i-Phones in Telemedicine.
The Health 4.0 & i2i era

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Abstract—**The quick introduction of iPhone, iPad, iPod products in medical delivery, together with the approval of several diagnostic-prognostic-distant care -management applications by the FDA, assure a non-stop deployment in modern medicine of mobile applications starting the i2i era. The present paper not only list approved application but already developed applications together with future deployments.**

Index Terms—**iPhone, iPad, iPod, Telemedicine, Vital signs, Image diagnosis, hand-held devices.**

Abstract—**La rápida introducción del iPhone, iPad e iPod en la atención medica, junto con la reciente aprobación de la FDA de varios de estos sistema como adecuados en el entorno médico, indican que su introducción va a ser imparable en la moderna medicina iniciándose la era medica i2i. Este articulo recoge no solo las aplicaciones aprobadas, sino aquellas pendientes de aprobación o en desarrollo así como los posible desarrollos futuros, muy particularmente en el campo de las imágenes.**

Index Terms—**iPhone, iPad, Telemedicina, signos vitales, diagnóstico por imagen, dispositivos móviles.**

I. Introduction

FUTURE of medical devices are hand-held devices in a pervasive environment that use WIFI and Cloud computing allowing to miniaturized the systems.

For that reason, the present paper try to bring awareness of what is already achieved, and towards where are we moving.

We include in the paper not only individual doctor initiatives (**iDoctor**) to assist patients (**iPatients**) starting the **i2i era** of medical applications, but the approved FDA applications integrated with controlled Health IT services.

The paper will be distributed in several subheading that mainly separated quality controlled versus non-quality controlled applications.

In the first group we are including those applications that in short or long time will be integration of what we

called HEALTH 4.0. In other words

I.- Applications that fulfill **3 criteria of availability**:
- Anytime connections: On the move, indoors and outdoors, day & night.
- Anyplace connection: On the move, outdoors, indoors, at any PC.
- Anything connection: At any PC, H2H (human to human), H2T (human to thing), T2T (thing to thing)

II.- Applications that include **image enhancement & RFID** readings to be use for:
- People→by faces recognition and access to relevant information (home, work, medical, HER, PHR, medical schedule…).
- Object→by use & by owner recognition.
- Food→by principle content & by diet requirements.
- Medication→by principle & by indication-contraindication.

III.- Application taking **Web 3.0** items such as:
- HCQ Health Care Quality: ISO 13485-ISO 2700 or security.
- 3S: Social-Semantic-Services
- Cloud accessing (SAAS, pCloud or personal cloud were the iPhone can be included).

IV.-Applications taking **Web 4.0** items such as:
- KBL o Knowledge base learning, including literature base learning (LBL), Evidence Based learning (EBL), trial base learning (TBL), Image based learning (IBL) etc…
- QBE o Query by example, including query by image (QBI) etc…
- CoLD or Cloud of link data with Artificial intelligence.

Examples of the IV.1 and IV.2 will be detailed in the paper entitle: "Optical biopsy data base content retrieval from smartphones" in chapter 7.

In the group of non-quality control applications we include mainly the Web 2.0 applications without control o regulation, and particularly iDoctors and iPatients.

Extending the definition of **iMedicine**, we should include as stated in the definition of the WHO any medical environment at distance with iPhones or any other pervasive and personalized hand held device that provide tele-control, tele-prevention, tele-management, tele-

learning etc… in Medicine. In the latter the **iLearing** application developed inside of the medical students training of pathology, will be the developing show case.

Interesting enough is that from the OS-3, Apple has a specific class of services directly linked to MD or medical devices that allow to developed applications and synchronize them with the MD through Bluetooth or USB.

Right now there are nearly 1,500 smart phone applications for health care professionals are already available for downloading and the Plug & Play busses the iBUS are arriving to the market (http://catai.net/blog/2011/03/md-bus-vs-ibus/) approved by the FDA transforming the hospital into smart rooms that integrate mobile phones, and not requiring any more connectivity specifications telemetric devices.

II.   IPHONE-HCQ Ó IPHONE HEALTH CARE QUALITY APPLICATIONS.

The FDA have recently approved several applications controlled with iPhones listed here. Nevertheless it is important to consider that:

> The Verizon version of the iPhone is different from the AT&T version of the iPhones.

They are separate devices. Therefore, it will be necessary to test those separately for iPhone FDA applications.

A. iPHONE Ultrasound

El first smartphone capable of record and send ultrasound medical images is the MobiUS from Mobisante, approved in USA by the FDA (Food and Drugs Administration). The price is at the moment 10,000 $, much less than the regular US station (from 20.000 $ – 100.000 $).

To our understanding too much, considering that the hand-held version of an US, the so-called VSCAN from General Electric cost 6000 euros.
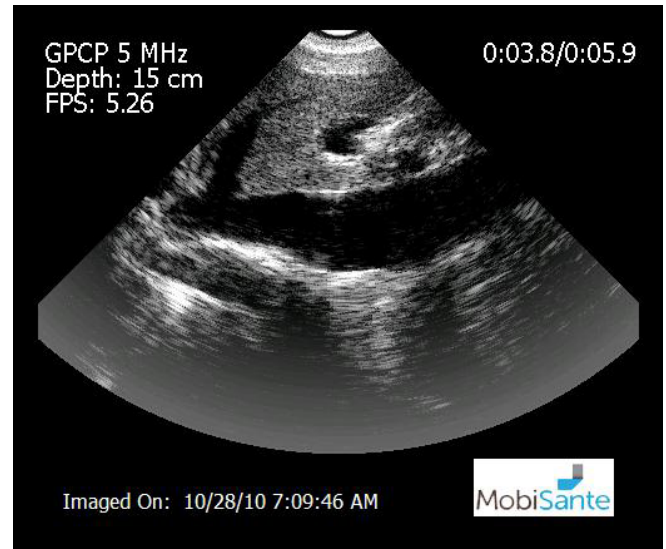

Figure 1. MobiUS. An IVC Longitudinal View

B. iPHONE Radiology

A number of companies have DICOM compliant applications that can be installed on the iPhone. As OsiriX (www.osirix-viewer.com/MobileOsiriXWorkflow.pdf)

The DICOM visor of OsiriX had two versions.

1) Osirix-X

The free open-source software (FOSS), is not certified as a commercial medical device for primary diagnostic imaging, and therefore,

> OsiriX is not FDA/CE-1 certified.

In USA and Europe, you can only use OsiriX as a reviewing, research or teaching software, not for primary diagnostic, used in clinical workflow and/or for patient care.

For these reasons, several commercial versions of OsiriX exist. They are certified as medical devices for primary diagnostic imaging.

II) OsirixMD

Distributed also by OsiriX is the FDA-Cleared version called OsiriX MD. Therefore

> Osirix-MD can be used in the iPhone for primary diagnostic, in clinical worklfow and/or for patient care.

This is the one integrated in many of the systems that allow handling medical images through mobile phones such as the View1 from Global Care Quest en cooperation con Karl Storz. Major players such as GE Healthcare are also getting involved.

III) MobileMIM

The display performance of mobile devices can experience significant variations in luminance levels even between mobile devices of the same model. The Mobile MIM application includes sufficient labeling and safety features to mitigate the risk of poor image display due to improper screen luminance or lighting conditions. The

device includes an interactive contrast test in which a small part of the screen is a slightly different shade than the rest of the screen. If the physician can identify and tap this portion of the screen, then the lighting conditions are not interfering with the physician's ability to discern subtle differences in contrast. In addition, a safety guide is included within the application.to commercially available MIMvista's Mobile MIM with the commitment to get the FDA clearance (http://www.mimvista.com/iphone).

IV) Telestroke ResolutionMD

The vascular neurologist remotely interacts with patients, their families, and emergency department staff and is able to observe diagnostic brain imaging using **ResolutionMD™** (http://www.calgaryscientific.com/), cardiac monitors, and patients' performance on a structured neurological examination (the National Institutes of Health Stroke Scale). This is the Mayo Clinic Stroke Telemedicine for Arizona Rural Residents (STARR) Network. Ubiquitous access to 2D, 3D and MIP/MPR viewing of CT and MR images and delivery of high-quality, interactive video. Support for both Wi-Fi and cellular data networks (3G & 4G) allows for cost-effective delivery of world-class care to even the most remote patient populations.

The ResolutionMD image viewing solution is FDA, Health Canada and CE Mark approved. The same server software that provides ResolutionMD Web with browser-based advanced visualization functionality provides images directly to mobile devices in ResolutionMD Mobile.

C. iPHONE Vital signs

http://catai.net/blog/2010/11/iphone-con-signos-vitales/

AirStrip Technologies provide all type of Applications on mobile phones including Android OS for Obstetrics that include the cardiac analysis of the fetus, together with Vital sign monitoring at distance connecting with hospital monitoring devices to view and control on line the patients.

Figure 2. AirStrip vital sign control on iPhones.

D. iPHONE diabetes control

http://catai.net/blog/2010/09/medidor-de-glucosa-de-i-phone/

There are many diabetes management control systems at distance approved by the FDA.

The iBGStar device developed by Sanofi-Aventis in cooperation with AgaMatrix is a new glucosae device detector linked to an iPhone or to an iPod touch, that not only showed the values of glucemia in an immediate manner, but store measurements and allow to send them at distance for control purposes..

The BGStar® and iBGStar™ use Dynamic Electrochemistry® to assure the exact measurements as well as its DSS (Decision Support System).

Figure 3. iPhone with the iBGStar device.

E. iPHONE HER
1) PrimeMobile
http://catai.net/blog/2010/07/i-phone-ehr/

Figure 4. Prime Mobile from Greenway medical tecnology

Greenway medical technologies, Inc., facilitate an EHR-Electronic Health Record integrated in a unique data base handled by the **PrimeSuite**® solutions. The Prime suite is certified since 2008 for connectivity by CCHIT and is available for iPhone through its PrimerMobile.

II) GE-EHR
The EHR of GE- General Electric for iPhone obtained the CCHIT certification in 2011.

F.   iPHONE auscultation

I)   TeleSteth

The **TeleSteth On line consultation** by Zargis (*http://zargis.com/index-2_3.php*) is linked to a Libman Stethoscope, not to a mobile iPhone and it is HIPPA compliant.

Together with the StethAssist® heart and lung sounds visualization software, allow the on line diagnosis and teleconsultation. TeleSteth permits patient sounds to be remotely evaluated in real-time (synchronous) or store-and-forward (asynchronous) mode.
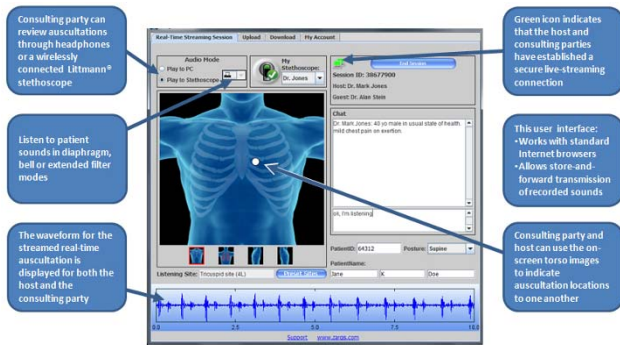

Figure 5. TeleSteth user interface

II) RNK-PCP-1

RNK Products, in February 2011 announced that the FDA has approved its newest telephonic stethoscope. The PCP-1 Stethoscope, combines state-of-the-art sensor technology (patents pending) with PC based communications software to provide an economical telephonic stethoscope. It includes Streaming Stethoscope Over IP (**sSOIP**) software to securely transport the stethoscope signal from a patient at one site over the Internet to a clinician at another site for an auscultation exam.

III.   iPHONE-NON HCQ APPLICATIONS.

Among the good iPhone applications that still have not passed the any CE or FDA approval include.

A.   iPHONE auscultation

1) iStethoscope
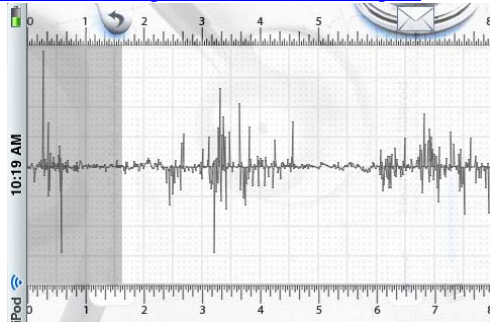http://catai.net/blog/2010/09/i-estetoscopio/

Figure 6. Graphic recorded in the iPhone with i-Stethoscope

It take the heart sound through the microphone of the i-Phone. This does not work in iPod-Touch because the microphone is located in the same location of the audio entrance. Nevertheless it can be used with the earphones of the i-Phone.

B.   iPHONE EKG.

The majority of EKG devices are compatible with ANT+ heart strip, that allow to capture and introduce the date into mobile phones. http://e-whizz.com.au/ANT-Soft-heart-Rate-Belt-for-iPhone/prod_1095.html

With an interface for the iPhone
http://e-whizz.com.au/HRM-iPhone/prod_1094.html

1) AliveCor
http://catai.net/blog/2011/01/ecg-para-iphone-4/
AliveCor, is a new application for iPhone, to obtain the ECG in real time placing a metal cap on the back of the iPhone containing two electrodes. The cap records the electric potential: for example of V1 is taken honling the iphone and placing two fingers from right and left hand in the back electrodes. The rest is obtained placing the iPhone over the chest direction on the skin.
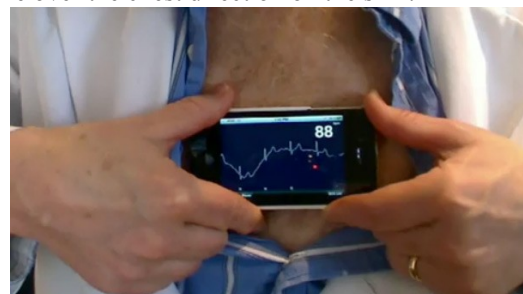

Figure 7. Alive Cor

Although is not jet FDA approved, it looks very simple and very useful to obtained the ECG and send it at distance. The FDA is interested in analysing more collection data during Phase IV follow up with drugs for some atrial defibrillation patients. According the designer

Dr. Devid Albert "Pharma companies working in this field are going to be very interested in deploying this kind of device to hundreds of thousands of patients," because "It's really disruptively inexpensive."
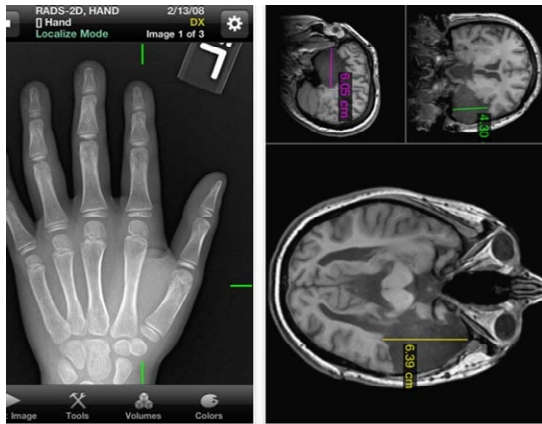
C. iPHONE Osirix

Figure 8. Mobile MIM

As explained in II-B section, the Open software from the Dicom viewer Osirix is not quality controlled, and therefore cannot be used for diagnostic purposes.

D. iPHONE Blood Pressure monitor

Two systems are now in the market, both are based in the usual blood pressure cuff and not in the wrist sensors. In both cases the profile is unique for one person, and at the moment no possibilities to store several patients profile is allowed.

http://catai.net/blog/2011/01/tensiometros-para-iphone-ipad-y-ipod/
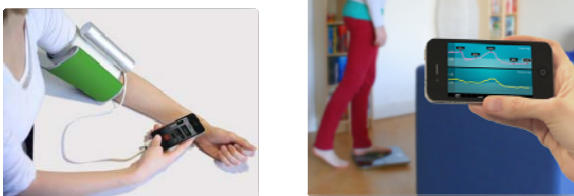
1) Withings

Figure 9. Withings blood pressure and weight scale.

Is a cuff connected with the iPhone. The application of Withings is common with the Weight scale, and allow to create in the web site several user, listed in the device.

I1) iHealth
Is a support for the iPhone that have the cuff.

Figure 10. iHealth blood pressure cuff.

E. iPHONE Pathology

1) Intellipath
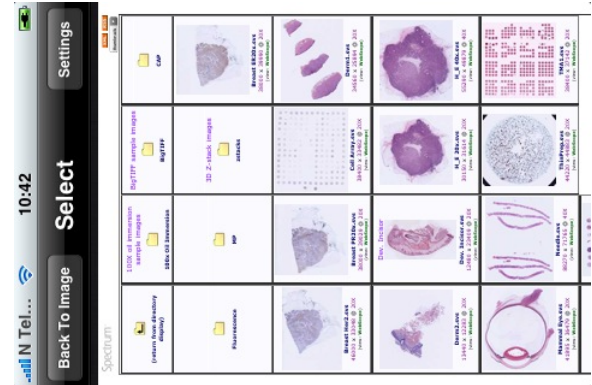http://catai.net/blog/2010/06/anatomia-patologica-en-iphone/

Figure 11. Intellipath

A detail structure and function can be seen in chapter 2, where the author explains the application.

I1) Anytime Anywhere-Nikon

With Anytime Anywhere (http://www.rmtcentral.com/) Nikon achieve an on-line vision of microscopic images for teleconsultation and display in an iPad.
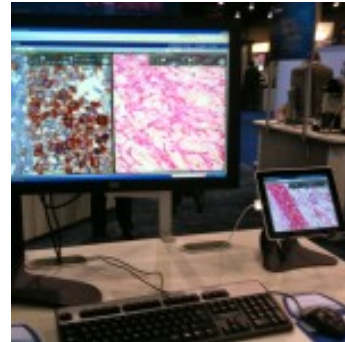
II1) Olympus

Figure 12. Olympus VS800 on an iPad

The most important issue of the latest VS800 scan microscope is the optics with very sharp, clear, bright images of superb quality. It has a high numerical aperture and extraordinary flatness from edge to edge. Because virtual slide images typically comprise multiple fields that are aligned with one another, capturing the best edge-to-edge quality of each image helps ensure both optimal scanning speed and more accurate alignment. Incidentally those images can be seen in an iPad, since once digitized can be shared immediately.

F. iPHONE anestesia

iPad had been progressively introduced in operating rooms, not only to handle EHR but to share and see images, in the latter with Osirix-MD, but also had been used for managing anaesthesia. The McSleep, based on Skype and iPad, can be perfectly well be implemented in an i-Phone through the cloud.
http://catai.net/blog/2010/09/tele-anestesia/
http://catai.net/blog/2010/12/los-ipads-ganan-el-quirofano/

G. iPHONE and 4M microscopes

http://catai.net/blog/2009/06/microscopios-4m-y-la-telepatologia/

Figure 13. iPhone adapter 60xwith a led illumination

The **4M-microscopes** (Multimodal Miniature Microscopes) based on very small lenses allow to build highly effective microscopes using iPhones as already stated [6][7], in the same way dermatoscopes were built (see below- Section I).

One of such systems in the Brando (http://www.mobile.brando.com/iphone-4-microscope-with-white-2-led-and-note-detector-led_p05863c0921d092.html) of about 18 $ that allow 60x augments.

H. iPHONE & weight control

http://catai.net/blog/2009/09/bascula-wifi-para-iphone/
See section D I) Withings

I. iPHONE -dermatology

That teledermatology with an iPhone is possible is a scientific evidence since 2009 with the publication of Holemn & Backe in the British Medical Journal.

http://catai.net/blog/2009/07/tm-diagnostica-12-mpx-en-telefonia-movil/

1) DermScope

Figura 14. DermScope, cost 10 $

The DermScope was just added to the iTunes medical apps directory (9.99 $). It's an external iphone case that has a dermatoscope embedded into the case. Essentially, you slip your iphone into the case and it transforms your iphone into a magnifying glass for moles and other skin lesions. You can capture images, store them, organize them by patient, and email images directly from the application.

Still it is unknown how much the hardware will cost. But it would be a bad idea to price it that high in the US considering that the other iphone medical peripherals are only around $100 dollars.

II) Handyscope

An international iphone dermatoscope retailing for $1500 dollars. http://www.handyscope.net/

Handyscope from FotoFinder is a smartphone accessory that transform your iPhone into a digital dermoscope 20x, for monitoring skin condition.

See also the training software for dermatology diagnosis in section IV

J. iPHONE – teleophtalmology

With available applications can be utilized as a near vision card, Amsler grid, color plates, OKN drum, and pupil gauge in non office emergency and consultation settings. These devices can also be used in the pediatric exam with novel optotypes & attention getting pictures/videos that can be used to facilitate fixation in a child.

Its conceivable that in the future Pachymetry, and A & B scans could be performed with a smartphone.
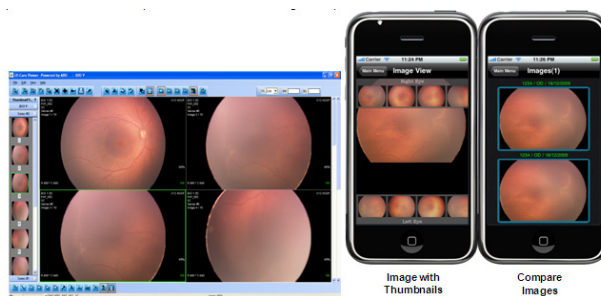
I) EyeRoute® Mobile

Topcon has introduced EyeRoute® Mobile, the first iPhone® application for ophthalmic image management. http://www.topconmedical.com/products/eyeroutemobile.htm

II) i2i teleophtalmology

http://catai.net/blog/2010/06/en-india-el-hospital-mas-eficiente-del-mundo/
http://i2itelesolutions.com/teleopth.html

Figure 15. i2i teleophtalmology

III) Near-Eye tool

For Refractive Assessment (NETRA) on which the patient tests their eyesight by staring into a small, cheap plastic lens which fits over the iPhone's screen. Instead of just estimating which of two views is less blurry the user adjusts their own display to make a scene come into
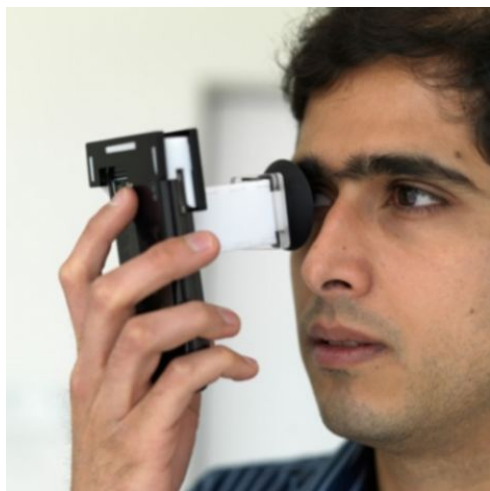
Figure 16. Near-Eye tool

IV) Crystalens iClear iPhone

A free iPhone application from Bausch + Lomb to test a patient's visual acuity and colour vision, enable them to learn more about cataracts and Crystalens and to find a suitable surgeon.

K.   iPHONE – cervix cancer screaning

http://catai.net/blog/2010/07/smartphone-y-screeening-cancer-cervix/

They take with the iPhone the images from Visual inspection with application of 4% acetic acid (VIA) for distant consultation.

L.   iPHONE - neurofeedback

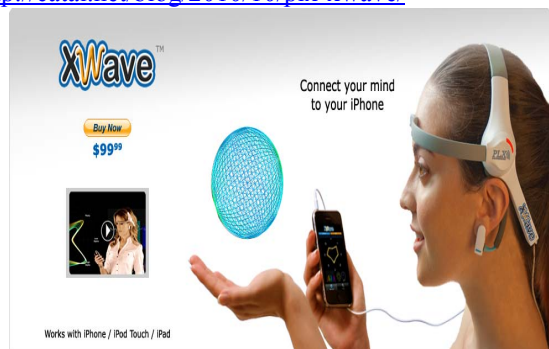http://catai.net/blog/2010/10/plx-xwave/

Figure 17. Xwave

Neurosky interface similar to a handset of brain interaction used in neuro feed-back. They specifically say that this is not designed for medical use, but in fact they are testing it in Attention Deficit- TDAH. They specify this because still is not approved by the FDA or food and drug administration.

M.   iPHONE - iPrescribe

Billed as the "the first and only standalone electronic prescription application for smart phones", iPrescribe allows for easy electronic prescription using an iPhone app.

The app has 3,500 FDA approved medications including available dosages. Once a prescription is entered, the app offers you to save it as a favourite, saving steps the next time the drug is prescribed.

IV.   IPHONE-ILEARNING.

This include all the iPhone applications for learning medicine, including our own applications in i-Anapat, developed by us.

A.   iPHONE Harrison

The Harrison´s manual of Medicine is available for iPhone paying for it.

B.   iPHONE Science Direct

http://catai.net/blog/2010/11/ciencia-en-iphone/

Science Direct can be consulted trugh the iPhone, obviously after registration.

C.   iPHONE Vademecum

The Vademecum is a pay for it application very useful since it include al medications appearing in the Vademecum with composition, indications and dosis.

D.   iPHONE surgery books & other books

Medical Books of all type can be found for iPhone such as: surgery, ophthalmology, dermatology etc.

E.   iPHONE iAnapat

A new iPhone app is being developed at the moment by CATAI. It is dealing with an online exam for training in Pathology (Anatomia Patologica in Spanish) in Medicine in University of La Laguna. This application helps students to test practical exams with images.

The app was developed on Adobe FLASH. New questions are adding to the database at the moment. An image can be enclosed to each question. The questions are corrected when the button "Corregir" is pressed, giving them a message of write or wrong. Another control button is used to move to the next question.

A future connection with the app iPhone Moodle is being considered for this app to improve the teaching possibilities for iPhone apps in the ULL (University of La Laguna).

Figure 19. iAnapat from the University of La Laguna

F. iPHONE Moodle

http://catai.net/blog/2010/07/moodle-iphone-en-sanidad/

The moodle for iPhone had been used in Peru to support continous training of health workers in 20 clinics spread all over and far from cities.

G. iPHONE Dermatology

1) Visual-DX
http://catai.net/blog/2010/11/iphone-y-dss/
A list of images to train in Dermatology.

Figure 20. Visual DX

H. iPHONE Ophtalmology

The University of Missouri Kansas City have developed the "Eye Handbook" (http://www.eyehandbook.com/). This is a free application developed for the iPhone.

Ophthalmic Knowledge Assessment Program (OKAP) study and Ophthalmologic recertification preparation

V. IPHONE-WEB 2.0.

This include the totally uncontrolled applications that provide **iDoctor** and **iPatients**.

A. iPHONE -iDoctor

1) Cloud Nine development
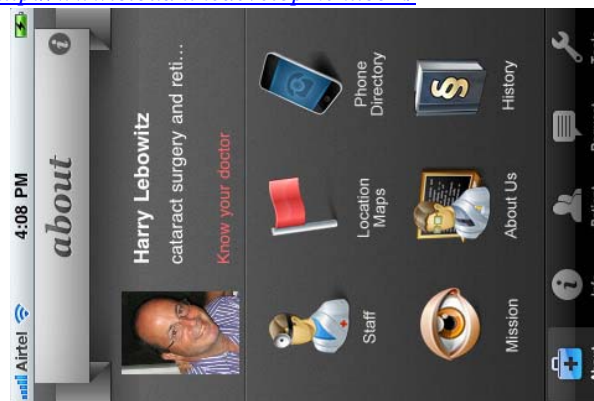http://www.cloudninedevelopment.com/

Figure 21. iMedicine

B. iPHONE -iPatient

Similar to an i-Doctor, patients can create its own collectivity of patients to talk, interact and search common solutions.

C. iPHONE EMR

http://catai.net/blog/2010/10/i-phone-health-passport/

It is an **EMR**, with all functionalities. The **i-phone** Health Passport created by Easy MedMobile allow in any place in the world allow the doctor to access to a patient clinical record and interact with the patient sending SMS reminders or any type of information to acces other doctor or drug-stores.

D. iPHONE -iPatientTouch

http://catai.net/blog/2011/02/patienttouch-iphone-app/

It is developed by *PatientSafe Solutions* and its main goal is to reduce medical errors. With that App, medical personnel can manage and get information from a variety of work processes or work flows through the iPhone. Medical teams can communicate one each other and with other teams on duty, can receive warnings and cruzial information of inmediate diagnosis. At the moment this App is only available at the USA-AppStore and we could not tested yet.

E. iPHONE –PHR (personal health records)

1) mHealth clinical summary
https://store.cerner.com/items/82
https://login.cerner.com

Figure 22. mHealth- Mobile clinical summary

The Cerner systems are the ones https://store.cerner.com/hospitals_and_health_systems/acute_care_electronic_medical_record that facilitate connectivity with the plug & play Careware-iBus mentioned in the introduction.

Furthermore the Cerner applications had been introduced in the Spanish Health-care delivery systems particularly in Valencia as well as in Germany with the Asklepios hospitals. In fact Denia-hospital had received in 2009 the prize to the best international project by CERNER Millennium (http://networkedblogs.com/fto1i). The application is active in 22 countries in 5 continents .

VI. CONCLUSION

The report called "Networks, Digital Healthcare and the Transformation of US Healthcare, 2006-2011″[8] specify that in USA the HIT (Health Information Technology) related industry will increase 8.4% in 5 years evolving from $7.5 billons in 2008 to $11.3 billons in 2013. The health care expenditure will go from 6% of the IGP (Interior Growth product) to 16-18%. This means that in the very near future applications with sufficient quality control will appear in all mobile devices including iPhones, fact already in place since the number of iPhone applications approved by the FDA or having CE are increasing per minutes.

Next generation of Health Care will be no doubt the **i2i-Health** and the **Health 4.0**.

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