6.976 / MAS.965 / SP.716 - Nextlab I

The Emerging Role of Cellphones;
Resource-friendly healthcare

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Existing Technology & Infrastructure

- Old legacy hardware & instruments
- Generally paper notes, static information
- Poor communication channels
- Poor drug storage and supply

- Poor waste disposal
- Poor transport
- Intermittent electricity
- Information shortage
- Skills shortages

What is changing?

- **Over 80% of humans live within range of a cellphone tower**

- **Over 2 billion cellphone subscriptions worldwide**

- **Cellphone usage increasing up to 30% annually***

- **Cost per *flop* dropping analogous to Moore's law**

- **Integrated peripherals increasing every year (Camera, Video, Accelerometer, GPS, larger screens)**

- **Battery storage technology improving every year**

- **Cost per kilobyte dropping every year**

- **Cost of hardware dropping every year**

* (India, 2007)

Map removed due to copyright restrictions.
Tigo's GSM coverage in Guatemala.
http://www.tigo.com.gt/seccion/mapa-de-cobertura-gsm-y-35g

Why particularly cellphones?

- Don't think of it as a phone – it's a mobile hand-held computer with integrated communication and sensors.
- What's unique about this hardware for medical care?
  - **Multi-functional and self-contained**: but parts are no use for other devices; user will not strip it for battery or other uses.
  - **Easy to charge** even when no grid electricity available (can even use wind-up generators),
  - **Easy to hide**, disguise and keep safe (in pocket),
  - **Interchangeable & standardized**,
  - **Easy to replace** – plenty of supply,
  - **No proprietary cabling** to replace (wireless communication)
  - **Significant computational power** in one device! – **A.I.?**
  - **Humans want (*need*) to communicate** – they will ensure that the device is always working and are highly motivated to have it repaired quickly if it is their primary method of communication!

An example: Cervical cancer screening

Issues:

- Skills to read images of cancer are limited (e.g. menopause is difficult to differentiate from cancer)

- 2nd opinion requires a multi-step process to send image & receive feedback

- Patient may have left clinic (and never return) by time diagnosis arrives

- Images can be out of focus over/under-exposed or contain lighting artifacts

Image removed due to copyright restrictions.
Three stages in development of cervical cancer, from
http://www.preventcervicalcancer.ie/what_causes_it.asp.

Peri-urban and rural health care

- ~5 minutes per patient!
- Rapid & accurate evaluation and information retrieval needed

What can cellphones do to help?

- Replace existing cameras for taking and storing images

- Provide instant transmission of images for remote diagnosis

- Archive data for follow-up and quality audits

- Provide training for automated classifiers:
  - *Artificial Intelligence* (AI) can be thought of as the mimicry of complex human task, such as medical diagnosis, by a computer.
  - AI can be achieved through computer algorithms that have been trained on data labeled by humans
  - AI algorithms that have been trained on data labeled by human experts can often be taught to classify similar data as well as the human experts themselves (in less time, and more consistently)

[Balas 2001, Phinjaroenphan *et al* 2004, Tulpule *et al* 2005, Zimmerman *et al* 2006, Luck *et al* 2006, Gordon *et al* 2007]

Usage Scenario

- Standard Smartphone with built-in 5MP+ camera and flash.

- Transmit data to remote website/database

- Multiple experts label images (and parts of images)

- Consensus of experts decides on real classification

- SMS diagnosis and treatment back to doctor

- Patient treated immediately – not lost!

Future directions: Decision support

- After data is labeled, **software is trained** and downloaded to phone

- On-board software will:
    - present image to on-board classification software
    - upload image to remote server with meta-data
    - provide feedback *to* user

- **Feedback** *from* user to improve data set after expert consultation

- Automated back-up of data, **classification accuracy** assessment and **treatment efficacy** tracking

- Users can be encouraged to **improve data collection at the source**; if the algorithm isn't sure, or thinks the image is out of focus or at strange angle, it can ask user to take another picture

Modality of use

- AI can provide instant classification in most cases

- In dubious cases, images can be retaken with software guiding user; in this way, user is trained to take better photos.

- If still unclear, image is referred to multiple experts.

- Expert classifications are folded back into training set and phone software is updated automatically.

- Database can cross-validate in background and detect if changes are occurring in population – Is the disease manifesting in a previously unknown manner? Software can adapt to changes in population over time.

- Software can show user where it suspects the cancerous region may be and provide an explanation of why it is cancerous ("large dark mass") or not ("patient is post-menopausal")

Conclusions

- Potential of **_mobile computing_** is enormous

- Can provide <u>expert diagnosis</u> in an instant

- Will provide a <u>large database</u> of cases to continue improvements of diagnosis, and of allow doctors to track patient's recovery over time

- <u>Low cost</u> and <u>easily maintained</u> technology.

- Very <u>few points of failure</u> (no cables, local hard disks or electricity supply problems)

- System can <u>train local talent</u> and improve local expertise

- <u>Secure Integrated Electronic Medical Record</u> will allow users to keep control of their medical data without worrying about it being lost when they transfer between clinics, see new doctors, or go on holiday.

- **<u>Software-intensive, extensible, resource-light solution!</u>**

Summary – why can this work where before it was difficult?

1. **Driven from within** - cellphones are not being imposed on developing countries - they are self-identified wants/needs.

2. **Users are incentivized to maintain them** (electricity and functionality) as they are their primary communication facilitator after the voice.

3. **Ubiquitous** - it's easy to get a replacement part/phone.

4. **Easy to carry & conceal** and harder to steal than usual

5. **No peripherals or cables required** so there are few points of failure

6. **Backing-up is automatic**, it doesn't require the user to remember or bother.

7. **The platform is intelligent** - it can be programmed in a similar manner to a computer and can assist in diagnosis and training. ***It can teach AND learn***.

8. **Flexible** - can provide a general platform for data gathering and diagnosis/treatment

9. **Extensible to other fields** (e.g. tracking agricultural crop growth/diseases)

Reading List

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