. This year are focused on management, specifically on BYOD or bring your own device and on gamification. From the technical point of view, TM devices expect dramatic innovation with the SoC (system on chip) and the new HD image techniques. TM devices are now miniaturized and capable to be included in smart phones.**

***Index Terms*—BYOD, gamification, light field, high definition, 5D, plenoptic function.**

***Resumen*— Cada año tratamos las innovaciones en telemedicina. Este año tiene dos vertientes igualmente trascendentes, la primera es la gestión de la asistencia sanitaria muy particularmente en los aspectos de BYOD o llevar su propio sistema al trabajo y en "gamification" o usar las técnicas de videojuegos en la gestión del trabajo. La segunda innovacion es tecnológica ya que el aparataje de telemedicina va a verse renovado de forma drástica incluyendo los SoC (sistemas en chips) que implementen desde laboratorios (LoC) a las tecnicas de imagen de alta resolución. Los sistemas de TM estarán miniaturizados para poderlos incluir en los teléfonos inteligentes.**

***Indice terminos*—BYOD, gamification, Imágenes sobre campo de luz, alta definición, 5D, función plenóptica.**

I. Introduction

THE present paper cover innovations in the field of telemedicine and e-Health not covered on previous years when we deeply study the Health 4.0, i4i health, health-cloud and crowdsourcing. This time, innovation is focused on management, particularly on **BYOD and gamification** ,as well as on hardware, particularly on the high resolution images always in focus with synthetic aperture used in the light field photography passing through Lab on Chip and System on Chip miniaturized devices.

According to the EWF (economic world forum) in Davos meeting, health care advices have been focused on data and information management, innovation in health delivery and on prevention by means of health living cities. The interest of the EWF in health care was because due to an increasing elderly population and the increase expenses, health is becoming a CRITICAL ECONOMIC ISSUE.

Whether this vision defocuses the main concern on health care innovation which is population health or on the contrary will re-enforce a total renovation of the health care delivery is a matter of discussion. To my point of view people and health is the core, and the rest are collateral considerations that can improve equity and accessibility fostering distance delivery and IT immersion.

Due to the world economic crisis phenomena that imply lack of funding together with high unemployment, the **imagination** had become an essential value overtaking the classical knowledge. This generates new ways of delivery and solving problems such crowdsourcing or cloud computing as well as the consideration that reverse innovation is a plus in healthcare problems. Similarly, the productivity has been linked to **motivation and imagination** meanwhile the classic channel delivery paradigm based on scale-knowledge human resources is going to disappear.

Machines are ready to bring more efficient health care delivery, assuring a better work than humans.

This is the main goal in Health care today. **Re-invent health delivery** with the approval of medical and nurse staff. Acceptance of IT by the health care staff and progressive replacement by intelligent machines only bring resistances. No way to accept that: "Machines will produce less mistakes then humans". Therefore, to promote acceptance of IT technology is an essential part of the success. On this respect BYOD and gamification will be introduce.

On the other hand, miniaturization and spread of technology put now better tools in the hand of mass devices than in the expensive medical devices. But **Reverse Innovation** is also rejected based on the high requirements and demands of Medical Devices. Fortunately, the **guidance of FDA for mHealth** applications had destroyed that myth, and SoC (System on chip) and LoC (Lab on Chip) tools have been built on smartphones and tablets.

Open source solutions had democratized technology except specific and essential items such as intelligent management of the cloud base on fabric switches.

And finally, optics have broken the resolution limit and provide high resolution synthetic aperture images always in focus, capable to be build in miniaturized cameras to be included in smartphones. A revolution that expect to land on an aware medical community but this is not the case at the present moment.

To cover all those aspects, we had divided the paper in four sections: Management innovations, Reverse innovation

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and free-software and Light field images with HD (high definition), while SoC and LoC devices will be covered by top leader speakers during the course.

II. MANAGEMENT INNOVATIONS

Two are the main management innovation introduce with success in the IT-revolution of the society. One is the BYOD or *Bring your own device* and the other one is the *Gamification* or use of games to increase efficiency and commitment.

A. BYOD

The so called *Bring Your Own Device* strategy will be an essential requirement as soon as all devices become wireless and of the size of smartphones or mini iPADs specifically in health care.

Is will be too complex to provide to healthcare workers with enough devices capable to access "on the fly" to patients, patient data or medical device data. It is much easier to assure security and use *light apps* to access but not to download personal data HIPPA or laws protected. In this case, the use of personal devices from health workers represents a plus on comfort and on expenses. Do not forget that just now 85% of doctors have tablets and most patients use smartphones, particularly in Spain, the top country on smartphone versus dummy phones penetration. Seemly, to be familiar with your own device increase productivity, increase patient satisfaction since allow direct access to care givers and reduce IT costs.

Where are the drawbacks? In the hospital IT-staff, not enough in number and not prepared to secure patient data and assure bandwidth availability and vital signs delivery 24x7 days.

The main advantages that BYOD brings are:

1. Changes in CLINICAL WORKFLOW.
   a. Improving access to information
   b. Enhancing coordination by enhancing collaboration and communication
   c. Enforcing interdisciplinary workforce processes, very necessary now-a-days.
   d. Increasing physicians and patients satisfaction.
2. Flexibility and ACCESS.
   a. To communicate with colleges, teams and patients.
   b. Review laboratory results
   c. E-prescriptions
   d. Build clinical documentation
   e. View radiological images
   f. Capture billing activities
   g. Browse Internet for medical references.

The main disadvantages are particularly linked to **lack of literacy** and include among others:

1. Lost/Stolen devices, the physician's devices can be easily stolen although personal devices will be better guard.
2. Device security. Physicians often do not use their built in security resources, particularly because they limit their productivity.
3. Device monitoring. Physicians are resistant to allow IT monitor, manage and control their devices. They find it intrusive.
4. Virus and malaware protection. Physician's mobile devices lack of virus and malaware protection software.

We also have to add in well developed countries the QoC (Quality of Care) requirements that imply and IT pressure on:

1. Limited IT resources in a hospital
2. Limited help desk
3. Additional network administrations.

This IT-pressure could be partially overcome in an intelligent Cloud computing environment based on switch fabric and intelligent cloud network software hypervisor as we could deeply study in the previous Winter Course. The switch fabric assure an intelligent mesh that identify any new connected device by the MAC and allow to enter the cloud from anywhere with the security firewalls and secure communications. While the intelligent software that contain an orchestra director and the hypervisor will distribute, allocate and allow applications and resources.

A recent concern with the security issues have been the new TLS (transport layer security) protocol. All enterprises use the TLS for electronic commerce ciphering the data with protocols such as Open SSL, GnuTLS, PolarSSL or CyaSSL. With the MIM (man in the middle) technique those protocols are easy to decipher in wireless networks. We expect the in a near future this drawback will be patched.

As a result of this, what we expect in the near future of the Health care is a **highly reliable-scalable-ubiquitous wireless net**.

1. Highly available to assure the working process, access to data, to team and to patient at any time and in any emergency.
2. Highly scalable to support hundred if not thousands of mobile devices connected including the recent policy of UI (unique identifier) for Medical devices to assure direct access to medical devices, tracking procedures, etc..
3. Ubiquitous coverage to assure the physician is always on line regardless physical location and including administrative and conference rooms, clinical care, patient rooms, stairs, elevators, etc…

In fact we are closing the philosophy of the Health 4.0 as we envisaged to be in the previous publications. This networking solutions must

1.- Protect patient information
2.- Delivered QoS (Quality of Services)
3.- Remote manage of WiFi Medical devices
4.- Provide integration to staff & patient mobile devices and management tools.

B. GAMIFICATION

It is clear that the success on the **new healthcare delivery paradigm** is the people, the human resources. And that the breakthrough is to determine: How to motivate the staff to use the IT facilities, because now-a-days they dislike using it.

One policy was that of the EEUU paying doctors effectively using certified EHRs, meaning by "certify EHR" those which are harmonized with the public digital health care data and devices.

Nevertheless, **money** is not the top personal motivation but personal satisfaction, need and fun instead. **Need** is the strongest one, that is the reason why telemedicine and IT solutions are easily introduce in developing countries, that furthermore do not have strong regulations that limit their use. **Personal satisfaction** is achieved with the BYOD strategy and **fun** is achieved with the gamification strategy.

If apps are gamified <u>with rewards</u> virtual or physical, <u>with narrative</u>, creating an event feedback with a thin storyline that fix settings or create a context for an activity and finally <u>with mechanics</u>, such as point, badges, leadercards, avatars… fun and engagement is achieved. Anything that bring far away the tedious of computer applications not designed for doctors, humanistic people that enjoy having a personal relationship with patients and health workers and that now will become engaged by a computer, particularly if orders are not type but dictate by voice recognition.

Five are the well know achievements of the gamification policy:

1. POWER meaning to energize workforces, providing employees with a sense of purpose and aspiration for task that are repetitive and dull.
2. STAMINA or drive performance improvement. Provide timely feedback so people know what they are doing so they can improve.
3. INNOVATION. Innovate organically. Drive innovation by capitalizing on geographic and temporal diversity of workforce to foster new ideas.
4. BONNUS POINTS to motivate teams. Arrange motivating teamwork by defining what individuals get when the team wins.
5. LEVEL UP identifying emerging leaders. Level the playing field to allow new ideas to bubble from workers with little success to senior leadership.

C. IMPORTANCE LINKED TO ECONOMIC ISSUES

Health is a critical economic issue this was one of the points in the WEF (world economic forum) in Davos 2013. Three were the recommendations given: 1) Data and information in health care must be updated and digital 2) Health care delivery must be innovated to include home care, distant support etc… and 3) Health living cities must be promoted to foster prevention before cure.

The three recommendations are covered by digital distant health care support with self-care using wireless intelligent devices and therefore **eHealth & telemedicine** are the central items.

III. REVERSE INNOVATIONS

The philosophical base for reverse innovation includes several important considerations:

1) Not everything expensive is the best solution
2) Adoptions from the crowd are more intelligent than from the individual.
3) Low cost solutions are tested and improve in a wider and statistically more secure environment.

4) Free solutions are the most democratic and better improved solution.

This brings to the consideration the role of mass media, mass technical solutions, free software and innovation.

On this regard, mass solutions have approach us to the reality:

- Next year it will be as many mobile devices as inhabitants in the world. 6000 millions.
- 80% of doctors have tablets, and 95% of patients have phones.
- Spain has the highest smart-phone penetration in the world.
- Part of the mobile phones are Android, an OS derive from a Free-software such Ubuntu and Linux.

For that reason to use "Free software" solution and "mass media devices" instead of classical medical devices, lower down the price of digital requirements for telemedicine and e-Health. The problem is in both cases a certify body less complex and less expensive than FDA or CE-mark should be provided in order to lower down de prices.

The lack of regulations in developing countries or the lack of QoS (quality of services) or QoC (quality of care) demands brings the possibility to test and put into practice low cost solutions. When these low cost solutions want to be implemented in developed countries following the philosophy of the **Reverse Innovation**, then a Quality Control must be implemented as well as Data Security this lower the time of implementation and increase the costs.

During the winter course we will have other speakers that will extensively explain the development of the free software called GNU-Health [3][4][14] and during the workshop easy to use wireless camera of high quality will be deployed together with the see-way device to robotic control an iPad at distance[5].



Figure 1. Low cost devices. A robotic foot for the iPAD and the Samsung Galaxy camera. The first from double robotics, the second with an Android OS that allows to use Ubuntu and also the GNU-health for mobiles devices using Tryton.

Now a day the telepresence robot from Double Robotics costs around 2000 $ and the Samsung camera around 400$. This is much less than any of the COWs (computer on wheels) or image capture devices existing on the market for medical applications. Medical devices in general have the cost multiply by 10 or by 100 and in many times the quality are lower.

IV. HIGH DEFINITION

The consideration of high definition can include the Video-HD but we also extend it to image enhancement that allows breaking the resolution limit, particularly the techniques of light field image and synthetic aperture.

A. HD-Video

The so-called High Efficiency Video Coding (**HEVC**) is a join development of the ITU-T and the ISO-MPEG, the ITU has standardized it as **H.265**.[9]

On the deployment and development Vidyo and Samsung have been actively working with the ITU-T in order to include open standards into the HEVC group.

By now Vidyo is the only company giving in their protocols Standard Scalable Video Coding open for the browsers either in H.264 or in H.265. Those solutions are based on software having an adaptive video layer that make the MCU unnecessary and offering a multipoint high definition videoconference on smartphones and tablets that is operative with H.323 and SIP facilitating the broadcast in the cloud.

TABLE I- Video coding standards based on equal PSNR

Video coding standard	**Average bit rate reduction compared to**			
	H.264/MPEG -4 AVC HP	**MPEG -4 ASP**	**H.263 HLP**	**H.262/MPEG -2 MP**
HEVC MP	35.4%	63.7%	65.1 %	70.8%
H.264/MPEG -4 AVC HP	-	44.5%	46.6 %	55.4%
MPEG-4 ASP	-	-	3.9%	19.7%
H.263 HLP	-	-	-	16.2%

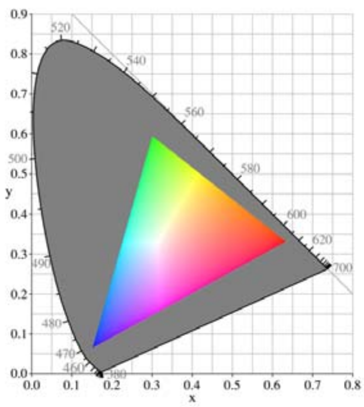

Figure 2. Triangle showing the classic color gamut CIE 1931 represented in the RGB computer monitors.

HEVC is targeted at next-generation HDTV displays and content capture systems because **it adapt to** bit rates and resolutions from QVGA (320×240) to 4320p (8192×4320), as well as **improved picture quality** in terms of noise, color gamut and dynamic range.

B. 4D-Light Field images.

Light-field technology heralds one of the biggest changes to imaging since 1826, when Joseph-Nicéphore Niépce made the first permanent photograph of a scene from nature. A single light-field snapshot can provide photos where **focus**, **exposure**, and even **depth of field** are adjustable *after* the picture is taken.

But light-field photography is based precisely on his idea that the light arriving at any point—what he called the "smallest part" of the air—carries all the information necessary to reproduce any view that can be had from that position.

In a conventional digital camera, the light rays hitting each point on the image sensor combine. The sensor records the total intensity of the light rays landing on each point, or photo-site, but in the process loses directional information about where the different rays came from. So the best a typical camera can provide is the familiar 2D photograph, which has a fixed point of view and a focus determined entirely by how the lens was set when the photo was snapped.

On the contrary, the **lightfield camera (LFC)** works as the compose eyes of the insects since gets an independent information in each of the facets that in the case of this cameras represent the 100000 to 500000 lenses. It gets an independent view of the point and therefore this view can be reproduced from each different angle any time. This provide **4D photograph** (of one view) showing not only the *x*, *y*, and *z* information but also the angle on which a static picture (one view) is taken.

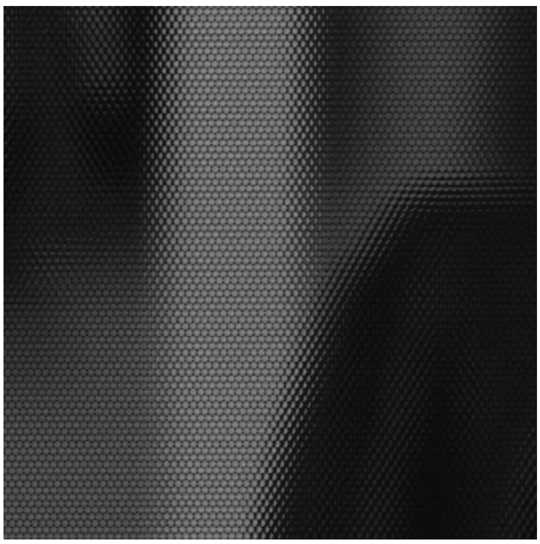

Figure 3. Raw image. Detail of the density and pixel structure on LFC (light field cameras).

1) 5D-Plenoptic Function.

Nevertheless a light-field camera aims to measure the intensity and direction of every incoming ray. This generate not just one but *every possible image* of whatever is within the camera's field of view at that moment.

A light-field camera records the **plenoptic function**. This function describes the totality of light rays filling a given region of space at any one moment. It's a function of **five dimensions 5D:** because you need three (*x*, *y*, and *z*) to specify the position of each vantage point, plus two more (often denoted θ and φ) for the angle of every incoming ray.

When measuring light in a region that's free of any obstructions, you have to keep track of only four dimensions rather than five. Think about it: If you know that a ray isn't blocked, it's simple to follow where it goes. Record where it hits one plane (*x* and *y*) and the angle at which it hits (θ and φ) and you can work out where it came from and where it's headed. The same is true for any other ray hitting that plane at any angle. So with just the knowledge of the light crossing a single plane, you can calculate the position and direction of the rays filling the surrounding region, so long as there are no obstructions present. This four-dimensional function is called the light field (hence the term light-field camera).

The principle of the camara is know since the beginning of photography in 1908 Gabriel Lippman invented the "integral camera" integrated by tiny lenses projecting the scene in a single sheet of film that viewed through an identical lens array give a 3D image. Three years latter the Russian Sokolov built the first "integral camera" using a pinhole array.

The today´s Litro camera uses, instead of a film and a pinhole, a sheet of thousand microlenses between the main lens that focuses the subject into the sheet of microlenses which bring the information into a standard 11 megapixel image sensor.

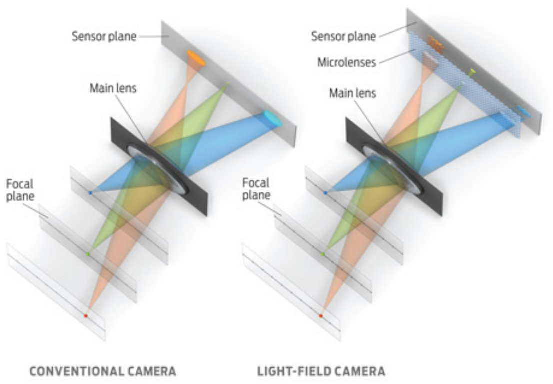

Figure 4. Microlenses galore. Comparison between a conventional camera (left) and the LFC (right). In the conventional camera the light from the focal plane (green)is the one focused in the image plane, the rest are out of focus points (blue and orange). The LFC proyected the 3 planes into a microlenses array that focused the image in the sensor plane therefore the out of focus image is digitally synthesized. Taken from [7]

2) Motion Parallax function.

Having all spatial and angular information of the scene allow to produce motion parallax, changing the perspective and detecting objects otherwise cached.

This motion parallax improve the sense of depth similarly to what some animal do (birds)

3) LFCameras on the market.

Cameras existing on the market based on those techniques are limited and include one high quality camera (Raytrix) and a low price mass camera (Lytro). The fist one is use in the NASA and space experiences, the second one can be bought by 400 $ but still is not available in Europe, in spite that we thought to have for the CATAI 2013.

Figure 5. Lef the Lytro camera, Right the Raytrix camera.

In any case in both case the technology implemented inside is the following one:

- Single-lens 3D
- Calibration-free
- Software refocus
- Multiview perspectives
- Extended depth-of-field
- Most of them with Giga bit Ethernet USB3

The drawback is that LFC demand serious computing power, and that there is a limit in resolution and image quality.

4D images are transformed into 2D images by intensive Fourier transform computations and ray tracing algorinthms that require powerful and compact processors.

Lytro, is a Silicon Valley start-up that launched the world's first consumer LFC, which shoots pictures that can be focused long after they're captured, either on the camera itself or online. The camera takes 5 seconds to show the image and the microlenses are focused to the infinite.

Raytrix system focus the microlenses on the image formed by the main lens similarly to a refractile telescope to create an array of sharpen inverted images on the sensor. In this case the number of microlenses do not longer limit de final image [6].

The next generation of light-field optical wizardry will bring ultra-accurate facial-recognition systems, personalized 3-D televisions, and cameras that provide views of the world that are indistinguishable from what you'd see out a window. This technique therefore approaches to the users the Health 4.0 as we had defined years ago.

The two other companies working in LF technology are Pelican Imaging and Rebellion Photonics both specialized in its miniaturization for smartphones.

4) Smartphone light field cameras.

LFC are now possible to implement into smartphones is due to the miniaturization of the Graphic Processing Units (GPU) [12]. Now a days the GPU have hundred of processors packed into a little device working in parallel.

Toshiba announced the miniaturization of the Lytro LFC (infinite focused microlenses) using 500,000 lenses each one of . 30 µm diameter in front of an image sensor or arround 5x7 mm packed into a 1x1 cm system.

The technology has its drawbacks: the **resolution** being significantly **lower** than a traditional camera with the same image sensor since sensors are occupied receiving different angle images and **the focus** effect being **limited by** the capabilities of the **fixed-aperture lens**.

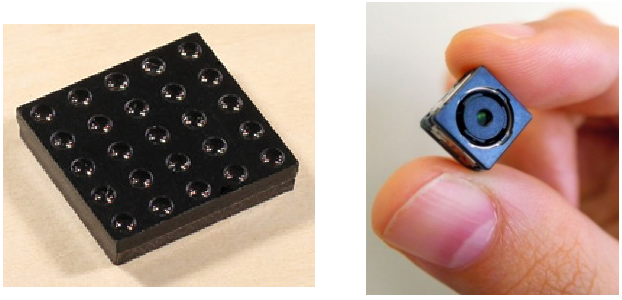

Figure 6. Left detail of the microlenses from Pelican Imaging Corporation. Right . Taken from [11]. Toshiba miniature lightfield camera (LFC) module for smartphones and tablets.Taken from [12]

C. Superesolution and synthetic aperture.

Superresolution is defined as a process of obtaining an image at a resolution higher than that afforded by the sensor used in the imaging. The concept of signal resolution is shown to be intimately related to the notion of perfect reconstruction. As such, the major issue addressed in this work is in establishing an appropriate set of bases for the reconstruction of images in these domains in terms of a finite set of collected samples.

The resolution of a signal addresses the ability to perfectly reconstruct a continuous signal from a set of samples. The idea come particularly from SAR (Synthetic Aperture Radar images), but it can be implement into any images, from optical biopsy to microscopic images.

One of the speakers [13] will explain in detail the process and it is the base of many of the LoC systems build in mobile phones.

We have extensively worked on the whole slide microscopy using low power to capture a wide area, the so called SSVS or small size virtual slide working with superresolution algorithms[16].

V. Conclusion

The paper include all innovations expected in the field of telemedicine an eHealth in the near future from managing to technology. All of them based on digital medicine, which make in evidence that training in the faculties of medicine is not fulfilling the minimum requirements for future doctors, unless it include eHealth, digital medicine and temedicine. As we extensively have explain they should be trained in Health 4.0 and in the i2i era[18]

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Working as pathologist in the Clinic Hospital of Barcelona since 1972 got the Assistance Professorship in Pathology in 1974 and the Chair of Pathology of the University of La Laguna in 1982. Commercialized a pathology image analysis system TEXCAN ® ™ specialized in visual textural analysis of the cell chromatin and DNA and immunohistochemical quantification. Founded the CATAI association in 1993, being the president since then. Got the UNESCO Chair of Telemedicine in 1999 for the University of La Laguna. Since 1996 train on Telemedicine the students of medicine and Computer Science, creating the European Master of Telemedicine and Bioengineering applied to Telemedicine in 2004, at distance.

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