A/D conversion:
a) Sampling, Quantization
b) factor: Sampling Rate
2. Signal-to-quantization error (SQNR) Nyquist frequency
c) sampling rate 滿足 $r=2f$
使 quantization 精確度提高

RLE: lossless (run-length-encoding)
(238,6), (242,4), (238,6), (255,4)

Entropy: shannon's equation 用 $\log_2(16)$
$H(S)=\eta=\sum_i p_i \log_2(\frac{1}{p_i})$ 机率

RLE: 原本 64 → 11組 × 2個
compressing ratio: 64:22

image histogram: ⊥lılı,

Mean of average: $\bar{x}=\frac{1}{n}\sum_{i=1}^{n}x_i$

$\sigma=\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^2}$

Bilinear interpolation:
Let A(i,j) be the original image (100×100)
B(i,j) be the scaled image (300×300)

```
for (x=1 ~ 300)
  for (y = 1 to 300)
     p = x/3 , q = y/3
     i = floor(p), j = floor(q)
     sum = 0
     for (m=0 to 1)
       for (n=0 to 1)
          H = |i+(1-m)-p| ;
          T = |j+(1-m)-q| ;
          W = H*T
          sum = sum + A(i,j)*w ;
  B(x,y) = sum;
```
i,j (i+1,j) (i,j+1) (i+1,j+1)

Aliasing: Sample rate 低於 Nyquist rate 說明 $r=2f$
導致原始訊号無法從取樣中还原.

Dynamic Range: ratio of the largest-amplitude sound (color) and the smallest that can be represented with a given bit depth.

Dithering: is a technique for simulating colors that are available in a palette by using available color that are blend by the eye so that they look like the desire colors.
決定 index color: finding the color that is most similar using the min mean square distance
$\min (R-r_i)^2+(G-g_i)^2+(B-b_i)^2$

Bitmap: 利用矩陣存圖,每個 pixel 存一個資料結構 (點陣图) 儲存快、檔案小 hard to edit / fast to create
Vector: 利用數學函式計算 graph 的向量图 易修改、放大、小較精確

Filter: is an operation performed on digital image data to sharpen, smooth, or enhance some feature

RGB: used for display monitor, 和人類眼睛感色頻色方式相同, 為 additive color mixing (有些色彩無法表現)
CMYK: used in printing, 為 substractive mixing, 但無法呈現黑色 (dark brown)
HSV: Hue 色相, Satuation 飽和度, Value 明度 (B)
YCbCr: 將顏色分為 luminance (Y) / chrominance (I,Q) 因人類对亮度較敏感, 用来对資料分析、過濾

average dithering: 算出平均 pixel value, 高的白, 低的黑.
Patter Dithering: 用一個 threshold matrix 為基準, 同上.
Error Diffusion: (x,y): e error 分散到整張图.

x,y	x+1,y	
x-1,y+1	x,y+1	x+1,y+1

$P(x+1,y)=p(x+1,y)+(7/16)e$ pixel value
$P(x-1,y+1)=\sim+(3/16)e$ ↓128: 0
$P(x,y+1)=\sim+(5/16)e$ ↑128: 1
$P(x+1,y+1)=\sim+(1/16)e$.
When the mask is moved to the right by one pixel, the next step will operate on a pixel that has possibly changed in a previous step.

Noise shaping: is another way to compensate 量化誤差
⇒ Move noise's freq to above the Nyquist freq, and filter it out, we are not losing anything we care about in the sound.

Interpolation 比較:
NN: 快, poor quality
bicubic: 慢, very good
bilinear: 中, 中

DFT: $F(n)=\frac{1}{N}\sum_{k=0}^{N-1}f(k)e^{-i2\pi nk/N}$; inverse: $f_k=\sum_{n=0}^{N-1}F_n e^{i2\pi nk/N}$
DC component: $a_0=\frac{1}{N}\sum_{k=0}^{N-1}f_k$ $0\le n\le N-1$
AC component: $a_n=\frac{1}{N}\sum_{k=0}^{N-1}f_k\cos(2\pi nk/N)$
$b_n=\frac{1}{N}\sim f_k\sin(2\pi nk/N)$ 則 magnitude of the n^{th} freq component: $A_n=\sqrt{a_n^2+b_n^2}$
phase $\sim$: $\phi_n=-\tan^{-1}(b_n/a_n)$ $0\le n\le N-1$
magnitude / phase form of the inverse DFT: $f_k=\sum A_n\cos(2\pi k+\phi_n)$
magnitude 表示實際 freq domain 上的 amplitude

$y(n)=h(n)\otimes f(n)=\sum_{k=0}^{N-1}h(k)f(n-k)$ FIR filter → convolution between signal f and filter h $=[h(0)\ldots h(M-1)]$
IIR filter: recursive form: $h(n)\otimes f(n)=\sum_{k=0}^{N-1}a_k x(n-k)-\sum_{k=1}^{M}b_k y(n-k)$
算出 $f\otimes h$ in freq domain: 用 DFT ⇒ $F=DFT(f)$, $H=DFT(h)$ ⇒ $Y=F\times H$, 取 $DFT^{-1}(Y)$ 得 $f\otimes h$

① cubic bezier curve: $P(t)=(T^*M)^*G=(1-t)^3P_0+3t(1-t^2)P_1+3t^2(1-t)P_2+t^3P_3$
方法(b) 每4個点為一組, 前後為 fixed point, 中間為 direction point, 分別為 $P_0\sim P_3$, 執行 blending function, 產生 fixed point 和 interpolated points 為 Bezier curve 的点, 再相連.
下一組的 P_0 為上一組的 P_3, 直到每個点都做過. 原点、
d) 不会 pass 每個 data point, $3n+1-1$ (不算原点) $/3+1=n+1$ 個.
因為每組只有2個 fixed point 是原本 data point 的点

Bezier curve: a parametric curve described by polynomial based on a sequence of control points.
$(3n+1-4)/3+1$: 第一次用 Bezier curve 為4個点、之後都会与上個 P_3 重疊一次, ∴往後的花3点

progressive scanning: each frame is scanned line by line, from top to btm. (one field)
Computer monitor.
Interlaced scanning: the line of frame 切成 2 field, odd (upper), even (lower) field. pulldown 3:2
1080/60 (i)(p)
frame height, frame freq
progressive Eliminate flicker screen in interlaced
tele-cine: the process of transfer film → video and the machine that performs the process
Pulldown: a method for using interlaced fields more than once, across frames, to make up for a discrepancy in frame rate as film is translated to video.

2D DCT: $F(u,v)=\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\frac{2C(u)C(v)}{\sqrt{MN}}f(i,j)\cos\frac{(2i+1)u\pi}{2M}\cos\frac{(2j+1)v\pi}{2N}$
(a) u,v: freq domain 的 vector
(b) F(u,v): 在 (u,v) 点上 frequency 的 magnitude, magnitude 為該頻率对應到 spatial domain 的 amplitude.
(c) 4:2:0 chrominace sampling.

Y,Cb,Cr	Y	Y,Cb,Cr	Y
Y	Y	Y	Y
Y,Cb,Cr	Y	Y,Cb,Cr	Y
Y	Y	Y	Y

一個 sample matrix 中,
一行 sample 4次 Y,
1st 行 sample 2次 Cb,Cr Cb: IDCT
2nd 行 sample 0次 Cb,Cr Cr: IDCT
一次DCT 轉換 64個 spatial domain component 成 freq
(故 16·16/64 = 4次 8×8 DCT, 16 by 16 block
(d) AC component 先 quantization (高頻為0) 利用 zig zag san, 和 RLE 壓縮 再用 VLC (AC Huffman coding)

Film frame	Field	video frame
A	A even, A odd	
B	B even, B odd	2
	B odd, C even	3
C	C even, C	4
D	D, D	5

MPEG compression:
I: inteaframes: are compressed independently, if they were isolated still images, using JPEG compression, serve as reference for the B,P frames.
P: 参考前面的 I frame 来做 compression (forward prediction)
B: bidirectional frame: 参考前後的 I,P frame 做 compression.
motion estimation: video 為多張图片串連而成, 若每張图都用 JPEG 压縮, 效果不好, 藉由 motion estimation 記錄前後 frame 的差異, 針对 difference 来压縮, 能減少重複儲存相同部分.
SAD let p,q be the position of T block in the target frame then the search range in the reference frame is $(p-15, q-15)$ to $(p+15, q+15)$

```
for (i = p-15 to p+15)              search range [-15,15]
  for (j = q-15 to q+15)     0≤x,y≤7          SSD: 差方平方
     SAD(i,j) = Σ_{k=0} Σ_{l=0} ( |T(x+k, y+l) - R(x+k+i, y+l+j)| )^2
     if (SAD < min) min = SAD
     record the corresponding position of min
     (assume m,n)  row column
motion vector = (p-m, q-n)
```

flow chart: compressing a P frame
Target frame → Current macroblock → ⊖ → Difference macroblock (Y, Cb, Cr)
Reference frame → Best match
full-search 2D-algorithm → Motion vector
For each 8×8 block ↓ DCT

DCT used in JPEG compression
input image → Level offset → 8×8 DCT → Uniform scalar Quantization → DC → Differential coding → VLC (DC Huffman table)
DCT: Spatial → freq domain; Quantization table
AC → zig-zag scan (low freq → high freq) → (RLE) Run level coding → VLC (AC Huffman table)
能有效率压縮多較且連續 0.

$Ts[i]=[\frac{S^*Tb[i]+50}{100}]$ 得新 table
MPEG1

3D-graphics: Phong model
Intensity = Ambient + Diffuse + Specular
⇒ (Ia·ka) + (Ip·kd·cosθ) + (Ip·ks·cos^n α)

JPEG image ratio/quality.
利用 Quality factor (Qf)