EEE116 – Multimedia Systems 2007/08
Tutorial problem sheet 1 (Week 2)

1 (a) Consider the analogue signal

x(t) = 3cos(2000t)+5sin(6000t)-10cos(12000t)

What is the Nyquist rate of this signal?

Signal x(t) contains 3 main frequency components. In this example frequency is shown in radians/sec. The 3 main frequencies are, 2000 rad/sec, 6000 rad/sec, and 12000 rad/sec.

The maximum frequency is 12,000 rad/sec.

Therefore the Nyquist limit is 2 x 12,000 rad/sec.

In real applications we usually measure frequency in Hz. Therefore, we should give the answer in Hz. To convert we use the following relationship:

$$\omega = 2\pi f$$

$$f = \frac{\omega}{2\pi}$$

$$f = \frac{2 \times 12000}{2\pi}$$

= 3.82 kHz.

(b) How many different symbols can be represented using a 16 bit digital code?

Using an N bit code you can represent 2^N different values.

A 16 bit code can show 2^{16} different values.

(c) The human eye can perceive 15,000 different colours. How many bits required to represent the full range of colours?

Using an N bit code you can represent 2^N different values.

$$2^N = 15000$$

$$N = \log_2(15000)$$

N = 13.9 As we cannot physically have fractional 'bits', we have to round the answer to the nearest highest integer.

Therefore N=14 bits are required.

(d) An alien species can perceive only half of the colours that the humans can perceive. How many bits can be saved when the colour range of aliens is represented in digital form compared to that of the humans?

> We can follow the same approach as above using 7500 as the number of different values we need to represent.
> $2^N=7500$;
> This will give N=13.
> That means we can save 1 bit. Or in other words the digital code for their visual colour range representation is 1 bit shorter.
>
> However, since we have already computed N for 15,000 values, we can avoid repeating the computation for 7500.
>
> We can use the laws logarithms (log(A/B)=log(A)-log(B)))
>
> $$\begin{aligned} 2^M &= 7500 \\ M &= \log_2(15000 / 2) \\ M &= \log_2(15000) - \log_2 2 \\ M &= N - 1 \end{aligned}$$
>
> Now try to work out how many extra bits needed to represent a colour range which contains as twice as the human visual perception range.

2 The output from a microphone to record the sonic pulses emitted by bats can be at frequencies up to 50 kHz and up to 1 V in amplitude.

What is the largest sampling period of an analogue-to-digital converter in order to be able to reproduce faithfully these signals?

> The maximum frequency of the signal is 50 kHz.
> Therefore, the Nyquist rate is 100 kHz.
> The sampling frequency (f) has to be greater than or equal to the Nyquist limit.
>
> $$\begin{aligned} f &\geq 100\times10^3 \\ \frac{1}{T} &\geq 100\times10^3 \\ T &\leq \frac{1}{100\times10^3} \end{aligned}$$
>
> The largest allowed sampling period is 0.01 milli seconds.

If we wish to record changes in the signal amplitude as small as 1 mV, how many bits will be needed to represent these signals in a digital memory?

We can assume the amplitudes vary from 0V to 1V.
Therefore, $V_{max}=1$, $V_{min}=0$.

We want to measure values as small as 1mV. This is the quantisation bin size (d).

Therefore the number of different symbols $= (V_{max} - V_{min})/d + 1$
$= (1-0)/(1\times10^{-3}) + 1$
$= 1001$

We need N bits to represent 1000 values.

$$2^N = 1001$$

$$N = \log_2(1001)$$

N= 10 bits

You have a 64 M byte flash memory stick, how many minutes of bat recordings can you store?

From the previous parts, we know the following:
For the digital representation we need 10 bits/sample and we sampled the signal at the Nyquist rate, i.e., 100 k samples/sec.

Now we can compute the bit rate of the digital signal.

Bit rate = 10 bits/sample x 100 k samples/sec
= 1000 k bits/sec

Time we can record = (Memory size) / (bit rate)
[check the units for the accuracy of this equation]

Memory size is 64 M byte.
We know 1 byte = 8 bits
Also 1 M = K x K (Remember K=1024 and k=1000).
The total memory size in bits = 64 x 8 x K x K
Bit rate is 1000 k bits/sec

Therefore the total time we can record is (64x8xKxK)/(1000k)
= 536.9 sec
converting into minutes gives 8.95 minutes .