



# MATLAB 程式設計入門篇

## 音訊讀寫、錄製與播放

(Audio Reading, Writing, Recording, and Playback)

---

張智星 張智星 (Roger Jang)

台大資訊系 多媒體檢索實驗室

CSIE/NTU, MIR Lab

# 音訊的基本介紹

- 聲音訊號 (**Audio Signals**) 簡稱音訊, 泛指由人耳聽到的各種聲音的訊號。
- 音訊的基本聲學特徵
  - 音量 (**Volume**): 聲音的大小稱為音量, 又稱為力度、強度 (**Intensity**) 或是能量 (**Energy**)。音量越大, 代表音訊波形的震幅越大。
  - 音高 (**Pitch**): 聲音的基本頻率 (**Fundamental Frequency**) 越高, 代表音高越高 (例如女高音的歌聲); 反之, 聲音的基本頻率越低, 代表音高越低 (例如男低音的歌聲)。
  - 音色 (**Timbre**): 音訊波形在每個週期內的變化, 就形成了此音訊的音色。不同的音色即代表不同的音訊內容, 例如不同的字有不同的發音, 或是不同的歌手有不同的特色, 這些都是由於音色不同而產生。
- **Demo via CoolEdit**

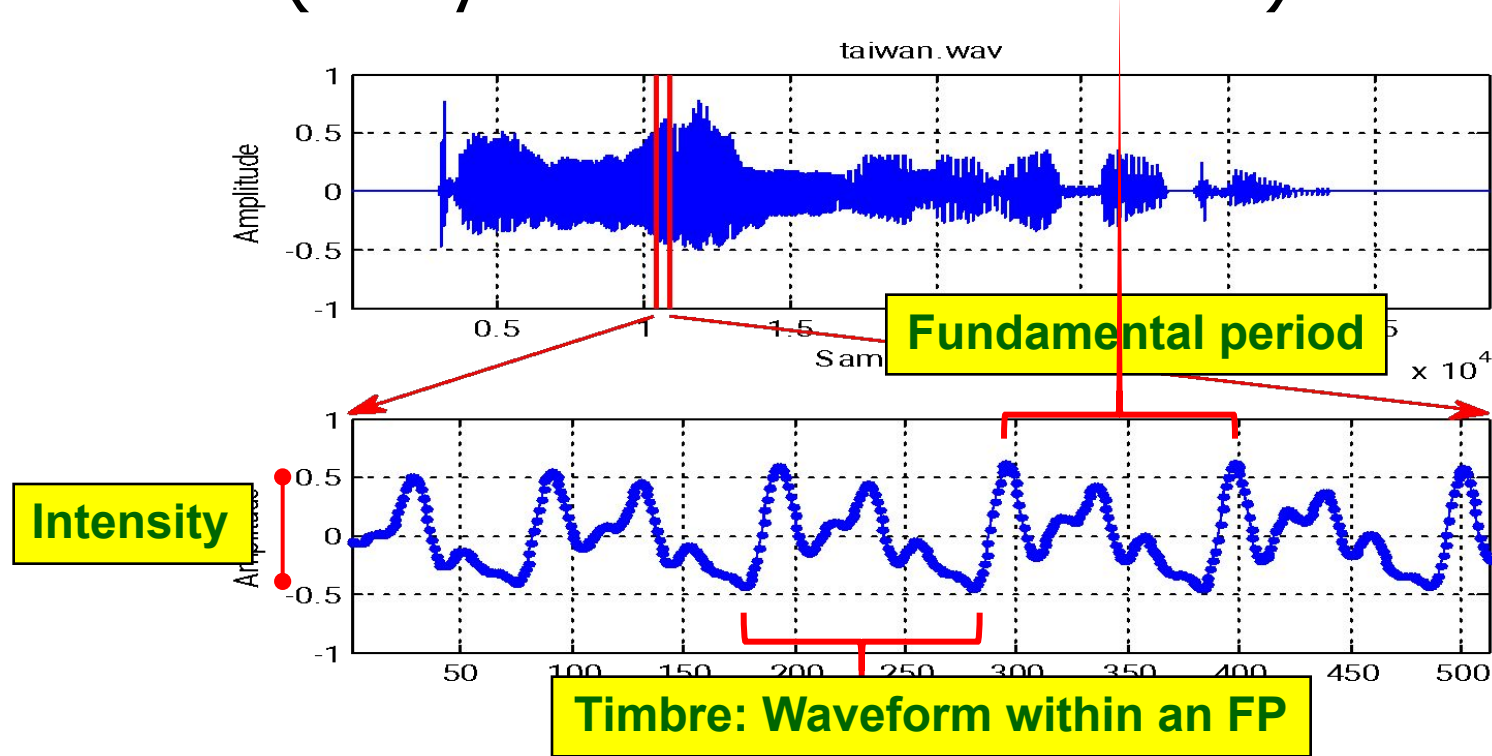
# Basics about Audio Signals

- Audio signals: signals that are audible to human
- Basic **perceptible acoustic features** of speech
  - Volume (音量): the amplitude of audio signals
    - Also known as intensity, or energy.
  - Pitch (音高): Fundamental frequency (the number of fundamental periods in a second) in audio signals.
    - Usually males have a lower pitch while females have a higher one
  - Timbre (音色): Waveform inside a fundamental period.
    - Different vowels have different timbres
    - Different singers also have different timbres.
- Demo via CoolEdit

Quiz!

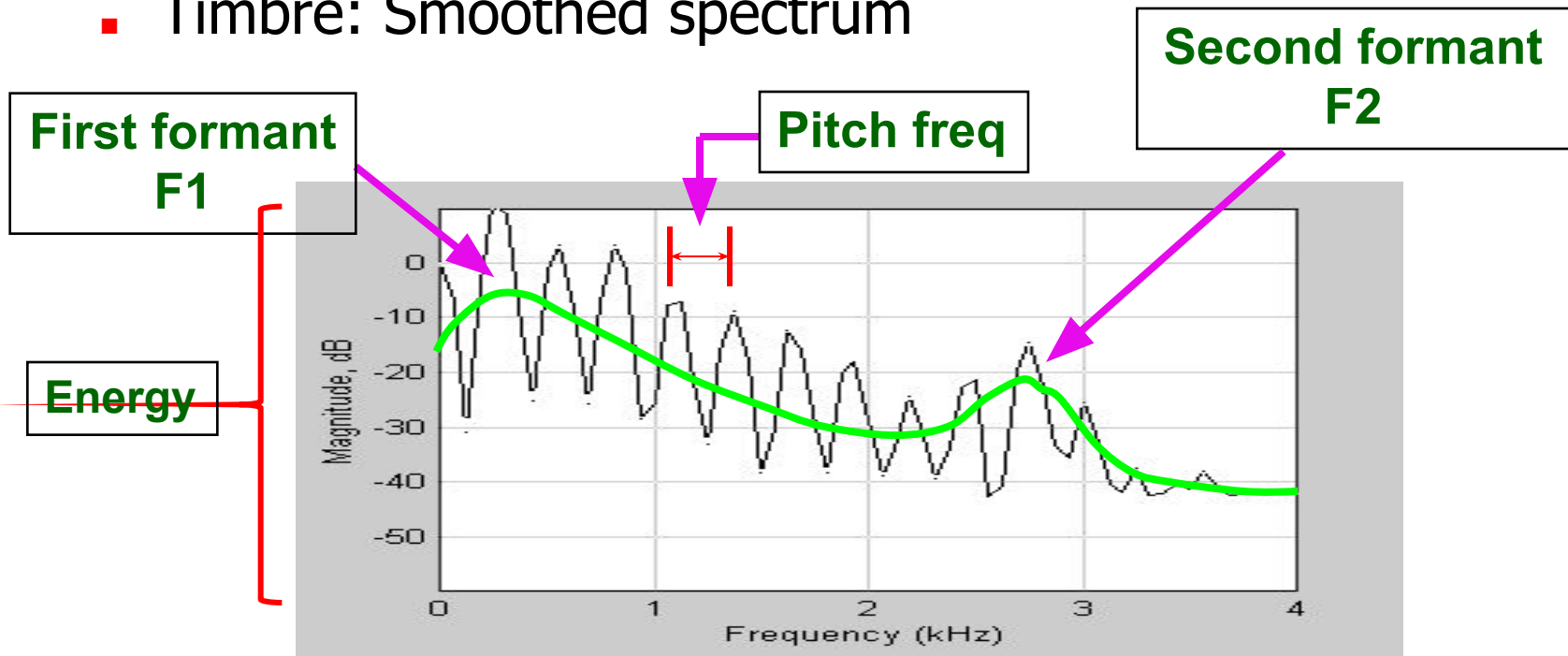
# Time-domain Features

- Time-domain audio features presented in a frame (analysis window of 20-40 ms)



# Frequency-domain Features

- Frequency-domain audio features in a frame
  - Energy: Sum of power spectrum
  - Pitch: Distance between harmonics
  - Timbre: Smoothed spectrum

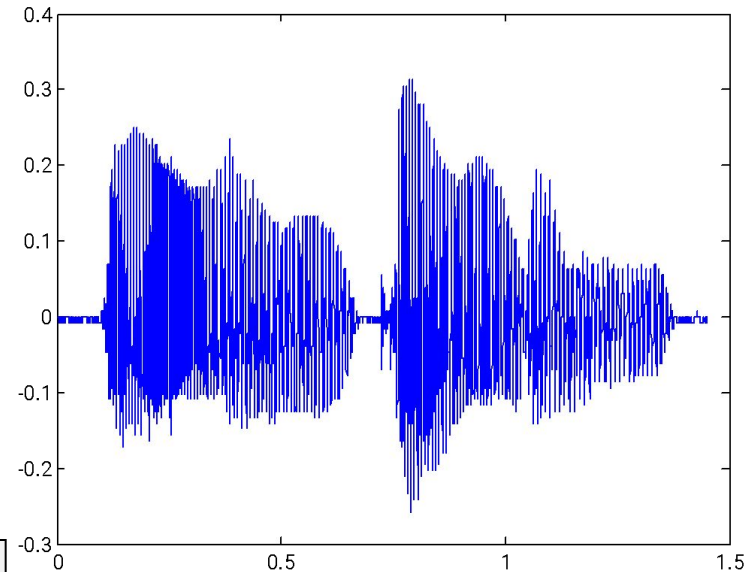


# 音檔的讀取、寫檔與播放

- 使用 `audioread` 讀取 `wav` 檔案，畫出音訊的波形並播放此音訊：
  - `audioRead01.m`

```
[y, fs]=audioread('welcome.wav');  
sound(y, fs);      % 播放此音訊  
time=(1:length(y))/fs;  % 時間軸的向量  
plot(time, y);      % 畫出時間軸上的波形
```

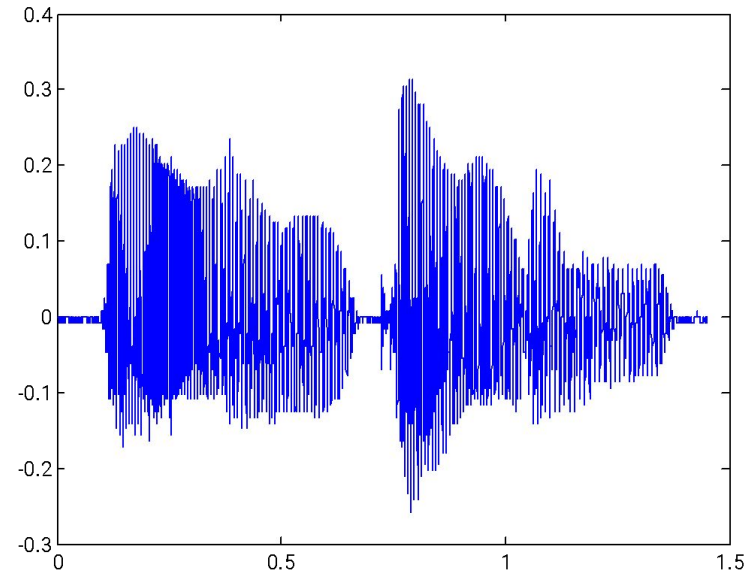
放大波形後即可看到基本週期！



# Read, Write and Playback

- Use "audioread" to read a .wav file, plot its waveform and play the sound.
  - audioRead01.m

```
[y, fs]=audioread('welcome.wav');  
sound(y, fs);           % Playback  
time=(1:length(y))/fs;  % Time vector  
plot(time, y);         % Waveform display
```



Enlarge to see  
fundamental periods!

# Read Metadata from .wav Files

- Reading metadata
  - info=audioInfo('file');
  - Different types of audio files may return different fields of info.
- Two types of reading data from audio files
  - Read audio signals
    - y= audioread('file')
  - Read metadata
    - info=audioinfo('file')

- Metadata of a .wav file
  - audioInfo01.m

```
fileName='flanger.wav';
info=audioinfo(fileName);
fprintf('檔案名稱 = %s\n', info.FileName);
fprintf('壓縮方式 = %s\n',
info.CompressionMethod);
fprintf('通道個數 = %g 個\n',
info.NumChannels);
fprintf('取樣頻率 = %g Hz\n', info.SampleRate);
fprintf('取樣點總個數 = %g 個\n',
info.TotalSamples);
fprintf('音訊長度 = %g 秒\n', info.Duration);
fprintf('取樣點解析度 = %g 位元/取樣點\n',
info.BitsPerSample);
```



# Metadata of Other Audio Files

- \*.aif

- audioInfo02.m

```
fileName='whale.aif';  
info=audioinfo(fileName);  
disp(info);
```

```
Filename: 'D:\users\...  
CompressionMethod: 'Uncompressed'  
NumChannels: 1  
SampleRate: 2000  
TotalSamples: 4000  
Duration: 2  
Title: []  
Comment: []  
Artist: []  
BitsPerSample: 16
```

- \*.mp3

- audioInfo03.m

```
fileName='youAtLeast.mp3';  
info=audioinfo(fileName);  
disp(info);
```

```
Filename: 'D:\users\...  
CompressionMethod: 'MP3'  
NumChannels: 2  
SampleRate: 44100  
TotalSamples: 317953  
Duration: 7.2098  
Title: '02_至少還有你'  
Comment: []  
Artist: '林憶蓮'  
BitRate: 128
```

# Scaling of Audio Signals by "audioread"

- Internal data types of audio signals in a file (音訊檔案內部儲存方式)
  - 8 bits □ uint8, [0, 2<sup>8</sup>-1]
  - 16 bits □ int16, [-2<sup>15</sup>, 2<sup>15</sup>-1]
- MATLAB's method to scale raw audio signals to the range [-1, 1]
  - 8 bits □ (y-128)/128
  - 16 bits □ y/32768

Original audio signals  
in integer

- Verification of MATLABs' scaling
  - audioRead03.m

```

fileName='welcome.wav';
[y, fs]=audioread(fileName);
info=audioinfo(fileName);
nbits=info.BitsPerSample;
% y0 是原先儲存在音訊檔案中的 值
y0=y*(2^nbits/2)+(2^nbits/2);
difference=sum(abs(y0-round(y0)))
    
```

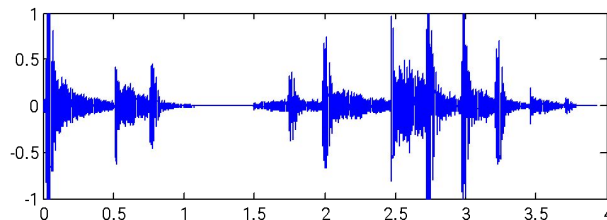
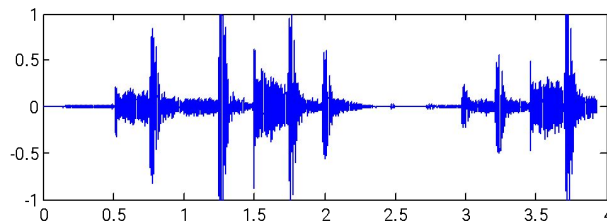
- difference = 0

# 讀取雙聲道檔案

- **audioread** 可以讀取雙聲道或立體聲 (**Stereo**) 的音檔，此時傳回的變數具有兩直行，每一直行代表一個聲道的音訊。

- **audioRead04.m**

```
fileName='flanger.wav';  
[y, fs]=audioread(fileName); % 讀取音訊檔  
sound(y, fs); % 播放音訊  
left=y(:,1); % 左聲道音訊  
right=y(:,2); % 右聲道音訊  
subplot(2,1,1), plot((1:length(left))/fs, left);  
subplot(2,1,2), plot((1:length(right))/fs, right);
```



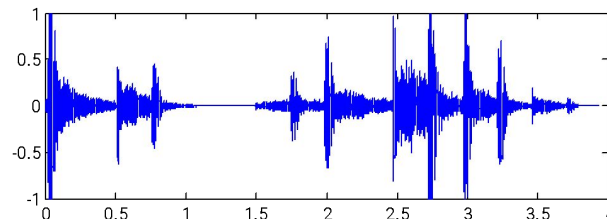
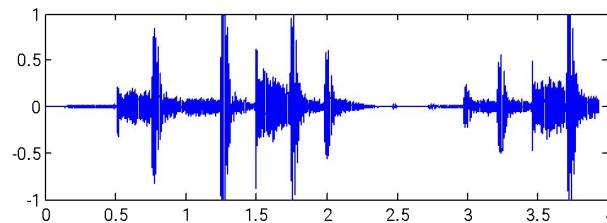
聲音會在左右喇叭游移！

# Read Stereo Audio Files

- “audioread” can also read stereo audio files. The returned variable has two columns representing two channels of audio signals.

- audioRead04.m

```
fileName='flanger.wav';  
[y, fs]=audioread(fileName); % Read  
sound(y, fs); % Playback  
left=y(:,1); % Left channel  
right=y(:,2); % Right channel  
subplot(2,1,1), plot((1:length(left))/fs, left);  
subplot(2,1,2), plot((1:length(right))/fs, right);
```

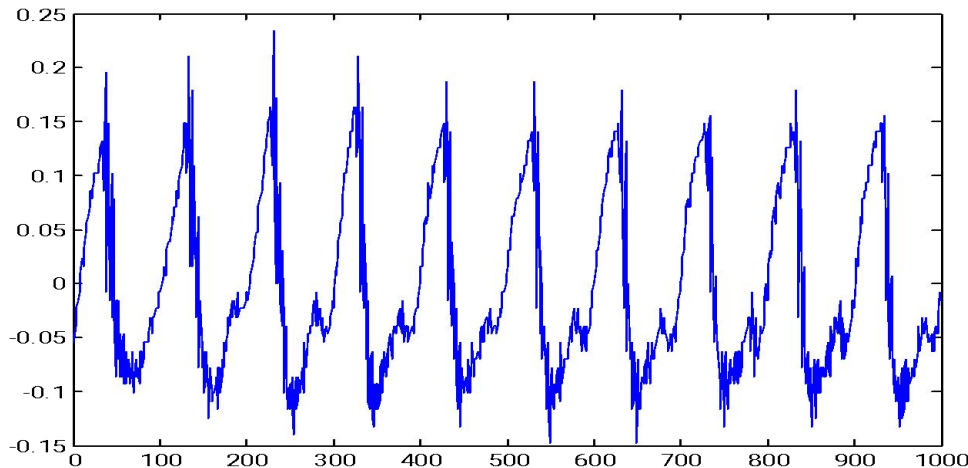


Moving sound source  
between two speakers!

## 讀取部分音檔

- 如果音檔很大，無法一次讀入記憶體，我們也可以使用 `audioread` 來讀出音檔的一部份，例如：
- `audioRead05.m`

```
[y,fs]=audioread('welcome.wav', [4001 5000]); % 讀取第4001至5000點  
figure; plot(y)
```



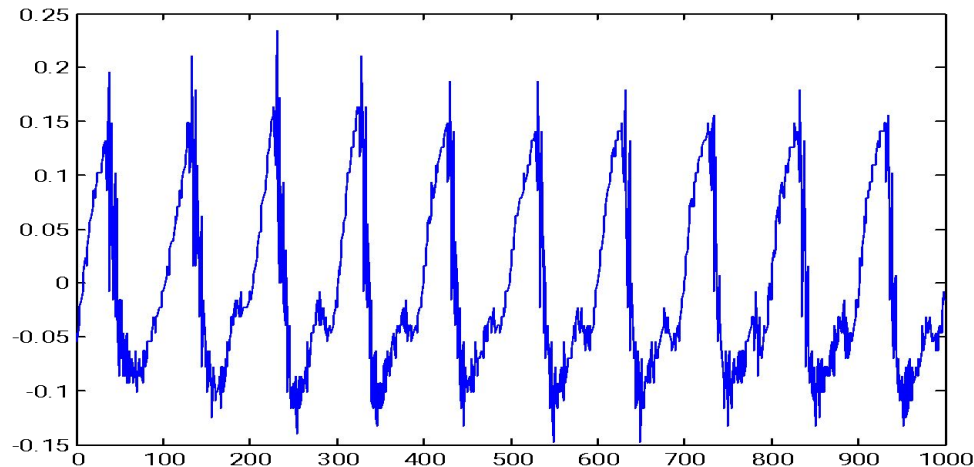
可看到明顯的基本週

期！

# Read a Portion Only

- If the audio file is too big, we can read a portion from the whole file:
- `audioRead05.m`

```
[y,fs]=audioread('welcome.wav', [4001 5000]);    % Read data points 4001 to 5000  
figure; plot(y)
```



Obvious fundamental periods!

# 聲音訊號的播放

- 一旦我們可以讀入音訊檔案，就可以對聲音訊號進行各種處理，例如增大或減小音量、提高或降低音高、消除雜訊等。
- 要確認處理後的聲音訊號是否符合所需，就要能夠把音訊直接透過接到電腦的喇叭播放出來，本節就是要介紹如何使用 **MATLAB** 來進行音訊的播放。



# Playback of Audio Signals

---

- Once we have read audio signals, we can perform all kinds of processing, such as volume modification, pitch scaling, noise reduction, etc.
- To verify the result, you need to play the audio via speakers, as shown in the following examples.



# 播放聲音 (1/2)

- 一旦 MATLAB 讀入音訊資料，並將之設定成工作空間中的變數後，我們就可以使用 **sound** 指令來直接播放此變數。

- 播放單一聲音

- **audioPlay01.m**

```
load handel.mat    % 載入音訊
sound(y, Fs);     % 播放音訊
```

- 同時播放兩種聲音

- **audioPlay02.m**

```
[y, fs]=audioread('welcome.wav'); % 載入音訊
sound(5*y, fs); % 播放音訊
load handel.mat    % 載入音訊
sound(y, Fs);     % 播放音訊
```

sound的播放模式為「非同步播放」！

# Playback (1/2)

- We can use “sound” to play audio signals that has been read and stored as a variable in MATLAB’s workspace.

- Audio playback

- audioPlay01.m

```
load handel.mat    % Load audio
sound(y, Fs);    % Playback
```

- Simultaneous playback

- audioPlay02.m

```
[y, fs]=audioread('welcome.wav'); % Read audio
sound(5*y, fs); % Playback
load handel.mat    % Load audio
sound(y, Fs);    % Playback
```

Playback mode of “sound” is asynchronous!

## 播放聲音 (2/2)

- 若要控制聲音的播放模式，則必須採用功能較為強大的指令：

- `audioplayer`
- `play`
- `playblocking`

- 播放單一聲音

- `audioPlay03.m`

```
load handel.mat    % 載入音訊
p=audioplayer(y, Fs); % 產生播放物件
play(p);           % 播放音訊
```

- 循序播放兩種聲音

- `audioPlay04.m`

```
[y, fs]=audioread('welcome.wav'); % 讀入音訊
p=audioplayer(y, fs);             % 產生播放物件
playblocking(p);                  % 播放音訊
load handel.mat                   % 載入音訊
p=audioplayer(y, Fs);             % 產生播放物件
playblocking(p);                  % 播放音訊
```

`playblocking` 的播放模式為「同步播放」！

# Playback (2/2)

- If you want to control the playback mode, you need to invoke other commands:

- audioplayer
- play
- playblocking

- Single playback

- audioPlay03.m

```
load handel.mat    % Load audio
p=audioplayer(y, Fs); % Player object
play(p);          % Playback
```

- Sequential playback

- audioPlay04.m

```
[y, fs]=audioread('welcome.wav'); % Read audio
p=audioplayer(y, fs);             % Player object
playblocking(p);                  % Playback
load handel.mat                   % Load audio
p=audioplayer(y, Fs);             % Player object
playblocking(p);                  % Playback
```

Playback mode of “playblocking” is synchronous!

# 改變音訊的震幅

- 我們在第一節提到過，聲音的音量是由聲波的震幅來決定，因此我們可藉由震幅的大小來改變音量，例如：
- **playVolume01.m**

```
[y, fs]=audioread('welcome.wav');  
p=audioplayer(1*y, fs); playblocking(p);    % 播放 1 倍震幅的音訊  
p=audioplayer(3*y, fs); playblocking(p);    % 播放 3 倍震幅的音訊  
p=audioplayer(5*y, fs); playblocking(p);    % 播放 5 倍震幅的音訊
```

聲音聽起來並沒有變成3或5倍大聲，為什麼？

# Change of Audio Amplitude

- Volume of audio signals is determined by their amplitude. Here are modify amplitude to change the volume:
- `playVolume01.m`

```
[y, fs]=audioread('welcome.wav');  
p=audioplayer(1*y, fs); playblocking(p);      % Original audio  
p=audioplayer(3*y, fs); playblocking(p);      % Audio of 3x amplitude  
p=audioplayer(5*y, fs); playblocking(p);      % Audio of 5x amplitude
```

The playback doesn't sound like 5-times louder, why?

# 改變音訊播放的取樣率 (1/2)

- 如果在播放時，改變取樣頻率，就會改變整個音訊的時間長度，進而影響到音高。
- 在下例中，我們漸漸提高播放時的取樣頻率，聽到的聲音就會越來越快、越來越高，最後出現像唐老鴨的聲音。為什麼？
- **playFs01.m**

```
[y, fs]=audioread('welcome.wav');  
p=audioplayer(y, fs);  
p.SampleRate=1.0*fs; playblocking(p); % 播放 1.0 倍速度的音訊  
p.SampleRate=1.2*fs; playblocking(p); % 播放 1.2 倍速度的音訊  
p.SampleRate=1.5*fs; playblocking(p); % 播放 1.5 倍速度的音訊  
p.SampleRate=2.0*fs; playblocking(p); % 播放 2.0 倍速度的音訊
```

# Change of Sample Rates (1/2)

- Change of sample rate during playback   
Change of duration  Change of the  
perceived pitch
- Increase the sample rate during playback, and  
you'll hear Donald Duck (唐老鴨). Why?
- playFs01.m

```
[y, fs]=audioread('welcome.wav');  
p=audioplayer(y, fs);  
p.SampleRate=1.0*fs; playblocking(p); % Duration ratio: 1  
p.SampleRate=1.2*fs; playblocking(p); % Duration ratio: 1/1.2  
p.SampleRate=1.5*fs; playblocking(p); % Duration ratio: 1/1.5  
p.SampleRate=2.0*fs; playblocking(p); % Duration ratio: 1/2
```



## 改變音訊播放的取樣率 (2/2)

- 反之，如果漸漸降低播放的頻率，聽到的聲音就會越來越慢、越來越低，最後出現像牛叫的聲音。
- **playFs02.m**

```
[y, fs]=audioread('welcome.wav');  
p=audioplayer(y, fs);  
p.SampleRate=1.0*fs; playblocking(p); % 播放 1.0 倍速度的音訊  
p.SampleRate=0.9*fs; playblocking(p); % 播放 0.9 倍速度的音訊  
p.SampleRate=0.8*fs; playblocking(p); % 播放 0.8 倍速度的音訊  
p.SampleRate=0.6*fs; playblocking(p); % 播放 0.6 倍速度的音訊
```

# Change of Sample Rates (2/2)

- On the other hand, decrease the sample rate during playback, and you'll hear cow moo...
- playFs02.m

```
[y, fs]=audioread('welcome.wav');  
p=audioplayer(y, fs);  
p.SampleRate=1.0*fs; playblocking(p); % Duration ratio: 1  
p.SampleRate=0.9*fs; playblocking(p); % Duration ratio: 1/0.9  
p.SampleRate=0.8*fs; playblocking(p); % Duration ratio: 1/0.8  
p.SampleRate=0.6*fs; playblocking(p); % Duration ratio: 1/0.6
```

# Observations

## ■ Observations

Quiz!

- Larger sample rate for playback leads to...
  - Shorter duration and higher pitch
- Smaller sample rate for playback leads to...
  - Longer duration and lower pitch
- How to...
  - Generate higher pitch without duration change?
    - Pitch modification
  - Create longer duration without pitch change?
    - Duration modification
  - Demo

# 改變符號及改變時序

- 如果我們將聲波訊號上下顛倒，聽到的聲音基本上是一樣的，但是如果前後顛倒，聽到的聲音就如同錄音帶「倒放」的聲音，聽起來很像是某種外國語音，請試試下列範例：
- 範例20-11：playReverse01.m

```
[y, fs]=audioread('welcome.wav');  
p=audioplayer(y, fs); playblocking(p);           % 播放正常的音訊波形  
p=audioplayer(-y, fs); playblocking(p);         % 播放上下顛倒的音訊波形  
p=audioplayer(flipud(y), fs); playblocking(p); % 播放前後顛倒的音訊波形
```

# Change of Sign & Time Sequence

- Change of sign  No perceptual difference
- Reverse sequence  Sounds like another spoken language?
- 範例20-11：playReverse01.m

```
[y, fs]=audioread('welcome.wav');  
p=audioplayer(y, fs); playblocking(p);           % Normal playback  
p=audioplayer(-y, fs); playblocking(p);         % Change of sign  
p=audioplayer(flipud(y), fs); playblocking(p); % Reverse the sequence
```

# 同步及非同步播放

- 通常在播放音訊時，**MATLAB** 停止進行其他動作，直到音訊播放完畢後，才會再進行其他指令的運算，此種運作方式稱為「同步式」(**Synchronous**)。若需要一邊播放、一邊進行其他運算，就必須使用「非同步式」(**Asynchronous**)的播放方式。
- 範例20-12：playSync01.m

```
[y, fs]=audioread('welcome.wav');  
p=audioplayer(y, fs);  
playblocking(p);    % 同步播放 1.0 倍速度的音訊  
sound(y, 0.8*fs);  % 非同步播放 0.8 倍速度的音訊  
sound(y, 0.6*fs);  % 非同步播放 0.6 倍速度的音訊
```

# 非同步播放

- 在此例中，我們會聽到類似男女兩部合唱，一快一慢，這是因為 `sound` 指令的預設播放方式就是「非同步」。
- 範例20-13：playSync02.m

```
load handel.mat  
sound(y, Fs);  
sound(y, 1.2*Fs);
```

# Playback Modes

- There are two playback modes
  - Synchronous mode: Block everything till the end of playback.
  - Asynchronous mode: Nonblocking

- **playSync01.m**

```
[y, fs]=audioread('welcome.wav');  
p=audioplayer(y, fs);  
playblocking(p);    % Synchronous  
sound(y, 0.8*fs);   % Asynchronous  
sound(y, 0.6*fs);   % Asynchronous
```

- **playSync02.m**

```
load handel.mat  
sound(y, Fs);  
sound(y, 1.2*Fs);
```



# 音量自動調整

- 另一個類似的指令是 `soundsc`，可針對音訊變數的數值先進行正規化（介於  $-1$  和  $1$  中間）後，再送到喇叭播放，以達到最好的播放效果。
- `soundsc01.m`

```
[y, fs]=audioread('welcome.wav');  
sound(y, fs);  
fprintf('Press any key to continue...\n'); pause  
soundsc(y, fs);
```

在影像顯示方面，對應的命令是 `imagesc`。

# Automatic Volume Adjustment

- “soundsc” adjusts the volume (by normalizing the signals to have max of 1 or min of -1) before playback
- soundsc01.m

```
[y, fs]=audioread('welcome.wav');  
sound(y, fs);  
fprintf('Press any key to continue...\n'); pause  
soundsc(y, fs);
```

The corresponding command for image display is “imagesc”.

# 聲音訊號的錄製

- 我們在第一節已經說明了如何讀取音訊檔案，並在第二節說明如何播放。**MATLAB** 也支援直接由麥克風讀取訊號，因此可以直接進行聲音的錄製，所使用的指令是
  - `audiorecorder`
  - `recordblocking`



# Recording of Audio Signals

---

- We can use the following MATLAB commands for recording from the microphone directly:
  - audiorecorder
  - recordblocking

# 音訊的錄製範例 (1/2)

- 使用預設參數，由麥克風進行3秒錄音：

- **audioRecord01.m**

```
duration=3;          % 錄音時間
recObj=audiorecorder;
fprintf('按任意鍵後開始 %g 秒錄音:', duration); pause
fprintf('錄音中...');
recordblocking(recObj, duration);
fprintf('錄音結束\n');
fprintf('按任意鍵後開始播放:'); pause
play(recObj);
```

- 預設錄音參數

- 取樣頻率為 8000 Hz
- 取樣點解析度為 8 bits
- 單聲道錄音

# Recording (1/2)

- Use default setting for 3-sec recording:

- audioRecord01.m

```
duration=3;           % Duration of recording
recObj=audiorecorder;
fprintf('按任意鍵後開始 %g 秒錄音:', duration); pause % Prompt
fprintf('錄音中...'); % During recording
recordblocking(recObj, duration);
fprintf('錄音結束\n'); % End of recording
fprintf('按任意鍵後開始播放:'); pause % Press any key for playback
play(recObj);
```

- Default settings for recording

- Sample rate: 8000 Hz
- Bit resolution: 8 bits
- Mono

# 音訊的錄製範例 (2/2)

- 設定各項錄音參數來進行3秒錄音，並畫出波形：

- **audioRecord02.m**

```
fs=16000;      % 取樣頻率
nBits=16;     % 取樣點解析度, 必須是 8 或 16 或 24
nChannel=1;   % 聲道個數, 必須是1(單聲道)或2(雙聲道或立體音)
duration=3;   % 錄音時間(秒)
recObj=audiorecorder(fs, nBits, nChannel);
fprintf('按任意鍵後開始 %g 秒錄音:', duration); pause
fprintf('錄音中...');
recordblocking(recObj, duration);
fprintf('錄音結束\n');
fprintf('按任意鍵後開始播放:'); pause
play(recObj);
y = getaudiodata(recObj, 'double'); % get data as a double array
plot((1:length(data))/fs, y);
xlabel('Time (sec)'); ylabel('Amplitude');
```

設定錄音參數

取得音訊資料

# Recording (2/2)

- Set recording parameters, record, plot the waveform:
  - audioRecord02.m

```
fs=16000;      % Sample rate
nBits=16;     % Bit resolution (must be 8, 16, or 24)
nChannel=1;   % No. of channels (must be 1 or 2)
duration=3;   % Duration for recording in sec
recObj=audiorecorder(fs, nBits, nChannel);
fprintf('按任意鍵後開始 %g 秒錄音:', duration); pause
fprintf('錄音中...');
recordblocking(recObj, duration);
fprintf('錄音結束\n');
fprintf('按任意鍵後開始播放:'); pause
play(recObj);
y = getaudiodata(recObj, 'double'); % get data as a double array
plot((1:length(data))/fs, y);
xlabel('Time (sec)'); ylabel('Amplitude');
```

Set up recording parameters

Obtain audio signals



# 聲音訊號的寫檔 (1/2)

- 我們也可以經由 **MATLAB** 將音訊資料直接儲存為音訊檔案, 以便直接在電腦播放。寫入音訊檔案的指令是 **audiowrite**, 其格式為:
  - **audiowrite(audioFile, y, fs)**
    - **audioFile** 則是欲寫入資料的檔案名稱, **y** 是音訊變數, **fs** 是取樣頻率。
  - 範例: **audioWrite01.m**

```
load handel.mat
audioFile='handel.wav'; % 欲儲存的 wav 檔案
fprintf('Saving to %s...\n', audioFile);
audiowrite(audioFile, y, round(1.5*Fs));
fprintf('按任意鍵後開始播放 %s...\n', audioFile);
dos(['start ', audioFile]); % 開啟與 wav 檔案對應的應用程式
```

# Storing Audio Files (1/2)

- We can use “audiowrite” to save audio files, with the following I/O format:
  - audiowrite(audioFile, y, fs)
    - audioFile: file to write to, y: audio signals, fs: sample rate
  - 範例：audioWrite01.m

```
load handel.mat
audioFile='handel.wav'; % wav file to write to
fprintf('Saving to %s...\n', audioFile);
audiowrite(audioFile, y, round(1.5*Fs));
fprintf('按任意鍵後開始播放 %s...\n', audioFile);
dos(['start ', audioFile]); % Use default application to open the wav file
```

# 聲音訊號的寫檔 (2/2)

- 錄音、播放、存檔的範例：
  - 範例：audioWrite02.m

```
fs=16000; % 取樣頻率
nBits=16; % 取樣點解析度, 必須是 8 或 16 或 24
nChannel=1; % 聲道個數, 必須是 1(單聲道) 或 2(雙聲道或立體音)
duration=3; % 錄音時間(秒)
recObj=audiorecorder(fs, nBits, nChannel);
fprintf('按任意鍵後開始 %g 秒錄音:', duration); pause
fprintf('錄音中...');
recordblocking(recObj, duration);
fprintf('錄音結束\n');
fprintf('按任意鍵後開始播放: \n'); pause
y = getaudiodata(recObj, 'double'); % get data as a double array
plot((1:length(data))/fs, y); xlabel('Time (sec)'); ylabel('Amplitude');
sound(y, fs);
audioFile='myRecording.wav'; % 欲儲存的 wav 檔案
fprintf('Saving to %s...\n', audioFile);
audiowrite(audioFile, y, fs);
system(audioFile); % Use default application to open the wav file
```

# Storing Audio Files (2/2)

- Example of recording, playback, and saving:
  - 範例：audioWrite02.m

```
fs=16000; % Sample rate
nBits=16; % Bit resolution (must be 8, 16, or 24)
nChannel=1; % No. of channels (must be 1 or 2)
duration=3; % Recording duration in sec
recObj=audiorecorder(fs, nBits, nChannel);
fprintf('按任意鍵後開始 %g 秒錄音:', duration); pause
fprintf('錄音中...');
recordblocking(recObj, duration);
fprintf('錄音結束\n');
fprintf('按任意鍵後開始播放: \n'); pause
y = getaudiodata(recObj, 'double'); % get data as a double array
plot((1:length(data))/fs, y); xlabel('Time (sec)'); ylabel('Amplitude');
sound(y, fs);
audioFile='myRecording.wav'; % wav file to be saved
fprintf('Saving to %s...\n', audioFile);
audiowrite(audioFile, y, fs);
system(audioFile); % 開啟與 wav 檔案對應的應用程式
```



# Cross-version Issues

---

- File mapping for different versions of MATLAB
  - wavread  audioread
  - wavwrite  audiowrite
  - wavplay  audioplayer, sound
  - wavrecord  audiorecorder
- Other supports
  - audiodevinfo
  - playblocking
  - play
- SAP toolbox
  - Version-independent audio file reading  myAudioRead.m
  - Progressive bar  audioPlayWithBar.m



# Supplementary Material

---

- Other resources
  - ASPR: [Audio Signal Processing and Recognition](#)
    - Texts for this set of slides can be found at Chapter 4.
    - Pitch tracking by visual inspection can be found at Section 4 of Chapter 5. ([Slides](#))