Auscultation with the iPhone

Peter J Bentley

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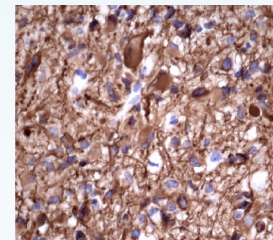http://www.cs.ucl.ac.uk/staff/p.bentley/

DIGITAL BIOLOGY
INTEREST GROUP

- The Digital Biology Group at UCL has a variety of projects related to biological modelling and bio-inspired computing.

- Today I'll describe two projects with medical applications:

- **Computer Assisted Neuropathology**

 and

- **Auscultation with the iPhone.**

Brain tumours are a common cause of cancer death. There were 4,471 cases of brain tumour diagnosed in the year 2001 in the United Kingdom alone.

Neuropathological diagnosis is required prior to treating almost all human brain tumours. Unfortunately diagnosis depends on a small number of specialist neuropathologists (less than one per million population in the UK), relying on subjective visual interpretation of histological slides.

In addition, the difficulty and potential danger in removing tissue from the brain means that often only very small quantities of tumour are available for assessment.

Malcolm Galloway

The development of computer aided diagnostic and prognostic assessment techniques could contribute to significant improvements to the management of patients with brain tumours.

This work focused on the development of a preliminary computational tool for automated analysis of brain tumors that exploits consistent quantitative measures to improve reliability.

Hassan, M. S., Bentley, P. J. and Galloway, M. (2006) Support Vector Machines for Computer Assisted Diagnostic Neuropathology. In Proc. of *CBMS 2006, the 19th IEEE International Symposium on Computer-Based Medical Systems. Salt Lake City, Utah*.
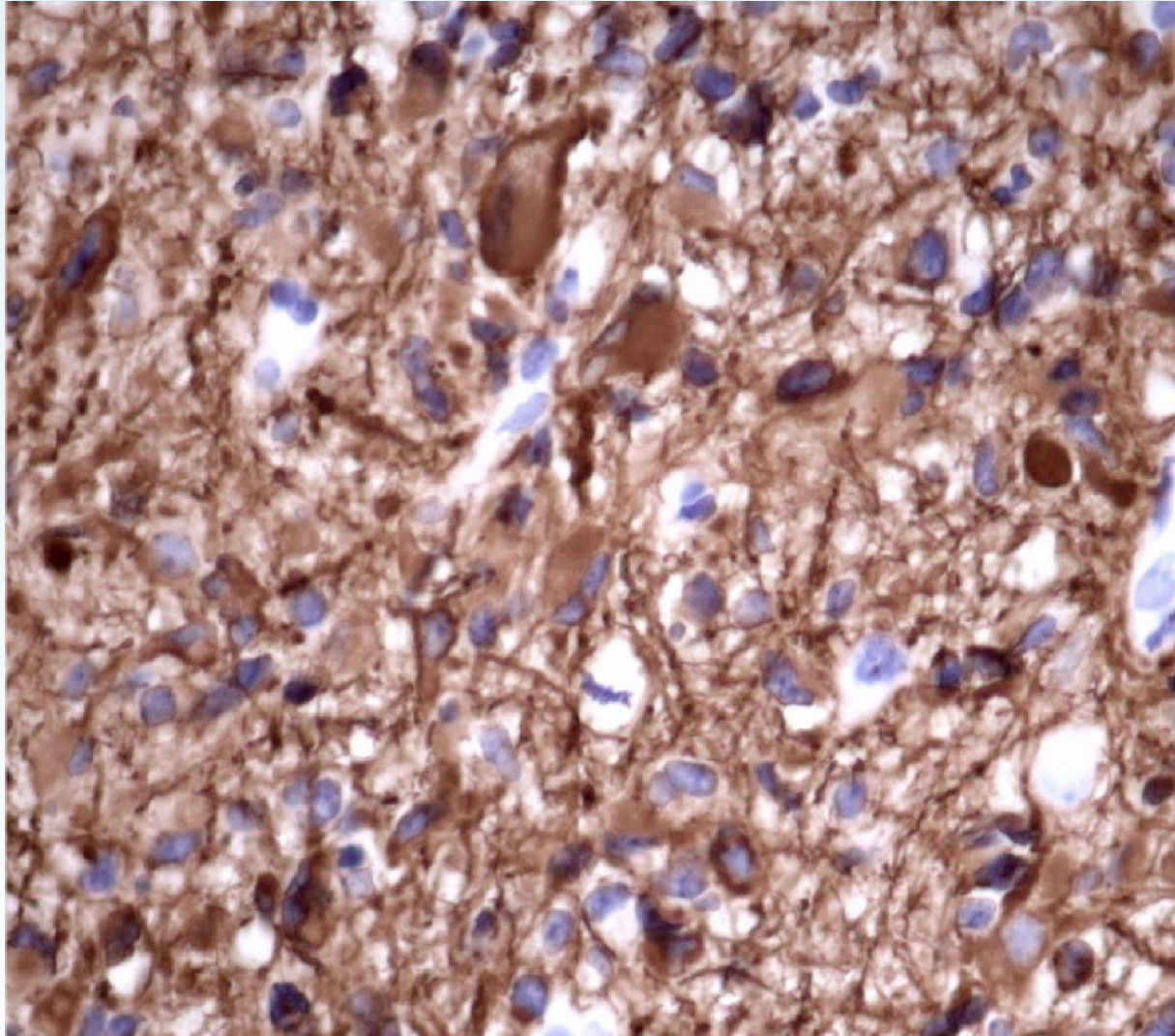
- In the first step all the input images are resized (reduced) to a size of 1300 X 1030 pixels using bicubic interpolation.

- A graphical user interface is used to select pixels from several features to be analysed in the image. These values are then used to compute a threshold value for the image.

- The minimum and maximum values of the RGB values of the user-selected pixels are used to calculate the range. Any pixel having all three of the RGB values in the range of minimum to maximum is considered to be the object pixel and is set to white, whereas all other pixels are considered to be part of background and set to black
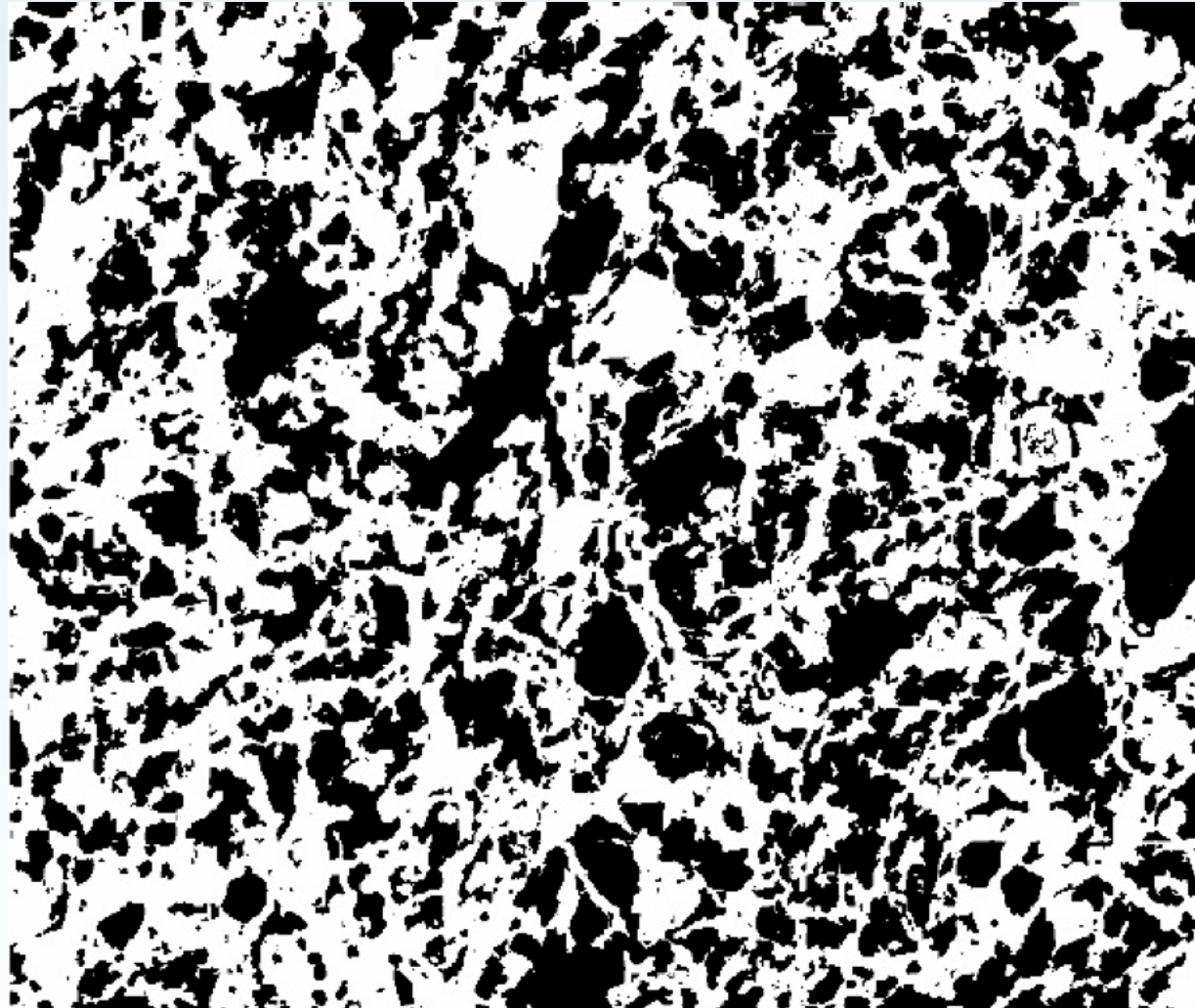
- The thresholded binary image is then processed using morphological operators to close any narrow gaps within the focal area and to eliminate small objects:

- *Erosion* is used to remove small objects and then *closing* is used (dilation followed by erosion), to fill any small gaps and fuse narrow breaks left within the regions of the focal area.

- Filtering is then used to remove any salt and pepper noise left in the image after thresholding and application of erosion and closing. A median filter using a 5x5 matrix of all ones gives the best result in these images.

- The canny edge detection method is used for boundary detection.
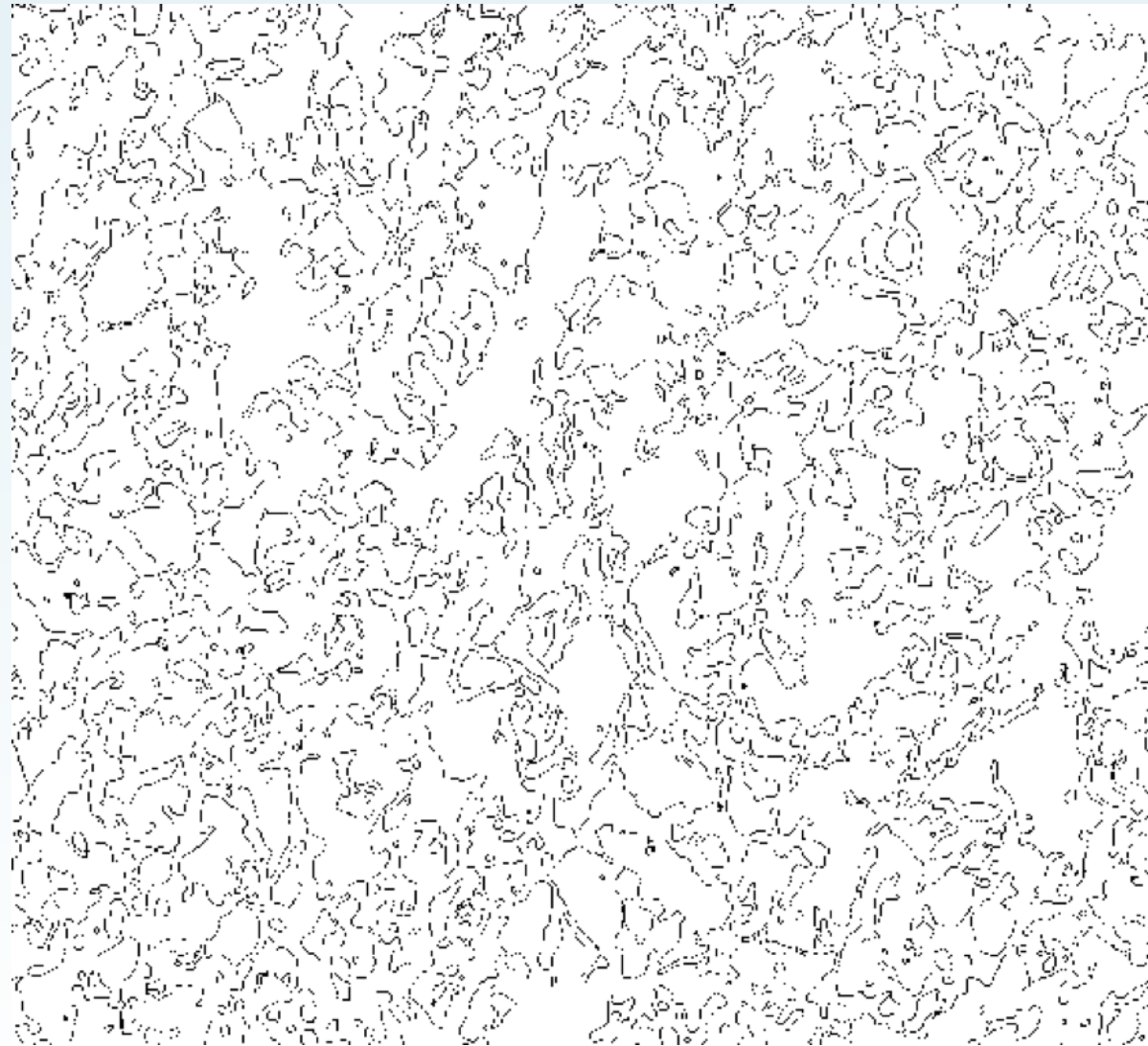
- Textural, topological and fractal features provide information about spatial interdependency and intensity based features and morphological features provide information about intensity of the pixels in the images.

- The use of features at tissue level does not require segmentation at cellular level.

- Three features were found to be most useful for classification:

- The *fractal dimension*, which measures the degree of self similarity and space filling properties of the object,

- *Compactness,* which measures the irregularity and

- *Co-occurrence matrix* which provides a measure of the degree of pixel invasiveness. These three features together give a relatively broad quantitative measure of the input images.

- The classification subsystem is an essential part of this computer assisted diagnosis system.
- Given a set of features, this subsystem must differentiate between malignant and normal cells.
- Support vector machines were used to make the classification subsystem.

- The basic steps involved in support vector machine learning are
1. Conduct simple scaling on the data and then normalize it.
2. Consider a kernel function to train the support vector classifier.
3. Use cross-validation to find the best parameter values (evaluation).
4. Use the best parameter values to train the whole training set.
5. Test.

- Data was collected from biopsy samples of ten different patients with three images for each patient's biopsies, at three different magnifications (x10, x20 and x40).

- An example image was shown earlier. As should be evident, the noise and variation in the images can make identification enormously difficult, even for trained neuropathologists.

- Out of 10 samples, 6 were from patients with glioblastoma multiforme (a malignant astrocvtic tumour) and 4 were from control cases of patients without astrocytic tumours (in total there were 18 images of malignant biopsies 12 images of non-malignant biopsies).

- The best overall system performance was obtained by the polynomial kernel using all features.

- The polynomial kernel is flexible in terms of its margin, i.e., it is a soft margin classifier.

- With a sensitivity of 0.9444 and specificity of 0.75, in 94% of the cases this approach correctly diagnosed a patient suffering from glioblastoma multiforme and in 75% of the cases it gave correct negative results for patients not suffering from an astrocytic tumour.

- None of the features obtained during the feature extraction phase can, on their own, make a highly reliable computer-assisted diagnostic system for neuropathology.
- This work showed that using combinations of features a more reliable system can be built with improved sensitivity and specificity.
- Neuropathology is a tremendously challenging area of medicine to work in. In this research we have showed the beginnings of a computer-assisted diagnostic system, which employs support vector machines using a second order polynomial kernel, with three features extracted from biopsy images: fractal dimension, compactness, and a co-occurrence matrix.
- Although the development of a system that can replace clinical neuropathology is unlikely in the foreseeable future, we believe that with appropriate development, computer-assisted diagnostic tools have the potential in the future to contribute to the care of patients with suspected brain tumours

iStethoscope Pro by Peter J Bentley, available in iTunes AppStore

- According to the World Health Organisation, cardiovascular diseases (CVDs) are the number one cause of death globally: more people die annually from CVDs than from any other cause.

- An estimated 17.1 million people died from CVDs in 2004, representing 29% of all global deaths. Of these deaths, an estimated 7.2 million were due to coronary heart disease.

- Any method which can help to detect signs of heart disease could therefore have a significant impact on world health.

- The iPhone application *iStethoscope* was developed at UCL two years ago. The app performs real-time amplification and filtering, providing the ability for the general public to sample their heart sounds with quality as good as or better than commercially available digital stethoscopes.

- **iStethoscope Pro real-time audio processing:**

- Audio sampling from microphone input
- Records last 8 seconds continuously
- Four separate filtering modes
- Each filtering mode has adjustable low pass, high pass filters and amplification settings.
- (Also fifth mode: mapping of accelerometers to tones.)

- **iStethoscope Pro offline audio processing:**

- Fast Fourier Transform and animated Spectrogram display combined with playback of last 8 seconds of audio
- Email audio and spectrogram image

- **Real time low-pass filter:**
- y(t) = y(t-1) + (x(t)-y(t-1)) / *Alpha*

- **High-pass filter:**
- y(t) = (y(t-1) + x(t)-x(t-1)) / *Beta*

- **Automatic Volume Control:**
- The filters are dynamically adjusted when input volume is excessive; the adjustments fade back to user settings after a couple of seconds.

- **Pulse detector (earlier versions):**
- Using heuristics about heartbeat "lub-dub" sounds, pulse rate was auto-detected and displayed. (Difficult to obtain consistent accuracy across various devices, body types and listening expertise, so discontinued.)

- Sample frequency and input to output delay are user-defined values

- Fast Fourier Transform to show spectrogram
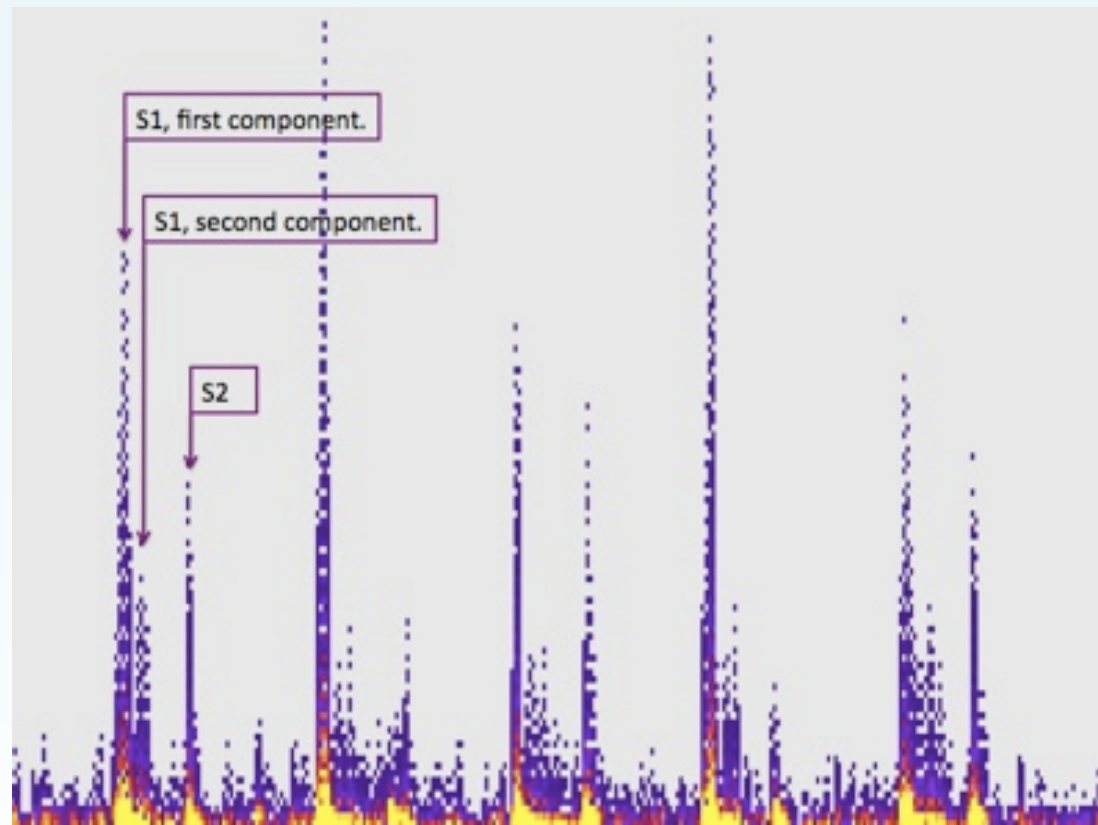
- Cardiologist Glenn Nordehn (Midwestern University, Chicago College of Osteopathic Medicine):

- "I have worked for years on heart sound collection and analysis - the iStethoscope app is amazingly good in its ability – amazing."

- "I would check the warnings on iPhones with regard to holding them close to pacemakers and other devices and add a warning to the iStethoscope app."

- "Overall, if we can create a safe-to-collect system, store the data, . . . , we can likely do a great benefit to the overall health of many people. Auscultation of the heart is my main 'thing' - physicians are not good at doing auscultation."

- **http://pascallin2.ecs.soton.ac.uk/Challenges/**
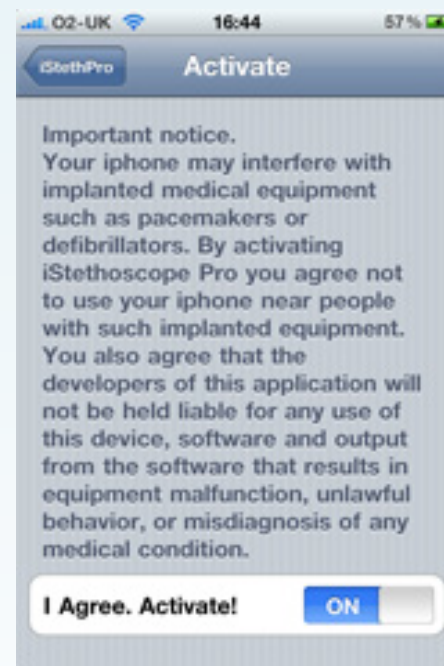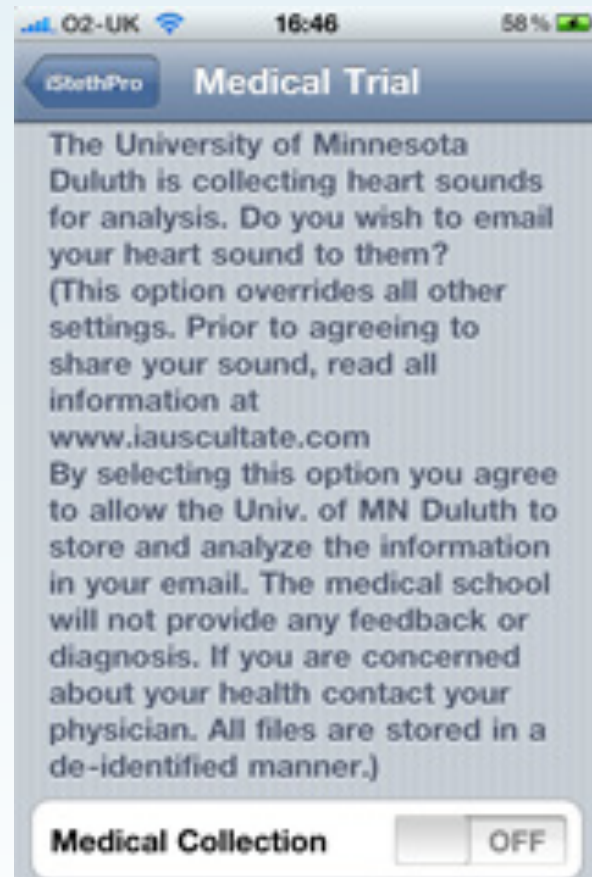
- A "medical trial" option enables users to email his server with their heart audio.

- Nordehn obtained ethical permission to store automatically anonymised heart audio files and enable them to be used for machine learning research.

- The resulting database containing heart sounds sent by members of the public will be used for a machine learning challenge.

- The purpose of this challenge is to attempt to automate the expertise of cardiologists using machine learning, by classifying heart sounds into classes corresponding to specific medical conditions.
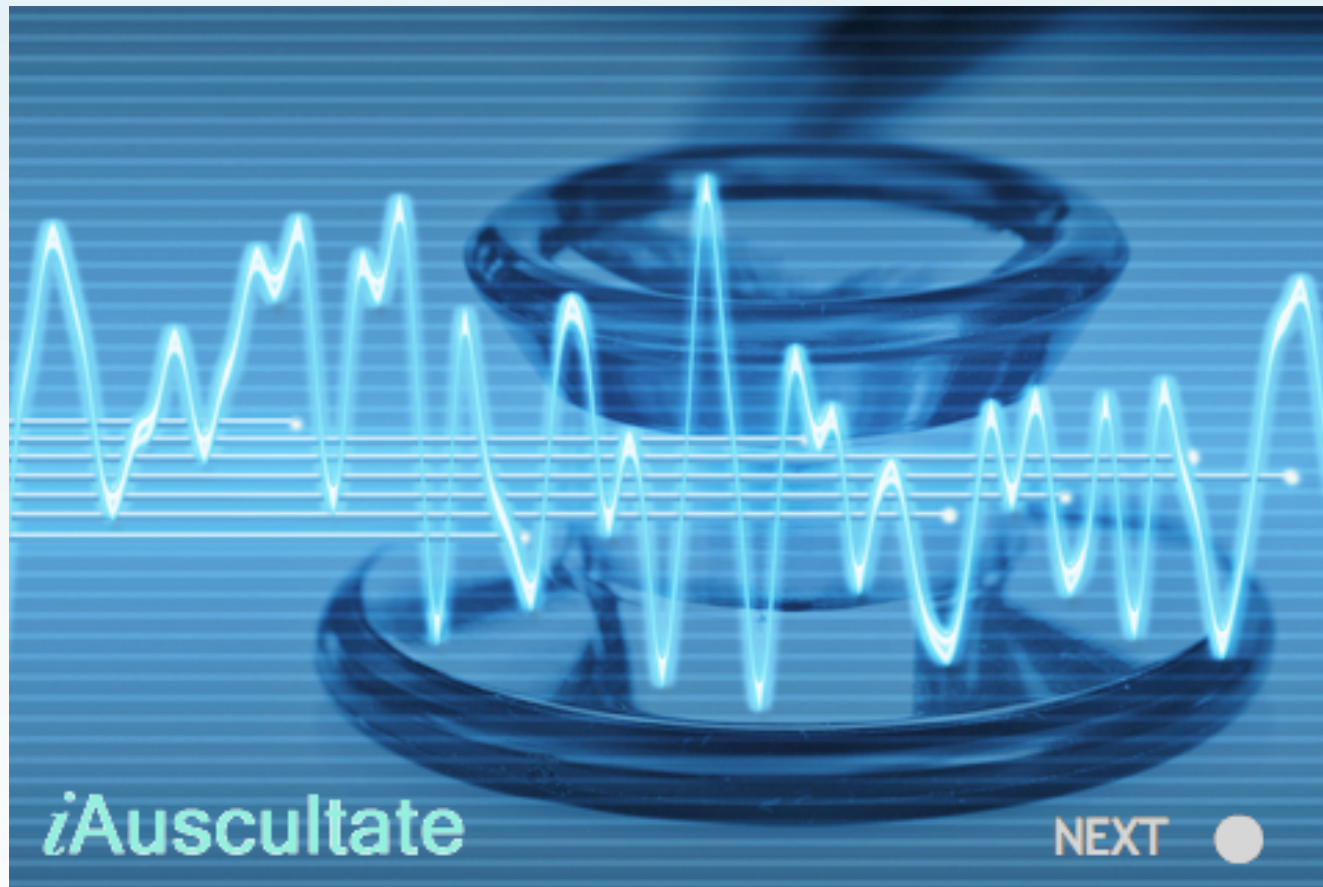
Objective:
Improve auscultation skills.

Method:
You will learn nine common heart sounds in this educational exercise. You will play one sound's video (with audio) for 200 seconds, take a 10 minute break, and replay the same sound's video for another 200 seconds. You will then proceed to the next sound.

Rationale:
The display of images while each sound plays makes it easier to remember the characteristics of each sound. The two 200-second listening sessions allow the user to absorb the sounds—again, this makes it easy to learn and remember the meaning of the sound.

For best results, you should complete the entire program within a 48 hour time period.

NEXT ●

Artificial Neural Network Analysis of Heart Sounds Captured From an Acoustic Stethoscope and Emailed Using iStethoscopePro

ABSTRACT

Dustin Palm
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Itasca Community College

Glenn Nordehn

Valvular heart disease is a significant problem. The primary care physician initially does assessment through auscultation. Accuracy in classification of sounds is suboptimal (20–40%). Technological advances have paralleled an increase in referral for Doppler echocardiography and a decrease in auscultatory skill. An increase in the referral of functionally innocent heart murmurs has contributed to the increasing cost of care. A computer-aided analysis has been shown to improve the accuracy of primary care

THE INDEPENDENT

December 14, 2009

59p stethoscope on iPhone proves a hit
By Jeremy Laurance

The stethoscope, the 200-year-old accessory without which no doctor is complete, could soon be replaced by the humdrum mobile phone.

A computer scientist who wrote a program that turns an Apple iPhone into a stethoscope has made a major advance in medical technology and created a sensation among heart specialists. The application, called iStethoscope, was developed as a "bit of fun", and has become a runaway success after being downloaded millions of times by users across the world.

Cardiologists say the software has saved lives and brought specialist expertise within reach of patients in remote parts of the world. Heart sounds can be recorded and emailed to doctors anywhere for an expert opinion.

Peter Bentley, a researcher who developed the application in the computer science department at University College, London, said he was amazed by the response.

"The idea began as an experiment," he added. "I had a new, popular science book out last year and I wanted to see if I could tell people about the book using a free iPhone application that did something useful.

"It was intended as a fun toy but to my astonishment it was downloaded by several million people all over the world in the first six months. Then I started receiving emails, phone calls and visits from cardiologists all over the world. They said it worked better than commercially available digital stethoscopes. They were tremendously excited. One flew over from the US just to discuss it with me."

The cause of the doctors' excitement was that the audio quality from the iPhone was far superior to that from digital stethoscopes. Mobile phones are a huge market compared with digital stethoscopes, and economies of scale mean they are made with better hardware.

Responding to requests from specialists, Mr Bentley extended the application to allow heart sounds to be recorded, emailed and analysed. The application costs 59p to download, but cardiologists say it does a better job than equipment costing thousands of times as much.

Glenn Nordehn, a US cardiologist researcher and specialist in digital stechoscopes at the University of Minnesota, said: "This is the best thing to come around in terms of medical equipment for a very long time. [His] closest competitor charges about 3,000 times as much"

Mr Bentley is now working on further iPhone applications, such as an electrocardiogram reader. "This is the way everyone wants to go," he said.

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iStethoscope by Peter J Bentley, available in iTunes AppStore

FDA U.S. Food and Drug Administration

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FDA Home > Medical Devices > Databases

Medical Device Exemptions 510(k) and GMP Requirements

Introduction

Following is a breakdown of 510(k) exempt and Good Manufacturing Practice (GMP)/Quality System exemptions listed by device class. All devices in this list are 510(k) exempt unless further qualified by a footnote. Only devices annotated by (*) are also exempt from GMP except for general recordkeeping requirements and compliant files.

Class I Devices

FDA has exempted almost all class I devices (with the exception of Reserved Devices from the premarket notification requirement, including those devices that were exempted by final regulation published in the *Federal Registers* of December 7, 1994, and January 16, 1996. Some 510(k) exemptions annotated with "\#\" are with certain limitations as noted in the footnotes. It is important to confirm the exempt status and any limitations that apply with 21 CFR Parts 862-892. Limitations of device exemptions are covered under 21 CFR xxx.9, where xxx refers to Parts 862-892.

If a manufacturer's device falls into a generic category of exempted class I devices as defined in 21 CFR Parts 862-892, a premarket notification application and FDA clearance is not required before marketing the device in the U.S. However, these manufacturers are required to register their establishment and list the generic category or classification name. Registration and listing information is submitted by using FDA's Unified Registration and Listing System (FURLS)/ Device Registration and Listing Module (DRLM) at:
http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/HowtoMarketYourDevice/RegistrationandListing/ucm053185.htm

IMPORTANT NOTE: Only the class I devices with an asterisk (*) are also exempted from the GMP regulation, except for general requirements concerning records (820.180) and complaint files (820.198), **as long as the device is *not* labeled or otherwise represented as *sterile*.**

Class II Devices

The Food and Drug Administration (FDA) has also published a list of class II (special controls) devices (those devices are annotated as "(II)"), subject to certain limitations, that are now exempt from the premarket notification requirements under the Food and Drug Administration Modernization Act of 1997 (the Modernization Act). FDA believes that these exemptions will relieve

Questions?

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