Student Name: _____ Student No: _____

The Hong Kong Polytechnic University
Department of Electronic & Information Engineering
Laboratory 2: Analysis of Motion JPEG and H.264 Video Coding

Objective:

This laboratory will address some issues in Motion JPEG and H.264 video coding. Programs are provided to encode, decode and display video sequence(s). You are required to encode various raw videos to Motion JPEG and H.264 video streams, and then decode them for analysis.

Required software and media clip:

Motion JPEG[1] encoder: *mj2encoder.exe*
Motion JPEG[1] decoder: *mj2decoder.exe*
H.264[2] encoder: *h264encoder.exe*
H.264[2] decoder: *h264decoder.exe*
YUV player: *YUVDisplay.exe*
YUV 4:2:0 Raw video: *RaceHorses_416x240_f40.yuv*

Both Motion JPEG and H.264 encoders perform their work according to input parameters as given in a configuration file. The bitstream output would be generated. The encoding process would be displayed in the console window. Statistical information such as bits and PSNR would also be displayed in the console window. (You may need to login for each time running the program.)

(Required software and required media clips are zipped into "*MJPEGH264VideoLab.zip*" which can be downloaded from the subject website: http://www.eie.polyu.edu.hk/~ylchan/course.htm)

Submission:

No Demonstration is needed.
This laboratory sheet together with the answers should be submitted to the lab tutor before the end of the lab session.

[1] Debian Open JPEG Package

[2] IHH H.264/AVC Package

Procedures:

Section A. Motion JPEG Encoder

1. Download the zip file "*MJPEGH264VideoLab.zip*" from website: http://www.eie.polyu.edu.hk/~ylchan/course.htm. Decompress it. Study the configuration file "*mj2encoder.cfg*". You can simply open it by any text editors such as "*Notepad*". Find out the following parameters:

a) Name of input file	
b) Name of the compressed bitstream	
c) Number of frames to be encoded	
d) Frame dimensions (Resolution)	(w) × (h)
e) Quality Factor	

2. Then, encode the uncompressed raw video file by running the encoder. The encoder would read the encoder configuration settings in the configuration file to start the encoding process, is depicted as below:

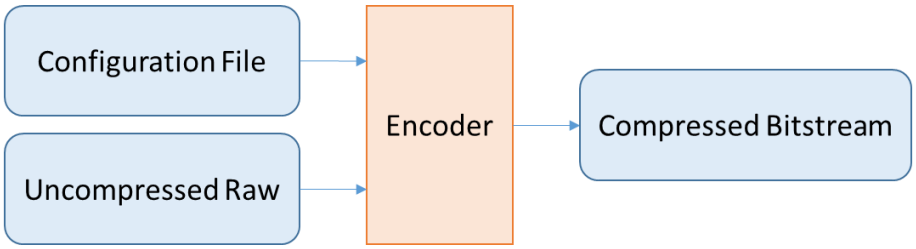
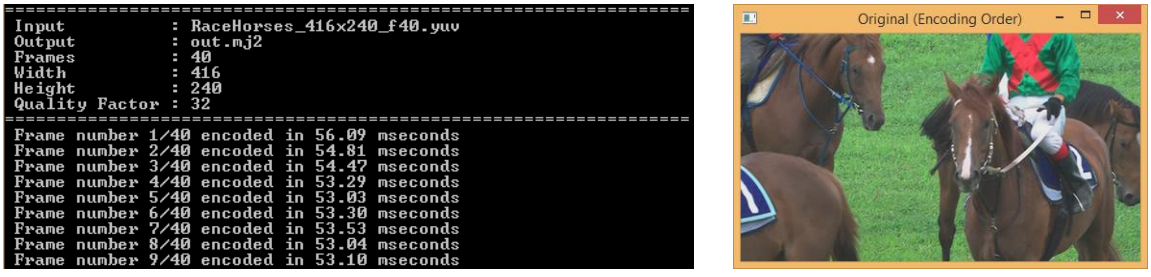


Fig. 1. Input/output of the encoder.

For Motion JPEG encoder "*mj2encoder.exe*", the uncompressed raw is "*RaceHorses_416x240_f40.yuv*". The configuration file is "*mj2encoder.cfg*". The compressed bitstream is "*out.mj2*".

Double click the Motion JPEG encoder "*mj2encoder.exe*". There should be two console window opened, one showing the encoder settings and encoding details while another one displaying the original frames, as depicted below:



(a) *(b)*

Fig. 2. (a) Console window for Motion JPEG encoder, and (b) Window displaying the original frame.

What is the total encoding time? _____

What is the total bits? _____

After finishing the encoding process, there would be an output file "*out.mj2*", which is the Motion JPEG compressed bitstream of the video sequence.

3. Now, decode the compressed bitstream by running the decoder. Similar to the encoder, the decoder would read the decoder configuration settings in the configuration file to start the decoding process, which is depicted as follows:

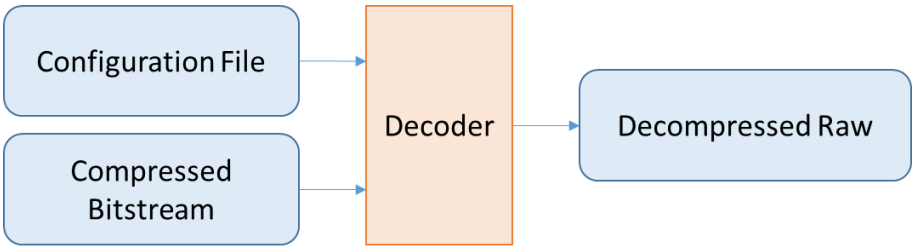
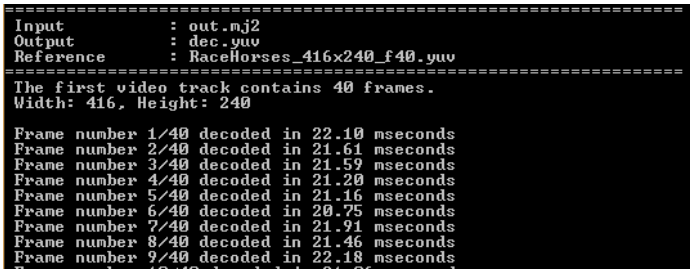


Fig. 3. Input/output of the decoder.

Double click the Motion JPEG decoder "*mj2decoder.exe*". There should be two console window opened, one showing the decoder settings and decoding information while another one displaying the decoded frames, as follows:



(a) *(b)*

Fig. 4. (a) Console Window for Motion JPEG decoder, and (b) Window displaying the decoded frame.

(a) What is the total decoding time? _____

(b) What is the PSNR? _____

PSNR (Peak signal-to-noise ratio) in dB is used to measure the objective quality of the compressed bitstream. The higher the PSNR, the better the objective quality.

Note 1: The pop-up window that displays the frame is the module from the previous laboratory (Laboratory 1) for displaying the frame onto the screen. This module has been implemented into the Motion JPEG encoder and decoder.

Note 2: The decompressed raw video is written to file system so that we can use any raw video viewers, e.g. "*YUVDisplay.exe*", which can be easily found in the Internet, to display it. Practically, the decompressed raw video is stored into memory by video players, e.g. VLC media player, and displayed onto the screen directly.

Section B. H.264 Encoder

1. Study the configuration file "*h264encoder.cfg*". Find out the following parameters:

a) Name of input file	
b) Name of the compressed bitstream	
c) Number of frames to be encoded	
d) GOP size	
e) Frame dimensions (Resolution)	(w) × (h)
f) Quantization Parameter (QP)	
g) Number of Successive B frames	

2. How many macroblocks are there in one frame of the video sequence?

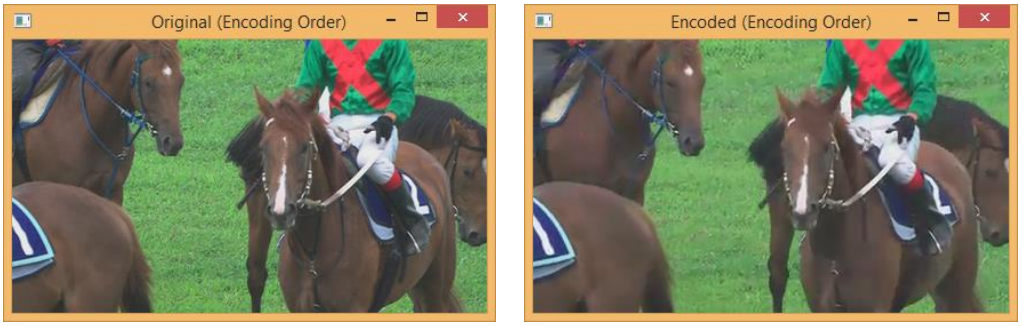
_____

3. Double click the H.264 encoder "*h264encoder.exe*". For the H.264 encoder, three windows should be opened. One is the console window showing the encoder settings and encoding details. The second one is the window displaying the original frames while the remaining one is the window displaying the encoded frames, which are depicted as follows:

```
Setting Default Parameters...
Parsing Configfile h264encoder.cfg........

---------------------------- H.264 Encoder Settings -----------------------------
 Input YUV file                    : RaceHorses_416x240_f40.yuv
 Output H.264 bitstream            : out.264
 Frames to be encoded              : 40
 Width x Height                    : 416 x 240
 GOP size                          : 0
 Quantization parameter (QP)       : 32
 Number of successive B frames     : 0
-------------------------------------------------------------------------------
 Frame | Frame |   Bits/pic | QP |   PSNR |    Encoding
   Num |  Type |            |    |   (dB) |    Time(ms)
-------------------------------------------------------------------------------
 00000 |     I |      80608 | 32 | 33.432 |         256
 00001 |     P |      19576 | 32 | 32.784 |         358
 00002 |     P |      22384 | 32 | 32.689 |         355
 00003 |     P |      21576 | 32 | 32.659 |         354
 00004 |     P |      21888 | 32 | 32.686 |         354
 00005 |     P |      21144 | 32 | 32.651 |         352
 00006 |     P |      21400 | 32 | 32.593 |         353
 00007 |     P |      22232 | 32 | 32.544 |         364
 00008 |     P |      23856 | 32 | 32.492 |         360
 00009 |     P |      22800 | 32 | 32.519 |         355
```

(a)



(b) *(c)*

Fig. 5. (a) Console window for H.264 encoder, (b) Window displaying the original frame, and (c) Window displaying the encoded frame.

After finishing the encoding process, there would be an output file "*out.264*" which is the H.264 output bitstream of the video sequence.

(a) What is the total encoding time? _____

(b) What is the PSNR? _____

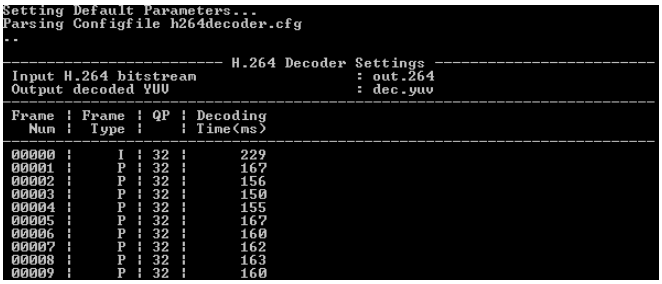
(c) What is the total bits? _____

4. What do you find by observing the encoding time of the Motion JPEG encoder and H.264 encoder? Give your comments.

_____

_____

5. Double click the H.264 decoder "*h264decoder.exe*". There should be two windows opened as follows. One is the console window showing the decoder settings and decoding information while the other one is the window displaying the decoded frame.



(a) *(b)*

Fig. 6. (a) Console window for H.264 decoder, and (b) Window displaying the decoded frame.

What is the total decoding time? And what do you find by observing the encoding time and decoding time? Give your comments.

_____

_____

_____

Note: The pop-up window that displays the frame is the module from the previous laboratory (Laboratory 1) for displaying the frame onto the screen. This module has been implemented into the H.264 encoder and decoder.

Section C. Performance Comparison for Motion JPEG Encoder and H.264 Encoder

1. By changing the quality factor in the configuration file to the listed values in Table 1, fill in Table 1 using the Motion JPEG encoder. And by changing the quantization parameter in the configuration file to the listed values in Table 2, fill in Table 2 using H.264 encoder:

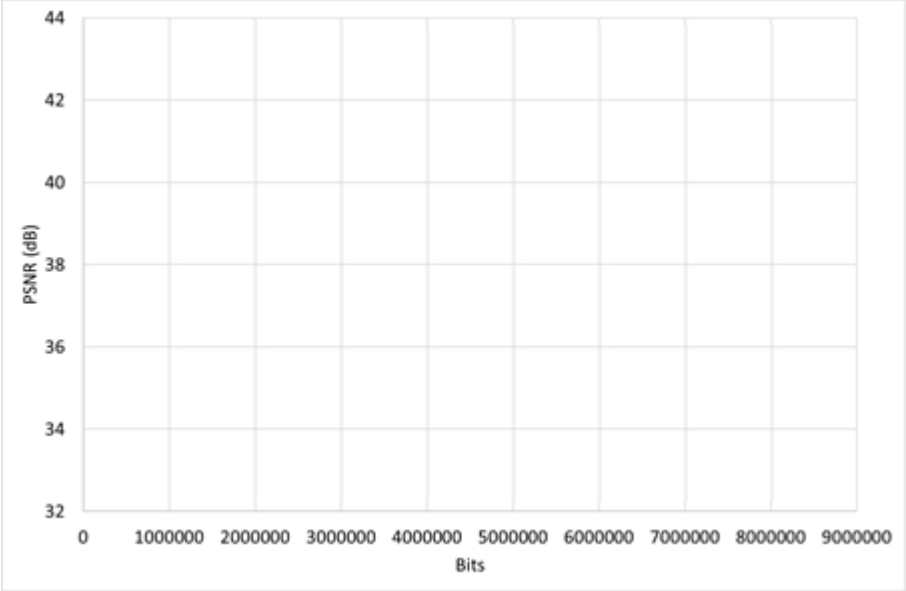
Table 1. Motion JPEG encoder

Quality Factor	Total Bits	PSNR
32		
34		
36		
38		

Table 2. H.264 encoder

QP	Total Bits	PSNR
32		
28		
24		
20		

2. Plot the rate-distortion (RD) graph based on Table 1 and Table 2. In this laboratory, we plot the total bits at *x*-axis and PSNR at *y*-axis. Remember to give your graph a legend.
   (a) Add the points based on Table 1, and concatenate the points as a curve.
   (b) Add the points based on Table 2, and concatenate the points as a curve.



There should be two curves now. They are called the RD curves. By comparing the RD curves, we can know which encoder (or which encoder settings) has better or worse performance.

(a) If the same PSNR is obtained, which encoder can obtain fewer bits?

(b) If the same amount of bits is obtained, which encoder can obtain higher PSNR?

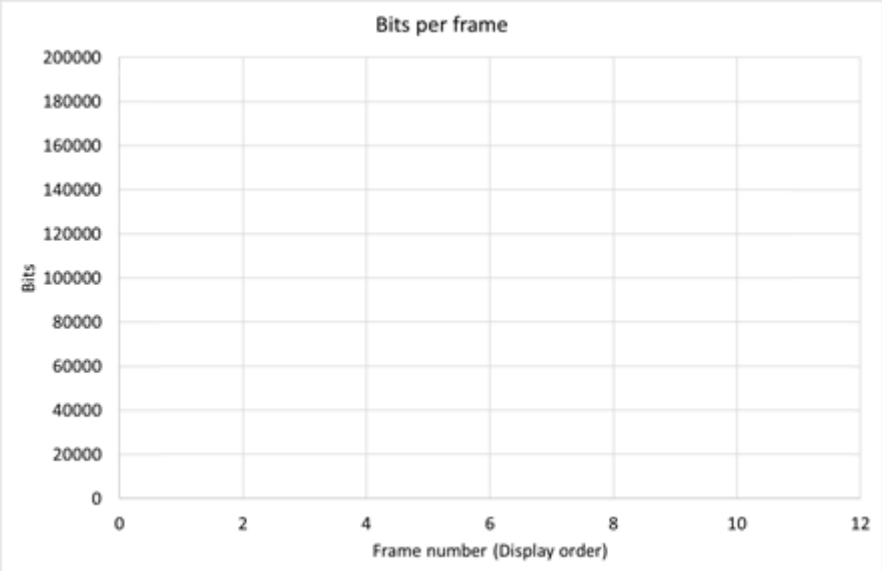
(c) So, which encoder has better performance? Why?

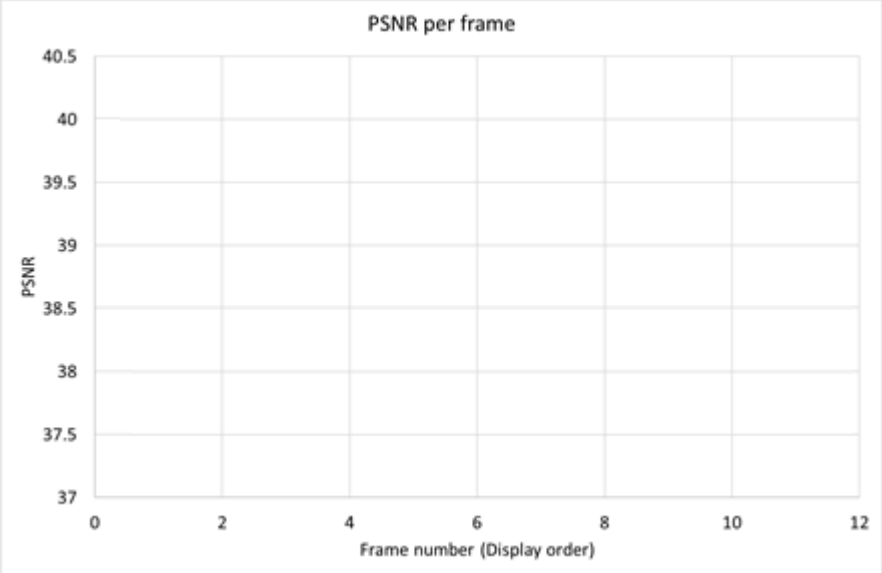
(d) By only observing one single curve, the curve for the H.264 encoder, briefly comment how the quantization parameter (QP) affects the total bits and PSNR in H.264 encoding.

Section D. Performance Evaluation for Bi-Directional Motion-Compensated Prediction

1. Use the settings, QP = 24, NumberBFrames = 3, then run "*h264encoder.exe*". You must study the information in the console window carefully. For each frame, you are able to find out the corresponding picture type (frame type), actual number of bits allocated, PSNR, quantization parameter, etc.

   Plot the bits per frame (bits/frame) and PSNR per frame (dB/frame) for the bitstream, in **display order**. You may consider the first 13 frames only (i.e. frame 0 to frame 12).





2. Before compression, the bits required to store a single frame of YUV 4:2:0 is (416×240 + 416×240÷4 + 416×240÷4) × 8, i.e. 1198080 bits. How many bits are required to store the frame 0 (I-frame) after compression)?

3. What is the Compression Ratio (CR) of frame 0 (I-frame)?

4. What is the CR of frame 4 (P-frame)?

5. What is the CR of frame 2 (B-frame)?

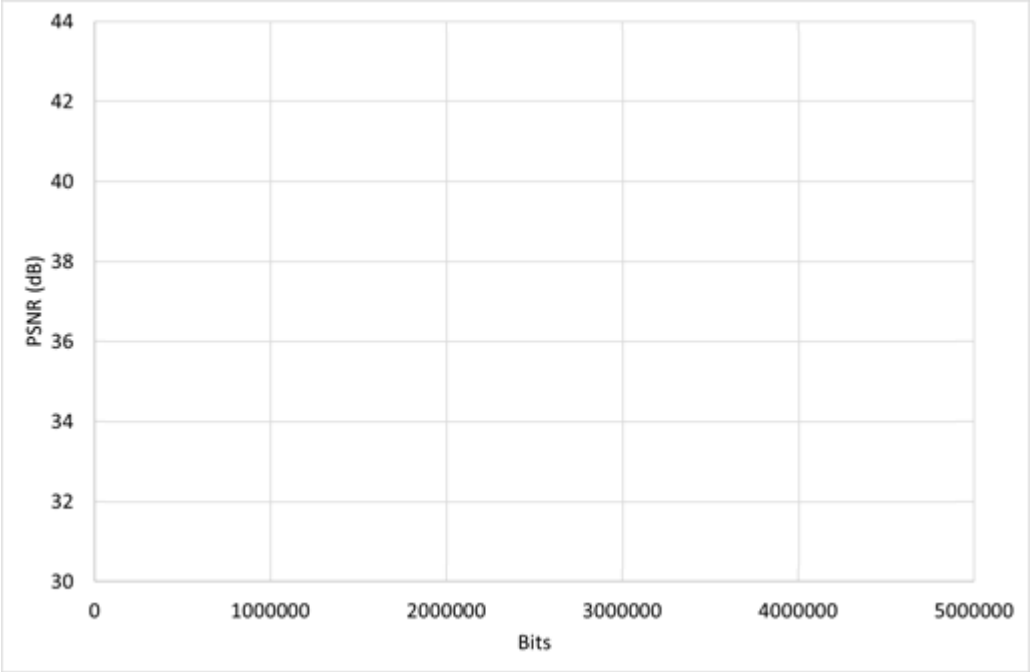
6. Based on the results of Section D. 3, 4, and 5, write down the frame with the order of CR in descending order. Please briefly comment the answer why the order like this.

7. By changing the quantization parameter (QP) in the configuration file to the following listed values, fill in Table 3.

Table 3. H.264 encoder with B frames

QP	Total Bits	PSNR
32		
28		
24		
20		

8. Plot the rate-distortion (RD) graph based on Table 2 and Table 3. Remember to give your graph a legend.
   (a) Add the points based on Table 2, and concatenate the points as a curve.
   (b) Add the points based on Table 3, and concatenate the points as a curve.



9. Which encoder has better performance? Why?

10. What is the encoding time for QP 32? What do you find by comparing the encoding time in Section B 3 (a)? Give your comments.

Section E. Different Configuration Settings for H.264 Encoder

1. Modify the "*h264encoder.cfg*" file to change the encoded H.264 bitstream with the following GOP structure.

   IBBBB BBB**P**B BBBBB B**P**BBB BBBB**I** …….

   Write down the values of your modified parameter(s) in "*h264encoder.cfg*" file.

   ---

2. Modify the "*h264encoder.cfg*" file to change the encoded H.264 bitstream with the following GOP structure.

   IBBBB BBB**I**B BBBBB B**I**BBB BBBB**I** …….

   Write down the values of your modified parameter(s) in "*h264encoder.cfg*" file.

   ---

3. Modify the "*h264encoder.cfg*" file to change the encoded H.264 bitstream with the following GOP structure.

   IIIII IIIII IIIII IIIII IIIII …….

   Write down the values of your modified parameter(s) in "*h264encoder.cfg*" file.

Section F. Evaluation of Different Motion Estimation Schemes for H.264 Encoder

1. Reset the "*h264encoder.cfg*" file settings to GOPSize = 0, QP = 32, NumberBFrames = 0.
2. Append a new setting to the "*h264encoder.cfg*" file in a new line.
   CountSearchPoint = 1
   SearchMode = 3
   Then run the encoder. The parameter "CountSearchPoint" would enable the counting of the number of search points during motion-compensated prediction while the parameter "SearchMode" is to enable different search methods.

3. What is the name of motion estimation scheme with SearchMode = 3?

   This is a fast motion estimation scheme to speed up the encoding process.

4. What is the total number of search points by the scheme stated in Q3?

5. By changing the search mode in the configuration file to the following listed values, fill in Table 4.

   Table 4. H.264 encoder with different motion estimation schemes

SearchMode	Name	Total number of search points
-1		
1		
2		
3		

   Note: In this practical encoder, there are some adaptive searching strategies for full search such that the number of search points for each frame is slightly different.

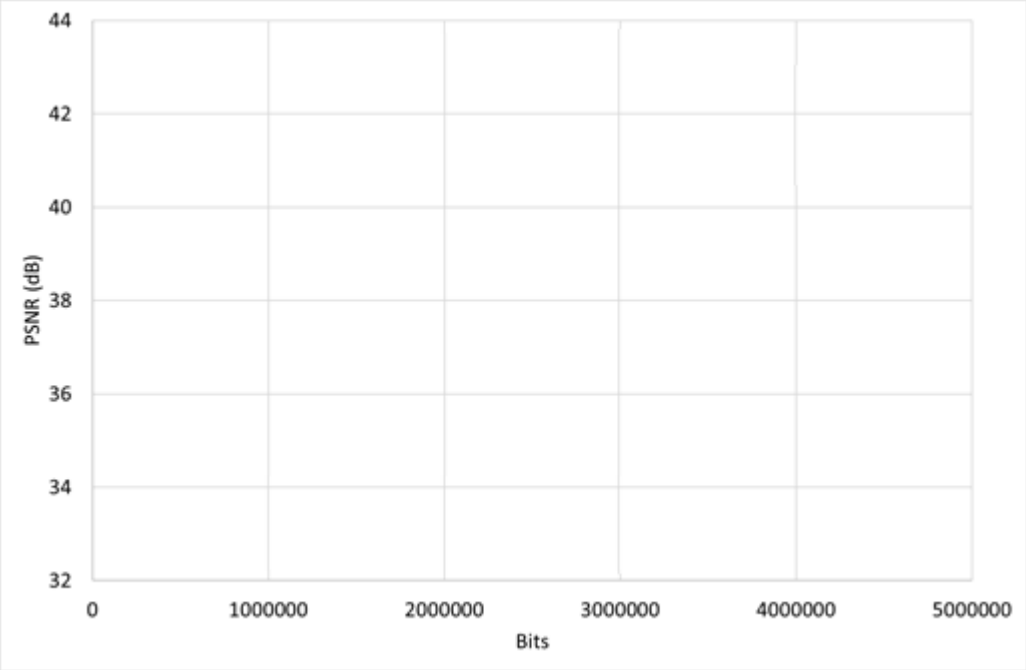
6. Which search mode has the longest encoding time?

7. Make sure the settings are GOPSize = 0, NumberBFrames = 0, CountSearchPoint = 1, and SearchMode = -1. By changing the quantization parameter (QP) in the configuration file to the following listed values for **full search**, fill in Table 5.

Table 5. H.264 encoder using full search

QP	Total Bits	PSNR
32		
28		
24		
20		

8. Indeed, the search mode used in Table 2 is EPZS fast search. Plot the rate-distortion (RD) graph based on Table 2 and Table 5. Remember to give your graph a legend.
   (c) Add the points based on Table 2, and concatenate the points as a curve.
   (d) Add the points based on Table 5, and concatenate the points as a curve.



9. Which encoder is faster?

_____

10. Are the RD performances of these two encoders similar?

_____

11. Which encoder would you choose? Why?

_____

_____

- END-

Appendix A: mj2encoder.cfg

```
RaceHorses_416x240_f40.yuv      #InputFile
out.mj2                         #OutputBitstream
40                              #FramesToBeEncoded
416                             #Width
240                             #Height
32                              #QualityFactor
```

Appendix B: mj2encoder.cfg

```
out.mj2                         #InputFIle
dec.yuv                         #OutputFile
RaceHorses_416x240_f40.yuv      #ReferenceFileForPSNR
```

Appendix C: h264encoder.cfg

```
#
# New Input File Format is as follows
# <ParameterName> = <ParameterValue> # Comment
#
###############################################################################
# H.264 Encoder Configuration Settings
###############################################################################

InputFile             = "RaceHorses_416x240_f40.yuv"      # Input Sequence
OutputFile            = "out.264"                         # Output Bitstream
FramesToBeEncoded     = 40          # Number of frames to be coded
Width                 = 416         # Horizontal Size (Width)
Height                = 240         # Vertical Size (Height)
GOPSize               = 0           # GOP Size (0=Only first frame is I-frame)
QP                    = 32          # Quantization Parameter (QP) (0-51)
NumberBFrames         = 0           # Number of Successive B frames (0=not used)

###############################################################################
# End
###############################################################################
```

Appendix D: h264decoder.cfg

```
#
# New Input File Format is as follows
# <ParameterName> = <ParameterValue> # Comment
#
###############################################################################
# H.264 Decoder Configuration Settings
###############################################################################

InputFile             = "out.264"    # Input encoded H.264 bitstream
OutputFile            = "dec.yuv"    # Output decoded YUV file

###############################################################################
# End
###############################################################################
```