

DIY Earthquake Detector: The software side

自製地震探測器：軟件篇

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Movement detection

移動檢測 (1/2)

- We will be introducing three software-only ways for detection of movements.
我們將介紹三種只用軟件檢測器件運動的方法。
- For the sake of diversity, three different approaches on three different software environments are introduced.
我們會介紹了在三個不同軟件環境上的三種不同的方法，以使內容多元。

Movement detection

移動檢測 (2/2)

- We will be introducing methods that are useful for building a DIY earthquake detector.
我們將介紹可用於自製地震探測器的方法。
- Makes use of hardware that comes with computers and mobile phones.
利用電腦和手機本已有的硬件。
- Specialized hardware are not needed.
毋需專門的硬件。

What to expect 有甚麼期待

- Participants are expected to exercise their creativity to design and implement a solution to the earthquake detection problem.

參賽者應運用他們的創造力來設計和實施地震檢測問題的解決方案。

- No complete solution will be presented in this talk.

這次講座將不會提供完整的地震檢測方案。

- Yet, the techniques presented are relevant.

然而，我們將簡介相關的技術。

The software 軟件

- We will be using **Processing** to process video from a digital video camera, **Pure Data** to process sounds from a microphone, and **HTML5** with **JavaScript** to process accelerometer data on a smart phone.
我們會用 **Processing** 處理和分析視頻資訊，用 **Pure Data** 處理咪高風來的聲音，和用 **HTML5** 和 **JavaScript** 處理智能手機的加速度計資訊。
- Note that these tools and environments are quite general, and are not limited to do what we are going to introduce.
這些工具和環境並非只能做到我們將要介紹的東西。
- e.g., Processing can be used for audio processing as well.
例如，Processing 也可以用作處理聲音。
- You are suggested to study what are possible in each environment to find out more.
我們建議閣下研究每個工具和環境的可能性，以了解更多。

Part 1: video camera-based movement detection

第1部分：利用攝像機檢測物件移動

Looking at a scene

看場景

- Suppose we take a video of an stationary object with constant lighting. The video would be like a photo where nothing changes.
假設我們拍攝具有恆定照明的靜止物體的視頻。視頻就像一張沒有什麼變化的照片。
- That is, in every frame of the video, the content is the same.
也就是說，視頻內每幀圖片，內容都是相同。

Spot the differences!

(1)

考眼力，
找不同！



Image difference 兩圖差距

- Differences are highlighted in red. 差距以紅色表示。



What if an object moves?
有物件移動時會怎樣？

Spot the differences!

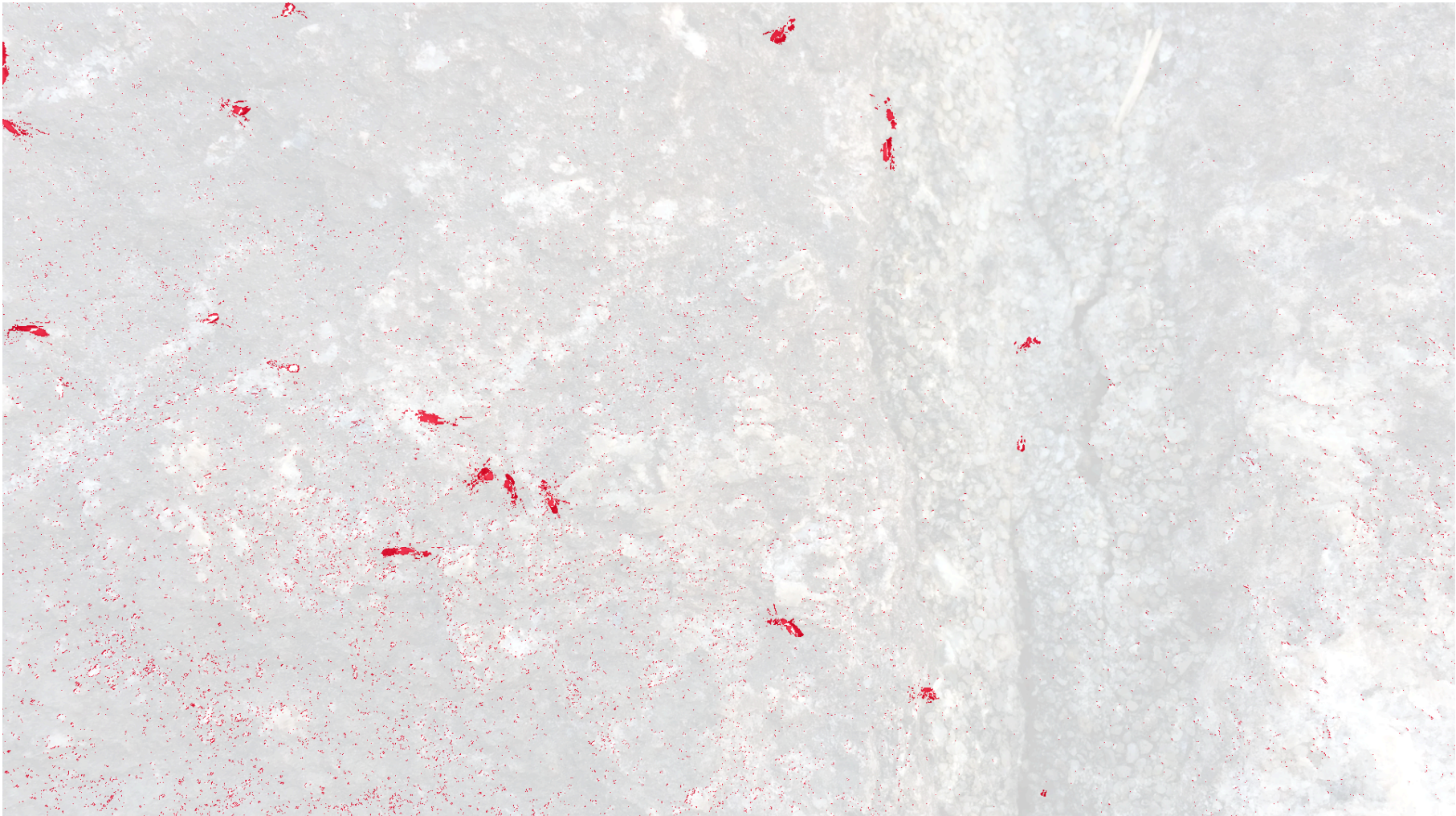
(2)

考眼力，
找不同！



Image difference 兩圖差距

- Differences are highlighted in red. 差距以紅色表示。



When there is change...

當有轉變時...

- When there is any change, consecutive frames of the video will not be the same in content.
當有任何轉變時，視頻的相鄰幀的內容會不同。
- i.e., the difference between contents of consecutive frames will be non-zero.
即是說，兩相鄰幀的內容差距不是零。

What would cause a change in the scene?
有甚麼會令到拍攝的內容改變？

Some reasons 一些原因

- Movement of objects. 有東西移動。
- Movement of camera. 攝影機移動。
- Change in lighting. 光線改變了。

How can we detect the change?

我們怎樣偵測改變？

- Compare the current frame to the previous frame to see if there is any difference.
比對此幀圖像和上一幀的分別。
- How to make it into a program?
如何將這變成程式？
- We need to first understand how image is represented in a computer.
我們需要先理解圖像是如何在電腦內表示的。

Digital image representation

數碼圖像表示

- A picture is a two-dimensional matrix of pixels.
一幀圖片是一個二維的像素矩陣。
- The values of a pixel at an (x,y) position tells the colour shade. 在矩陣 (x,y) 的數目代表顏色深淺。

Grayscale 灰階圖像

255	255	0	255	255
255	0	127	0	255
0	127	255	127	0
255	0	127	0	255
255	255	0	255	255

RGB image RGB 圖像

Red plane Green plane Blue plane

255	255	0	255	255
255	0	127	0	255
0	127	255	127	0
255	0	127	0	255
255	255	0	255	255

255	255	0	255	255
255	0	127	0	255
0	127	255	127	0
255	0	127	0	255
255	255	0	255	255

255	255	0	255	255
255	0	127	0	255
0	127	255	127	0
255	0	127	0	255
255	255	0	255	255

Screen coordinate system

屏幕坐標系統

- x-axis goes to the right, y-axis goes downwards.
x 軸指向右，y 軸指向下。
- Top left-hand corner has coordinates (0,0)
左上角坐標為 (0,0)。

	0	1	2	3	4	→ x
0	255	255	0	255	255	
1	255	0	127	0	255	
2	0	127	255	127	0	
3	255	0	127	0	255	
4	255	255	0	255	255	

↓
y

How to compare two pictures?

如何比較兩圖內容？

- Comparing two pictures is to compare two matrices of scalars (grayscale images) or vectors (RGB images).
比較兩張圖片就是比較兩個純量（灰階圖像）或向量（RGB圖像）的矩陣。
- We aim at defining a function that takes two images as input and output a number that tells how different they are.
我們的目標是定義一個以兩張圖像作為輸入，而輸出一個表示兩圖不同的程度的數字函數。

Some image difference functions (1/2)

一些圖像差函數 (1/2)

- Sum absolute error (SAE) : the sum of the absolute differences of pixel values at the same position.

絕對誤差和 (SAE) : 相同位置像素值的絕對差的和。

$$SAE(A, B) = \sum_x \sum_y |A_{x,y} - B_{x,y}|$$

- Mean absolute error (MAE): SAE divided by the number of pixels, to normalize effect of image size.

平均絕對誤差 (MAE) : SAE除以像素數，以歸一化圖像大小的影響。

$$MAE(A, B) = \frac{1}{||x|| ||y||} \sum_x \sum_y |A_{x,y} - B_{x,y}|$$

- (Note that we deliberately abuse the notation $||x||$ to mean the number of possible x's to make the equation simpler.)
(我們特意濫用 $||x||$ 來表示總共有多少個可能的 x 數，以簡化方程式。)

Some image difference functions (2/2)

一些圖像差函數 (2/2)

- Mean square error (MSE) : the mean of the square of differences of pixel values at the same position.

均方誤差 (MSE) : 在相同位置處的像素值的差的平方的平均值。

$$MSE(A, B) = \frac{1}{\|x\| \|y\|} \sum_x \sum_y (A_{x,y} - B_{x,y})^2$$

- Root mean square error (RMS error): Square root of MSE, to make dimension of the error value the same as that of pixel values.

均方根誤差 (RMS誤差) : MSE的平方根，使得誤差值的維數與像素值的維數相同。

$$RMSE(A, B) = \sqrt{\frac{1}{\|x\| \|y\|} \sum_x \sum_y (A_{x,y} - B_{x,y})^2}$$

How about colour images?

彩圖又怎樣？(1/3)

- The scalar difference $A_{x,y} - B_{x,y}$ in the image difference functions has to become a function that takes two vectors and return a scalar $d(A_{x,y}, B_{x,y})$, since A and B are now vectors representing colours. 因為現在 A 和 B 是代表顏色的向量，圖像差函數內的純量差 $A_{x,y} - B_{x,y}$ 需變成一個取兩個顏色向量，回一個色差純量的函數 $d(A_{x,y}, B_{x,y})$ 。
- The simplest is the Euclidean distance between the two RGB vectors. 最簡單的是兩個 RGB 顏色值向量之間的直線距離。

$$d(A, B) = \sqrt{(A_R - B_R)^2 + (A_G - B_G)^2 + (A_B - B_B)^2}$$

How about colour images?

彩圖又怎樣？(2/3)

- Since RGB does not model human perception well, Euclidean distance between two RGB values is not good to tell the difference between two colours.
因 RGB 不是人類顏色感知的好模型，兩 RGB 色的直線距離並不是表示色差的好方法。
- Other colour spaces such as $Y' C_B C_R$, $L^* a^* b^*$, $L^* u^* v^*$ are used for colour difference calculations.
我們很多時用其他色彩空間（如 $Y' C_B C_R$, $L^* a^* b^*$, $L^* u^* v^*$ ）的距離來表示色差。
- You are referred to the references for more information.
詳情請閱參考文獻。

How about colour images?

彩圖又怎樣？(3/3)

- You can also convert RGB colour values to grayscale before finding the difference. What is the problem of this approach?
你亦可將 RGB 色彩空間的顏色轉成灰階再作比較。
這方法有什麼問題？

Let's plan our program! Algorithm first. 準備編程了！先設計算法。

- Calculate the difference between the current frame and the previous frame.
計算此幀圖像和上一幀的差異。
- Issue alert if the difference is large enough.
如差異夠大，發出警告。

Write pseudocode

編寫偽代碼

- Write the scaffold of the program.
編寫程式的支架。

- Repeat
 - ◆ Get a frame `current_frame` from video camera.
 - ◆ Calculate difference between `current_frame` with `previous_frame`.
 - ◆ Alert user if the difference is large enough.
 - ◆ Set `previous_frame` to `current_frame`.

Write pseudocode

編寫偽代碼

- Handle boundary conditions and details.
處理邊界條件和細節。

main_program:

- ◆ **threshold** = a constant to be determined by experiment
- ◆ Get a frame **previous_frame** from video camera.
- ◆ Repeat
 - Get a frame **current_frame** from video camera.
 - **d** = **distance(current_frame, previous_frame)**.
 - If (**d** > **threshold**) alert user.
 - Set **previous_frame** to **current_frame**.

distance(A, B):

- **total** = 0
- for each pixel **pa** in A
 - ◆ **pb** = corresponding pixel in B
 - ◆ **total** = **total** + **d(pa, pb)**
- **total** = **total** / (number of pixels in A)
- return **total**

Real programming: Processing

真的編程了：用 Processing

- Software environment: Processing.
軟件開發環境為 Processing.

<https://processing.org/>



- Most updated version: version 3.2.3, released 2016-11-07

最新版本：2016-11-07 更新的 3.2.3.

- It is cross-platform and can run on the OS X, Windows, and Linux.

它是個跨平台的軟件開發環境，可在OS X，Windows，和Linux運行。

More about Processing

關於Processing

- Processing is a programming environment for manipulating images, animations, and interactions. Processing 可用作處理圖像，動畫和人機互動設計。
- It integrates with the programming languages Java and JavaScript, and can be deployed as Java applications, on the web with HTML5 and WebGL support, or as Android applications. 它利用Java和JavaScript的編程語言，可產生出獨立運作的Java應用程式、在支援HTML5和WebGL的瀏覽器上使用的網頁、或Android應用程式。

Learning Processing

學習 Processing

- Tutorials

<https://processing.org/tutorials/>

- Reference

<https://processing.org/reference/>

Implementing our program

寫我們的程式

- We need to process video frames from camera. Download a library for that.
需要處理影像。下載函式庫以獲支援。

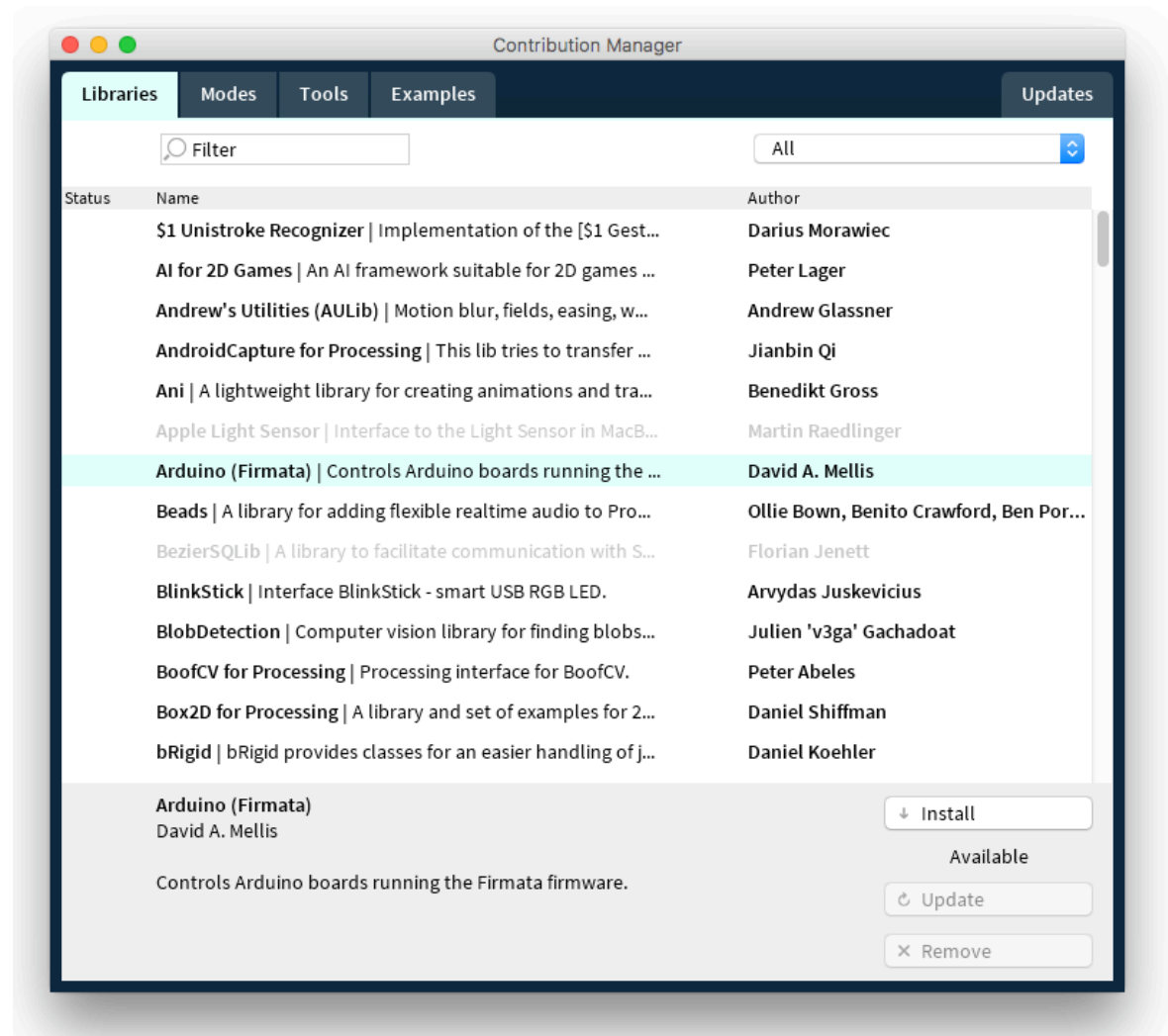
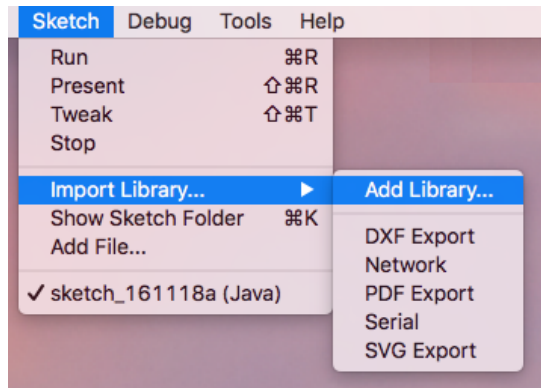
main_program:

- ◆ **threshold** = a constant to be determined by experiment
- ◆ Get a frame **previous_frame** from video camera.
- ◆ Repeat
 - Get a frame **current_frame** from video camera.
 - **d** = **distance(current_frame, previous_frame)**.
 - If (**d** > **threshold**) alert user.
 - Set **previous_frame** to **current_frame**.

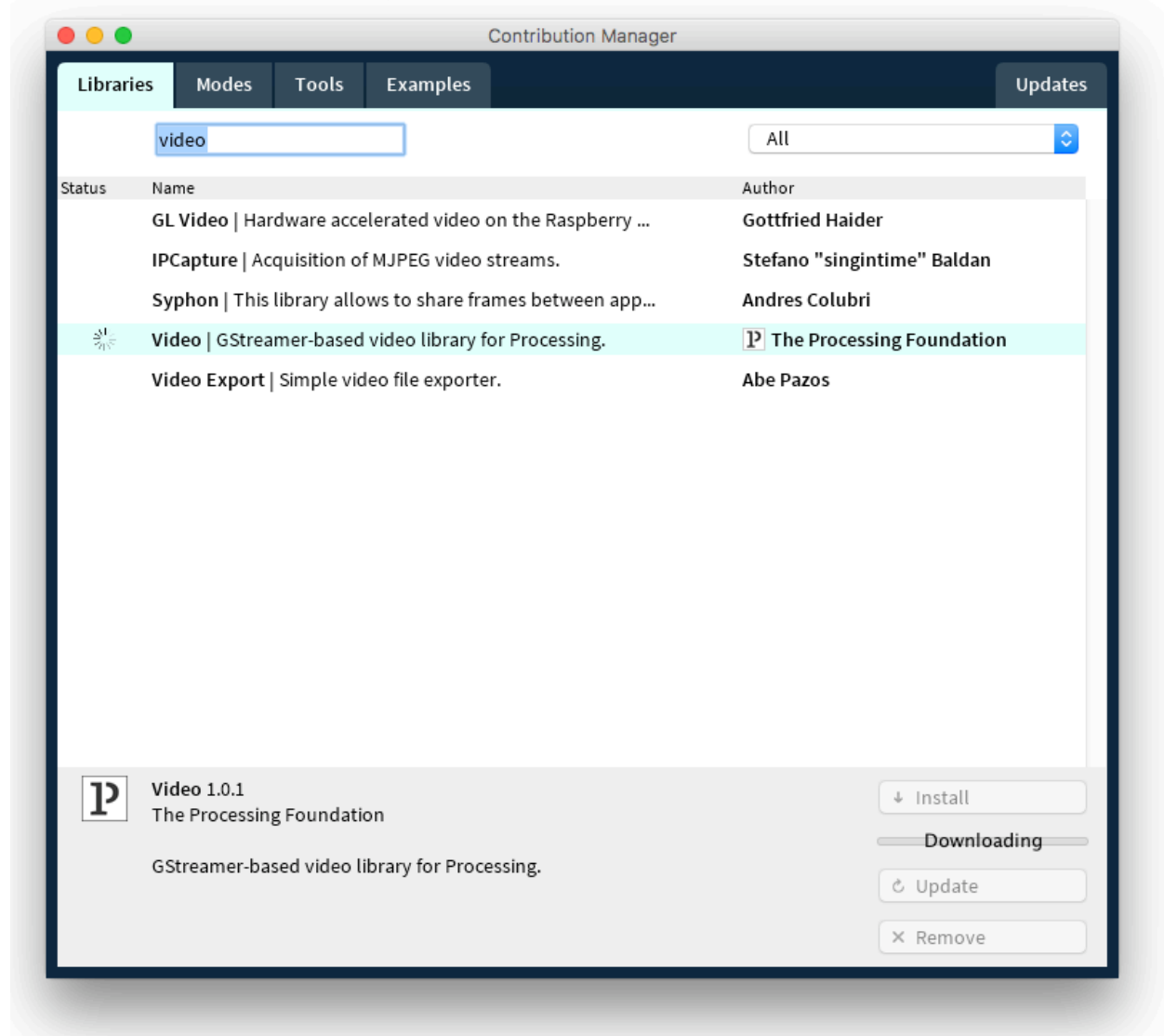
distance(A, B):

- **total** = 0
- for each pixel **pa** in A
 - ◆ **pb** = corresponding pixel in B
 - ◆ **total** = **total** + **d(pa, pb)**
- **total** = **total** / (number of pixels in A)
- return **total**

Downloading library 下載函式庫



Downloading library 下載函式庫



References 參考文獻 (1/2)

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Charles Poynton
John Wiley & Sons, 1996
ISBN 0-471-12253-X
- The Rehabilitation of Gamma
Charles Poynton
Human Vision and Electronic Imaging III, Proceedings of SPIE/
IS&T Conference 3299 San Jose, California, 1998-01-(26–30).
- Color FAQ.
Charles Poynton
<http://www.poynton.com/ColorFAQ.html>

References 參考文獻 (2/2)

- The SLL Lighting Handbook
The Society of Light and Lighting
Feb 2009, ISBN 9781906846022
- The Movies in Our Eyes
Frank Werblin and Botond Roska
Scientific American, April 2007
 - ◆ An article about how visual information is processed in multiple dimensions
- Sight for Sore Eyes
Alison Snyder
Scientific American, March 2007

Part 2: audio processing

第2部分：音頻處理

Listen to that sound!

聽這聲吧！

- Glasses clink and crockery clashes at a Modified Mercalli Intensity Scale of IV.

http://www.hko.gov.hk/gts/quake/mms_e.htm

修訂麥加利地震烈度 IV 時，門、窗、碗碟發出響聲。緊靠的玻璃及陶瓷器皿叮噹作響。

http://www.hko.gov.hk/gts/quake/mms_c.htm

- Let's see if computers can recognise that sound.
讓我們看看電腦能否識別這種聲音。

Software to use: Audacity

軟件：Audacity

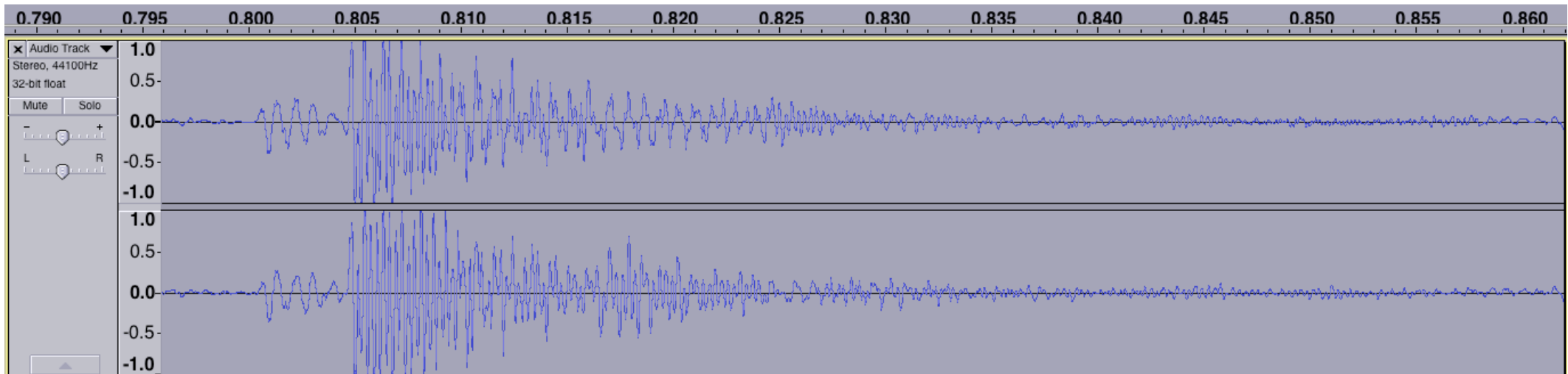


- <http://www.audacityteam.org/>
- Audacity is free, open source, cross-platform audio software for multi-track recording and editing.
Audacity 是自由、免費、開源及跨平台的多軌錄音和編輯音頻軟件。
- Latest version 2.1.2, available in Windows, Mac OS X / macOS, and Linux.
最新版本為 2.1.2, Windows, Mac OS X / macOS 和 Linux 皆可用。

Digital sound representation

數碼聲音表示方法

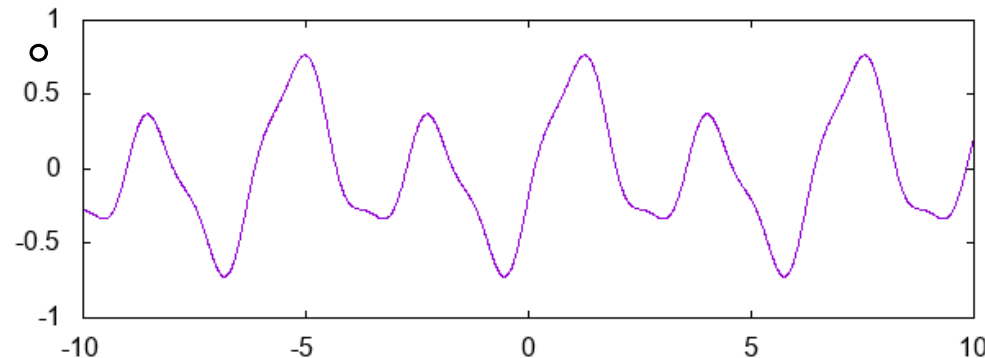
- Sounds are recorded as waveforms.
聲音以波形記錄。



Digital sound representation

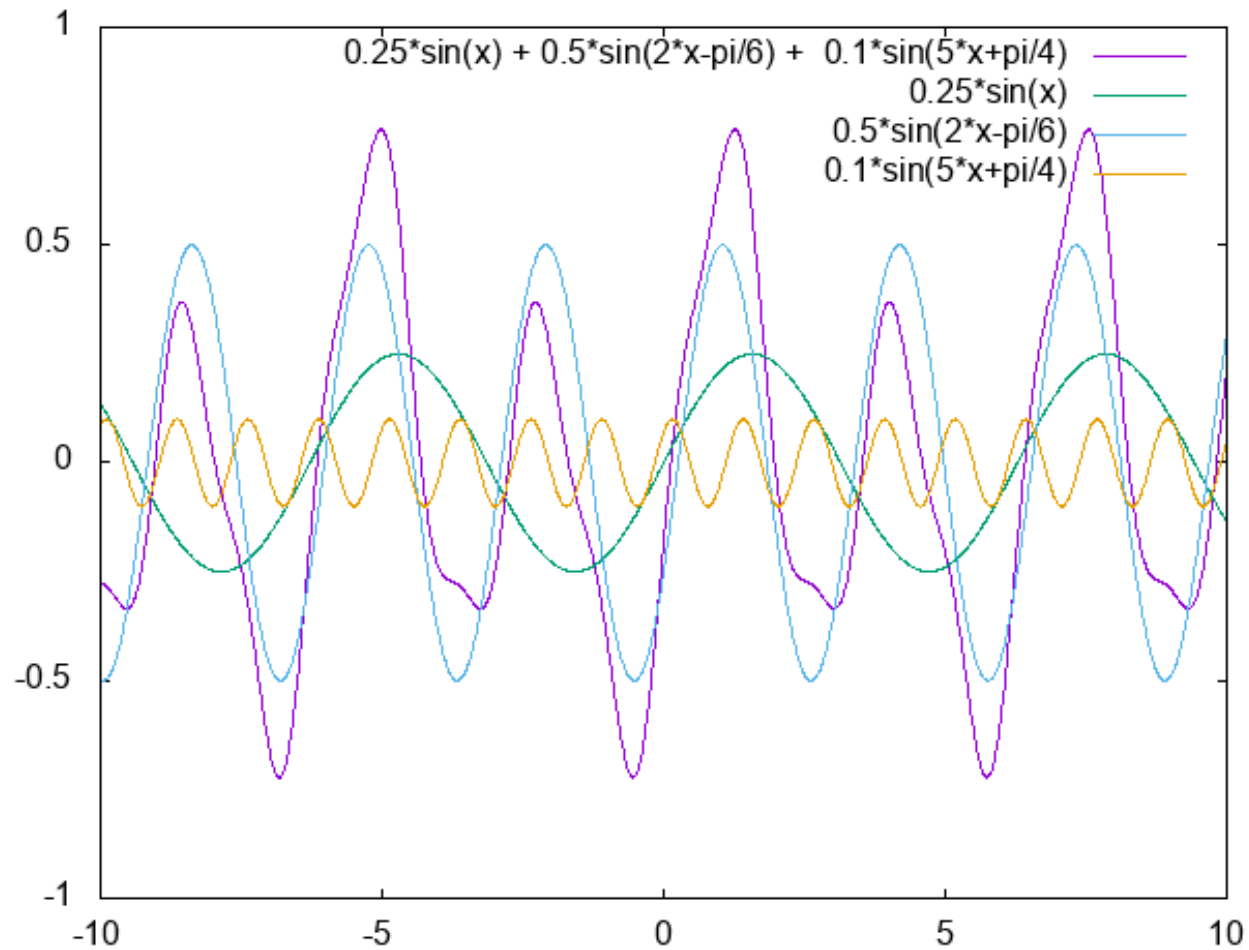
數碼聲音表示方法

- Human brain analyses frequencies in sounds.
人腦分析聲音的頻率。
- Any time domain waveform can be seen as a superimposition of many waveforms of different frequencies and amplitudes.
任何時域波形都可以看作是由許多不同頻率和幅度的波形疊加而成



Superimposition of waves

波形疊加



Finding the component waves

找出疊加的波形

- The component waves of a waveform can be found using Fast Fourier Transform (FFT).
可以使用快速傅立葉變換找到一個波形的分量波。
- Time domain to frequency domain conversion.
時域至頻域的轉換。

Finding the component waves

找出疊加的波形

- Any time domain signal $x(n)$ for $n=0, 1, \dots, N-1$ can be written as the sum of a series of complex sinusoid signals:

任何時域波形 $x(n)$ $n=0, 1, \dots, N-1$ 可寫成一系列複數
正弦信號之和：

$$x(n) = \sum_{k=0}^{N-1} c(k) e^{2\pi k n i / N}$$

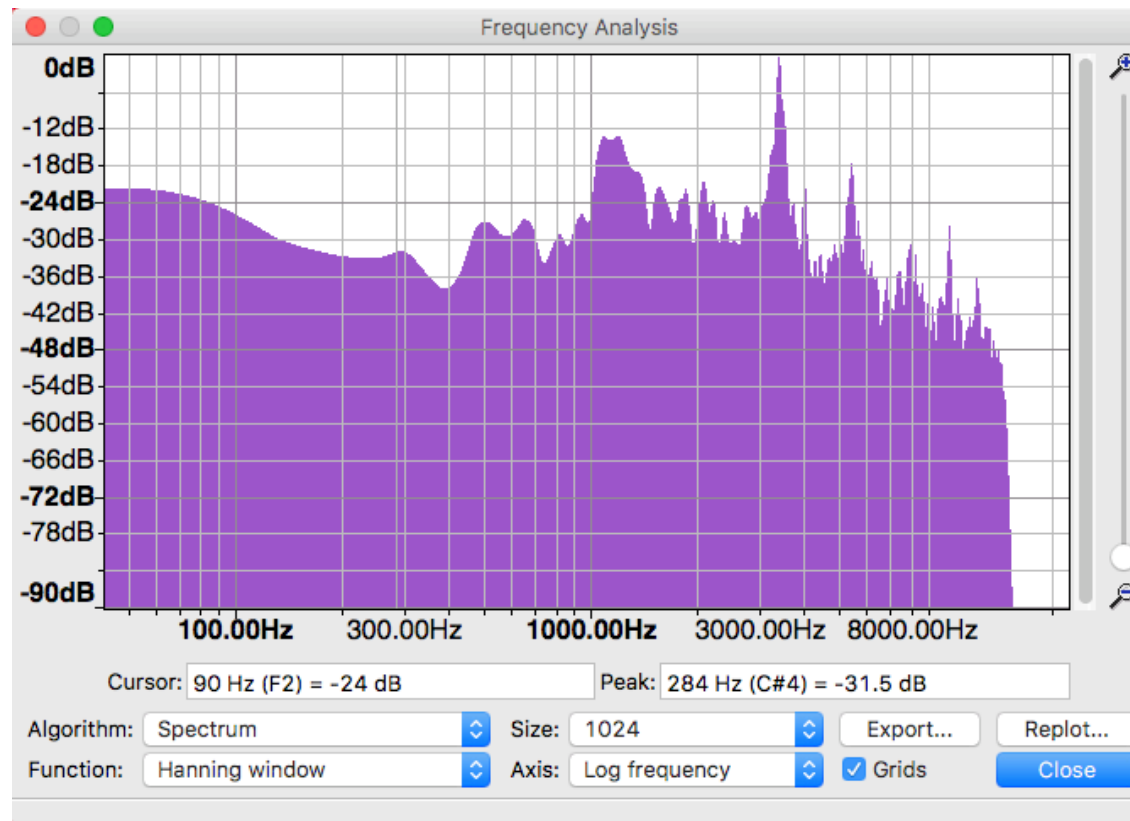
- $c(k)$ can be found using FFT:
 $c(k)$ 可用 FFT 找出：

$$c(k) = \frac{1}{N} \sum_{n=0}^{N-1} x(n) e^{-2\pi k n i / N}$$

Digital sound representation

數碼聲音表示方法

- The FFT results can be plotted as a spectrum.
FFT 的結果可以被繪製為頻譜。

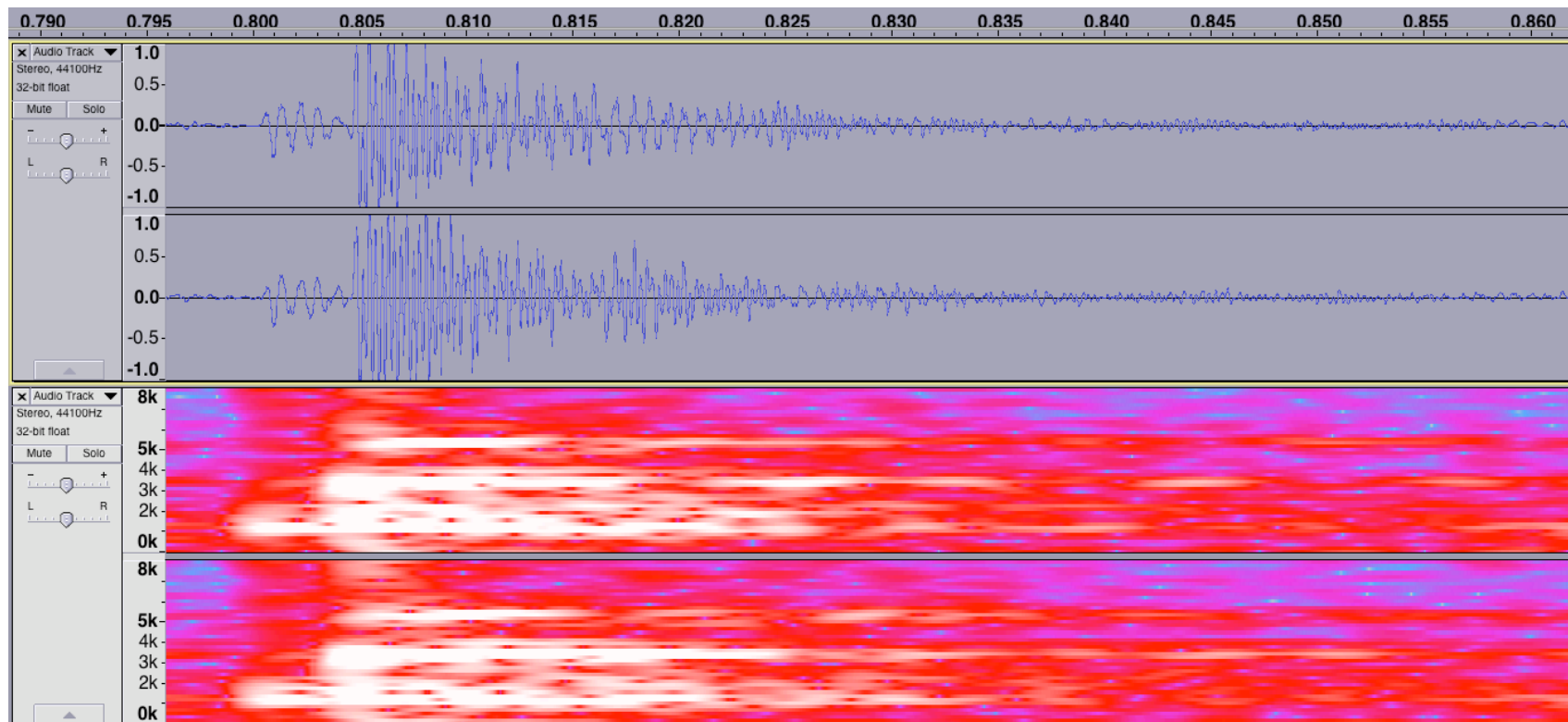


Spectrogram / sonograph

時頻譜 / 聲像

- Repeated spectral analysis of windows of waveform generates a spectrogram or sonograph.

時頻譜（聲像）以重複分析一個波形不同段落的頻譜製成。



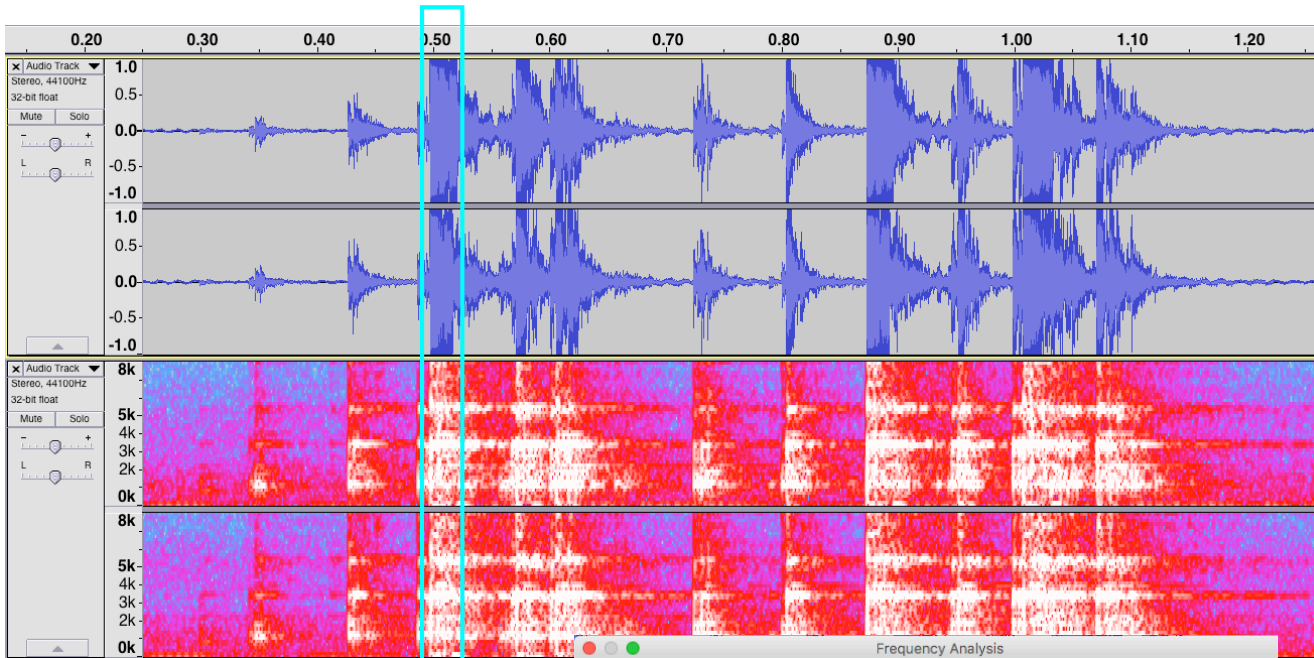
Spectral and time resolutions

頻率和時間分辨率

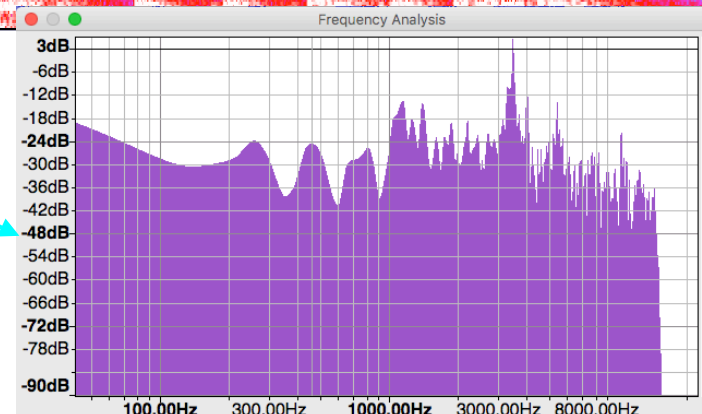
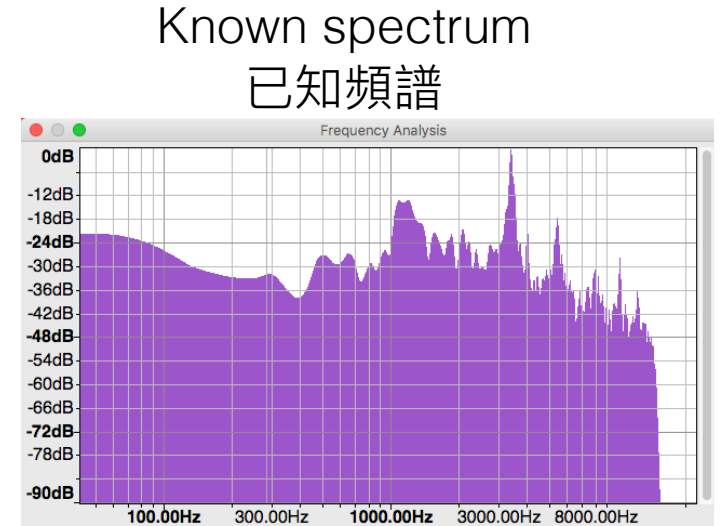
- Spectral resolution = sampling frequency / analysis window length
頻率分辨率 = 採樣頻率 / 分析窗口長度
- Highest frequency analysed = sampling frequency / 2
最高分析頻率 = 採樣頻率 / 2
- Time resolution = analysis window length / sampling frequency
時間分辨率 = 分析窗口長度 / 採樣頻率

Crockery clashes...

陶瓷器皿叮噹作響...



Spectral analysis
頻譜分析



How similar are they?
它們有多相似？

Programming environment: Pure Data

編程環境：Pure Data



- <http://puredata.info/>
- Pure Data (aka Pd) is an open source visual programming language that can run on anything from personal computers and Raspberry Pis to smartphones (via libpd, pddroidparty, and Rjdj).
Pure Data (又名 Pd) 為開源可視化編程語言，可於個人電腦以至樹莓派和智能電話上運行（利用 libpd, pddroidparty, 和 Rjdj）。

Visual programming in Pure Data

Pure Data 的可視化編程環境

- Enables musicians, visual artists, performers, researchers, and developers to create software graphically without writing lines of code.
使音樂家、視覺藝術家、表演者、研究人員和開發人員無需編寫代碼，而以圖像方式創建軟件。
- Music synthesis and audio analysis made easy.
音樂合成和音頻分析變得容易。
- Similar commercial product 類似的商業軟件：Max
<https://cycling74.com/products/max>

Learning resources 學習資源

- Tutorial: Programming Electronic Music in Pd
<http://www.pd-tutorial.com/english/index.html>
- Documentation
<http://puredata.info/docs>

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E. Brigham
Pearson, April 1988
ISBN 978-0133075052
- Digital Signal Processing: Principles, algorithms, and applications
John G. Proakis and Dimitris G. Manolakis
Maxwell McMillian, 1992
ISBN 0-02-946378-5
- Digital Processing of Speech Signals
Lawrence R. Rabiner and Ronald W. Schafer
Prentice-Hall, Sep 1978
ISBN 978-0132136037

Part 3: Processing accelerometer data using HTML5 and JavaScript Web API

第3部分：使用HTML5和JavaScript Web API處理加速度計數據

Sensors in smart phones

智能手機內的傳感器

- Smart phones often have sensors built-in.
智能手機通常內置傳感器。
- Since smart phones are programmable, they make good devices for detection of earthquake motion.
由於智能手機可編程，它們可用於檢測地震引起的運動。
- Two main smart phone operating systems: iOS and Android.
兩大智能手機作業系統：iOS 和 Android。

iOS software development

iOS 軟件開發

- <https://developer.apple.com/>
- Languages 編程語言：Swift 3, Objective C
- Integrated development environment 整合開發環境：Xcode 8.1
- Developer resources 開發者資源：
<https://developer.apple.com/develop/>

iOS: Relevant application programming interfaces (APIs)

iOS: 相關應用程序介面

- Class `CMMotionManager`

<https://developer.apple.com/reference/coremotion/cmmotionmanager>

- For accessing accelerometer, gyroscope, magnetometer, and device motion data of the iOS device.
以取得加速度計、陀螺儀、磁力計和 iOS 設備移動的數據。

- Event Handling Guide for iOS

https://developer.apple.com/library/content/documentation/EventHandling/Conceptual/EventHandlingiPhoneOS/motion_event_basics/motion_event_basics.html

Android software development

Android 軟件開發

- <https://developer.android.com/>
- Languages 編程語言：Java
- Integrated development environment 整合開發環境：Android Studio 2.2
- Developer resources 開發者資源：
<https://developer.android.com/develop/>

Android: Relevant application programming interfaces (APIs)

Android: 相關應用程序介面

- Classes `SensorManager`, `Sensor`, `SensorEvent`, and `SensorEventListener` in package `android.hardware`
<https://developer.android.com/reference/android/hardware/SensorManager.html>
- For accessing accelerometer, gyroscope, magnetometer, and device motion, temperature, light, and proximity data of the Android device.
以取得加速度計、陀螺儀、磁力計、Android 設備移動、溫度計、光度計、近距傳感器的數據。
- Sensors Overview.
https://developer.android.com/guide/topics/sensors/sensors_overview.html

Any cross-platform solution? 有否跨平台的方案？

- Smart phone browsers are starting to support Web API.
智能手機瀏覽器開始支援 Web API。
- Sensors on the smart phone can be accessed via a web page.
可以通過在智能手機上訪問網頁讀取和分析傳感器資訊。
- Languages 編程語言：JavaScript
- Web markup languages 網絡標記語言：HTML5, CSS

Web: Relevant technologies and application programming interfaces (APIs)

Web: 相關技術和應用程序介面 (1/2)

- JavaScript at Mozilla Developer Network
<https://developer.mozilla.org/en-US/docs/Web/JavaScript>
- Web API: DeviceMotionEvent
<https://developer.mozilla.org/en-US/docs/Web/API/DeviceMotionEvent>
- Web API: DeviceOrientationEvent
<https://developer.mozilla.org/en-US/docs/Web/API/DeviceOrientationEvent>
- Web API: DeviceAcceleration
<https://developer.mozilla.org/en-US/docs/Web/API/DeviceAcceleration>

Web: Relevant technologies and application programming interfaces (APIs)

Web: 相關技術和應用程序介面 (2/2)

- HTML: The Living Standard
<https://developers.whatwg.org/>
- HTML 5.1
<https://www.w3.org/TR/html51/>
- Cascading Style Sheets Level 2 Revision 1 (CSS 2.1) Specification
<https://www.w3.org/TR/CSS2/>

Architecture for solution

解決方案的架構

- Host HTML, CSS and JavaScript files of a sensor data analysis page in a web site.
將傳感器數據分析頁面的HTML，CSS和JavaScript文件放上網站。
- Put the smart phone with sensors in an environment with external power supply. Visit the web page for data analysis.
安排智能手機接駁外置的電源。訪問網頁進行數據分析。