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An Experimental Analysis of the MPEG Compression Standard with respect to Processing Requirements, Compression Ratio, and Image Quality

by

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An Experimental Analysis of the MPEG Compression Standard with respect to Processing Requirements, Compression Ratio, and Image Quality

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Date

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Thesis abstract:

As computer use and capabilities have grown, people have become more interested in being able to create and access varies types of multimedia content. The MPEG video compression technique provides a method for compressing video content down to a size that computers and networks can handle. To properly make use of this algorithm it is necessary to understand the trade-offs that exist when choosing among the various options of the MPEG algorithm. Background information on the MPEG-1, MPEG-2 and MPEG-4 algorithms is presented. This thesis then provides an understanding of the trade-offs of applying different compression and decompression options of the MPEG-1 algorithm on various types of video streams. This allows recommendations on which options should be used for specific categories of video sequences to be made. The performance of an existing implementation of the MPEG compression and decompression algorithm is analysed to determine these resulting trade-offs . Various types of video sequences are used to observe the results of changing the various parameters of the algorithm. Some of the parameters that are investigated include the percentage of the I (only spatially compressed), P (forward predicted), and B (bi-directionally predicted) frames in the compressed stream, and the individual quantization of each of these frames. The results from each of the video sequences when these parameters are modified and analysed with respect to overall CR (compression ratio), play rate, average compression ratio of the I, P, and B frames separately, file percentages of the I, P, and B frame separately, and image quality. Image quality is measured subjectively using results obtained by polling a group of individuals who have observed the various video sequences. The main variables that are dependent on each other are: play rate, image quality, and compression rate. This resulting trade off analyses leads to statement on which types of parameter settings should be used in each of the various types of video sequences.

In order to complete this thesis first a working understanding of the MPEG algorithm was obtained. The various video sequences used were collected. The test video streams derived from these base cases were then created and analysed. As part of this analysis phase, a group of individuals viewed and rated these video streams with respect to an original base case. A systematic approach for reporting the effect of changing the MPEG parameters on image quality, play rate, and compression ratio was determined. These results are then presented along with suggestions on when to use the various parameter options. Areas for further research are then discussed.

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Glossary

AC coefficient: A DCT coefficient for which the frequency in one or both dimensions is non-zero.

AVI: Microsoft's digital video format.

B Qfactor; B Qscale: The scale factor for the quantization matrix for the B frames.

Backward motion vector: A motion vector used for motion compensation from a reference picture at a later time in display order.

Base layer: The minimum portion of a bitstream which can be decoded to produce an output video stream.

Bidirectionally predictive-coded frame; B-frame: A picture frame that is coded using motion compensated prediction from a past and/or future reference picture.

Block search Strategy: A method for finding the location in the search area which finds the best block-matching criteria result.

Block: An 8-row by 8-column orthogonal block of pixels.

Block-matching criteria: A numerical equation which gives an indication of how closely the pixel values in two macroblocks match.

Block-matching method: Attempts to find the best motion vector estimate by a pixel-domain search procedure.

Chrominance (component): A matrix, block or sample of pixels representing one of the two color difference signals related to the primary colors. The symbols used for the color difference signals are Cr and Cb.

Color space: Various methods exist for representing the colors in a color image. MPEG uses the YcbCr color space, which consists of one luminance channel and two chrominance channels. Original image frames must be converted to this color space before the MPEG algorithm can be used.

DC-coefficient: The DCT coefficient for which the frequency is 0 in both dimensions.

DCT coefficient: The amplitude of a specific cosine basis function.

Dequantization: Rescaling the quantized DCT coefficients after their representation in the bitstream has been decoded and before they are provided to the inverse DCT routine.

Discrete cosine transform; DCT: The forward discrete cosine transform or the inverse discrete cosine transform. The DCT is reversible, discrete orthogonal transform.

Display order: The order in which the decoded pictures should be displayed. This is usually the same order as they were presented to the MPEG encoder, but may be different than the order in which they were stored in the MPEG file.

D-picture; D-frame: These only store the DC component of each block, and are useful for browsing at very low bitrates.

Enhancement layer: Additional portions of the coded bitstream which allow video of better quality to be produced.

Entropy coding: Variable length lossless coding of the digital representation of a signal to reduce redundancy.

Fast forward: The process of displaying a video sequence in display-order faster than real-time.

FFT: Fast Fourier Transformation. A fast algorithm for performing a discrete Fourier transform.

Field pictures: These are the even and odd fields as separate pictures.

Forward motion vector: A motion vector that is used for motion compensation from a reference picture at an earlier time in the display order.

Frame pictures: Obtained by interleaving lines of even and odd fields.

Future reference picture: The future reference picture is the reference picture that occurs at a later time than the current picture in display order.

Group of pictures: A series of pictures intended to assist random access. The frame types of this series are defined by the frame pattern.

Huffman coding: A method for entropy coding.

I Qfactor; I Qscale: The scale factor for the quantization matrix for the I frames.

Inter coding: Compression coding of a block or picture that uses information contained in one or more reference pictures.

Interlace: The property of television pictures where alternating lines of the picture represent different instances in time.

Interlaced video: Formed by sequences of even and odd picture fields separated by a field period.

Intra coding: Compression coding of a block or picture that uses only information contained in that block or picture.

Intra-coded picture; I-frame: A picture frame coding using information only from itself.

Luminance (component): A matrix, block or sample of pixels representing a monochrome representation of the signal. The symbol used for luminance is Y.

Macroblock; MB: The four 8x8 blocks of luminance data and the two corresponding 8x8 blocks of chrominance data coming from a 16x16 section of the picture. Macroblock sometimes refers to the pixel data, while at other times it refers to the coded representation of this pixel data. The usage is clear from context.

Motion compensation: The use of motion vectors to improve the efficiency of the prediction of pixel values. The prediction uses motion vectors to provide offsets into past and/or future reference frames containing previously decoded pixels that are used to form the prediction.

Motion estimation: The process of locating motion vectors to nearly matching macroblocks in one or more reference frames and then only DCT encoding the differences between the current frame and the reference frame.

Motion vector estimation: The process of estimating motion vectors during video encoding.

Motion vector: A two-dimensional vector used for motion compensation that provides an offset from the coordinate position in the current picture to the coordinates in a reference picture.

MPEG: An acronym that stand for the "Moving pictures Experts Group". This group has developed a series of standards for encoding and compressing video along with the associated audio.

MQUANT: The quantizer scale factor. This value is contained in the MPEG header for I frames, while it is transmitted with the macroblock for P and B pictures.

P Qfactor; P Qscale: The scale factor for the quantization matrix for the P frames.

Past reference picture: The reference picture that occurs at an earlier time than the current picture in display order.

Pictures: Made up of slices. There are four types of pictures: I-pictures, P-pictures, B-pictures, and D-pictures. One of the layers of the MPEG bitstream.

Predictive-coded picture; P-frame: A picture frame that is coded using motion compensated prediction from the past reference picture.

Quantization matrix: A set of sixty-four 8-bit scaling values used by the dequantizer.

Quantization: The process of dividing the set of DCT coefficients by the values in the quantization matrix and truncating the results. The appearance of zero values allows for compression.

Quantized DCT coefficients: DCT coefficients before dequantization. A variable length coded representation of quantized DCT coefficients is saved as part of the compressed video bitstream.

Quantizer scale factor; Qfactor: A data element saved in the compressed bitstream and used by the decoding process to scale the dequantization.

Quicktime: A digital format created by Apple to play video on a variety of computer platforms.

Random access: The ability to read and decode the coded bitstream at an arbitrary point.

Reference Picture: The nearest adjacent I- or P-pictures to the current picture in display order.

Reverse play: The process of displaying the picture sequence in the reverse of display order.

Scalability: A feature which allows only part of the available bitstream to be decoded to obtain video at a certain resolution.

Scalefactor: Factor by which a set of values in scaled before quantization.

Sequences: Formed by several group of pictures. One of the layers of the MPEG bitstream.

Skipped macroblock: A macroblock which is not saved in the encoded bitstream because of its high degree of similarity to the macroblock in the same location in the reference frame.

Slices: These consist of macroblocks, and are mainly for error recovery. One of the layers of the MPEG bitstream.

SNR scalability: Decoding using different quantizer step sizes for the DCT coefficients. Enhancement layers contain the difference between the base layer and the original video.

Spatial redundancy: Repeated information that exists due to areas of solid colors in a picture frame.

Spatial scalability: The ability to decode video at different spatial resolutions without decompressing the entire frame.

Temporal redundancy: Repeated information that exists due to stationary objects in a sequence of video frames.

Temporal scalability: Decoding at different frame rates without decoding every available frame.

URL: Universal resource locator. This is an address used to locate information on the Internet.

Variable length coding; VLC: A reversible process for coding that assigns shorter code-words to frequent events and longer code-words to less frequent events.

Zig-zag scanning order: A specific sequential ordering of the DCT coefficients from approximately the lowest spatial frequency to the highest.

1. Background Research

1.1 Section 1.1 Goal of MPEG

MPEG is an acronym that stands for the "Moving Pictures Experts Group". The MPEG committee was started in 1988 with the goal of achieving a draft of the standard by 1990 (LEGALL91 47). The MPEG algorithm was designed for both asymmetric and symmetric applications. Asymmetric applications are those in which the compression process is performed once, while the decompression process is performed multiple times. These types of applications include electronic publishing and delivery of movies. Symmetric applications require equal use of the compression and decompression process (LEGALL91 50). Possible applications include video conferencing and videotelephone.

The following features are considered important since the MPEG standard was developed: random access, fast forward/reverse searches, reverse playback, audiovisual synchronization, robustness to errors, coding/decoding delay, editability, format flexibility, and cost trade-off. "Random access requires that a compressed video bit stream be accessible in its middle and any frame of video be decodable in a limited amount of time" (LEGALL91 50). This implies that access points exist which are coded only with reference to themselves. Fast Forward/ Reverse Searches are a more demanding form of random access where it is possible to scan a compress bit stream to obtain a fast forward or a fast reverse effect. "A mechanism should be provided to permanently resynchronize the audio and the video should the two signals be derived from slightly different clocks" (LEGALL91 51). Videotelephony needs to maintain a total system delay under 150 ms in order to maintain the face to face nature of the application. Other applications can tolerate a longer delay. Given the trade off between quality and delay, the algorithm should perform acceptably over a range of delays, with delay considered as a parameter.

1.2 Brief overview of MPEG Compression and Decompression

"The difficult challenge in the design of the MPEG algorithm is the following: on one hand the quality requirements demand a very high compression not achievable with intraframe coding alone: on the other hand, the random access requirement is best satisfied with pure intraframe coding" (LEGALL91 51). This situation calls for a balance between intra- and interframe coding. Intraframe coding refers to compression methods designed to take advantage of spatial redundancies within individual frames of an MPEG video sequence. Interframe coding refers to compression methods designed to take advantage of temporal redundancies between frames of an MPEG video sequence.

The MPEG video compression algorithm makes use of two basic techniques: transform domain (DCT) based compression for the reduction of spatial redundancy and block-based motion compensation for the reduction of temporal redundancy. Motion compression techniques are applied with both predictive coding and interpolative coding techniques. The resulting signal is further compressed using a DCT based technique. The motion related information is based on 16 x 16 blocks (called macroblocks) and is transmitted with the spatial information, which is coded using a DCT technique on 8x8 blocks. The motion information is compressed by using variable-length codes to achieve maximum efficiency.

1.2.1 Temporal Redundancy Reduction

The MPEG standard uses different types of frames and motion compensation to implement temporal redundancy reduction. The MPEG standard has three different types of frames, which lead to three different ways individual frames of a video sequence can be encoded. These different types of frames allow for the random access features of MPEG. These frames are known as I, P, and B frames. I frames (intra images) are self-contained and coded using a DCT technique very similar to JPEG. This technique is described later in the section on spatial redundancy reduction. These frames serve as random access points in the MPEG stream because they do not require knowledge of any previous or future frames for proper decoding. P frames (predicted images) are coded using a forward predictive coding technique. The frame is coded with reference to a previous frame (I or P). The compression ratio of these frames is significantly higher than that of I frames. This type of motion-compensation prediction assumes that "locally" the current image can be represented as a translation of the picture at a previous time. "Locally means that the amplitude and the direction of the displacement need not be the same everywhere in the picture" (LEGALL91 52). B frames (bi-directional or interpolated images) are coded using interpolative coding between a past and a future frame (which can be I or P frames). The signal to be reconstructed is obtained by adding a correcting term to a combination of a past and a future reference frame. This is shown as follows:

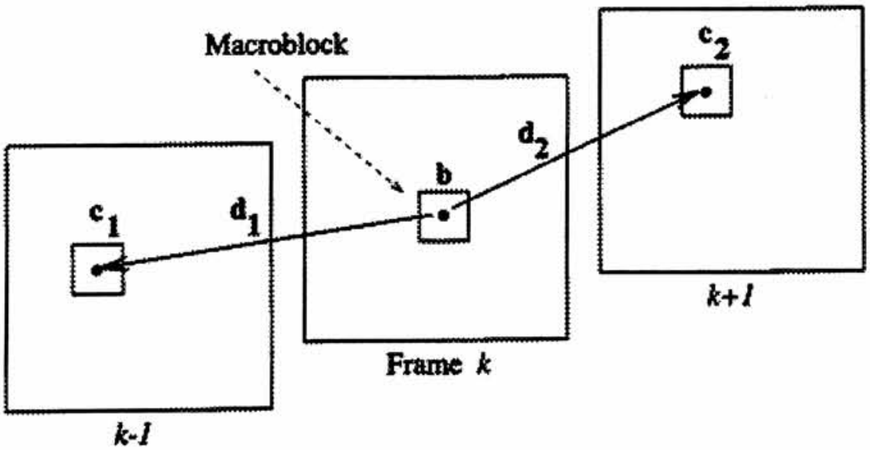
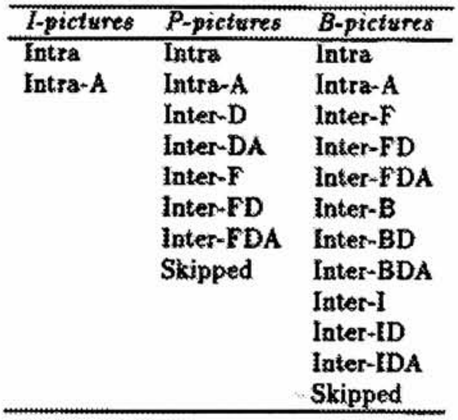


Figure 1 MPEG-1 bi-directional prediction (TEKALP95 446)

These frames provide the highest amount of compression. Bi-directional prediction also deals well with just uncovered areas. These areas are not predictable from the past reference frame, but can be predicted from the future reference frame. The effect of noise is reduced by the average between the past and future reference frames. Errors do not propagate if the B frame is coded with reference to an I frame. "Increasing the number of B-pictures between references decreases the correlation of B-pictures with the references as well as the correlation between the references themselves" (LEGALL91 52). Reference Frames are usually spaced at 1/10th second intervals for this reason. The following figure shows the available macroblock types in MPEG-1:



I-pictures	*P-pictures*	*B-pictures*
Intra	Intra	Intra
Intra-A	Intra-A	Intra-A
	Inter-D	Inter-F
	Inter-DA	Inter-FD
	Inter-F	Inter-FDA
	Inter-FD	Inter-B
	Inter-FDA	Inter-BD
	Skipped	Inter-BDA
		Inter-I
		Inter-ID
		Inter-IDA
		Skipped

Figure 2 Macroblock types in MPEG-1 (TEKALP95 443)

"Intra" macroblock do not use motion estimation during their compression, while "Inter" frames do. Notice that I-pictures only allow "intra" macroblocks. MPEG allows spatially adapted quantization by allowing a quantizer scale parameter MQUANT to be used. This value is contained in the MPEG header for I-pictures, while it is transmitted with the macroblock for P and B pictures. Macroblock types listed above containing the -A switch use the current quantization matrix scaled by MQUANT. Macroblock types without the -A switch are coded by using the unscaled quantization matrix. "It has been claimed that MPEG intra mode provides 30% better compression compared with JPEG due to adaptive quantization" (TEKALP95 444).

The subscript "D" indicates that the DCT of the prediction error will be coded. The subscript "F" indicates that forward motion compensation is to be used. The subscript "B" indicates backward prediction with motion compensation. The subscript "I" indicates interpolated prediction with motion compensation. In this case both a future frame and a previous frame are used as references. This is shown in the figure labeled "MPEG-1 bi-direction prediction". A macroblock is coded as "skipped" if the block in the same location from the previous frame is to be used. No other information needs to be sent in this case.

It is highly probable as a result of these three types of frames that the decoding order will differ from the encoding order. The MPEG application determines the proper sequence of I, P, and B frames. A sequence of these frames that is repeated throughout an MPEG file is called a group of pictures. For example fast random access requires more I frames, while better compression is obtained by using more B frames. These trade-offs will be examined in this project. A possible group of pictures is shown as follows:

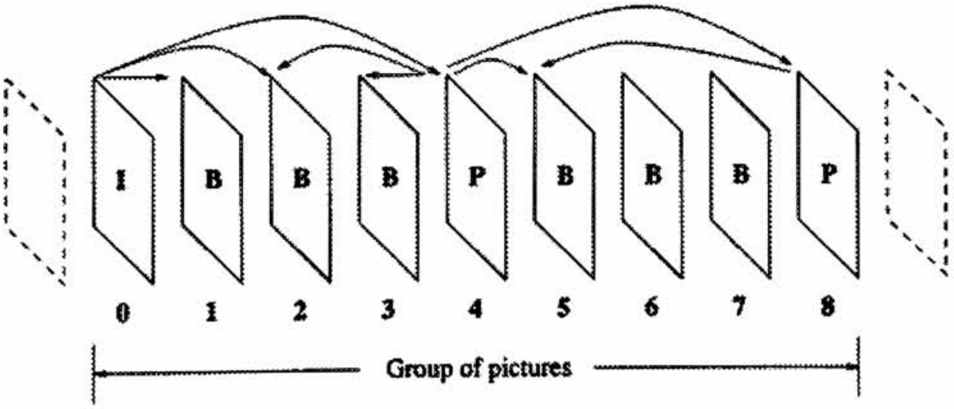


Figure 3 Group of pictures in MPEG-1 (TEKALP95 442)

This group of pictures could be encoded in the order 0, 4, 1, 2, 3, 8, 5, 6, 7 or 0, 1, 4, 2, 3, 8, 5, 6, 7.

Motion estimation is required for the coding of P and B frames. This technique tries to find the best matching macroblock in the available reference frames. B frames use bi-directional prediction that is also known as motion compensated interpolation, while P frames are always coded using forward prediction. B frames can also be coded by only using one reference frame. Motion estimation extracts the motion information from the video sequence. One motion vector is calculated for P frames and single reference B frames, while two motion vectors are used to code interpolated B frames.

The MPEG standard does not specify the motion estimation technique to be used. As a result this portion of the code can be varied. One popular choice is the mean-absolute difference (MAD) block-matching technique. In this technique the motion vector is obtained by minimizing the following cost function:

$$MAD(dx,dy)=\frac{1}{mn}\sum_{i=-n/2}^{n/2-1}\sum_{j=-m/2}^{m/2-1}\left|F(i,j)-G(i+dx,j+dy)\right|$$

where:

F(i,j) - represents a (m x n) macroblock from the current frame,

G(i,j) - represents the same macroblock from a reference frame (past or future),

(dx,dy) - a vector representing the search location.

There are several algorithms for minimizing this cost function. The algorithm chosen can affect the results obtained and the compression speed. The motion vector found indicates the distance between the actual and the reference blocks. The error terms between the actual and the reference block are then calculated and encoded using a DCT based technique. 16x16 macroblocks were chosen as the basic unit for motion-compensation. The 16x16 area is the least common multiple of 8x8 blocks, given the normal 4:2:0 chroma ratio. This chroma ratio means that the resolution of the chromanance (color) channels of a color image have half the number of samples in the horizontal and vertical directions as the corresponding luminance channel. The 16x16 area also provides a good balance between motion compensated prediction accuracy and side information overhead and complexity (MPEG-2 FAQ).

1.2.2 Spatial Redundancy Reduction

The still-image and prediction error signals both have high spatial redundancy. Many coding techniques exist to reduce this spatial redundancy. "Transform coding techniques with a combination of visually weighted scalar quantization and run-length coding have been preferred because the DCT presents a certain number of definite advantages and has a relatively straightforward implementation" (LEGALL91 54). The advantages are the following:

- The DCT is an orthogonal transform, which means it can be transformed into the frequency domain and acted upon by a filter (quantization) table. An 8x8 block of pixels is sufficient to calculate 64 transform coefficients.
- The DCT is the best of the orthogonal transforms with a corresponding fast algorithm providing a very close approximation to the optimal for a large class of images.
- The DCT basis function is sufficiently well behaved to allow the use of visual criteria.

The type of spatial redundancy reduction consists of three basic steps: the discrete cosine transform, quantization, and entropy coding. These steps will be described in greater detail later in the thesis.

1.2.3 MPEG compression and Decompression Block Diagrams

A block diagram of the MPEG-1 encoder is shown as follows:

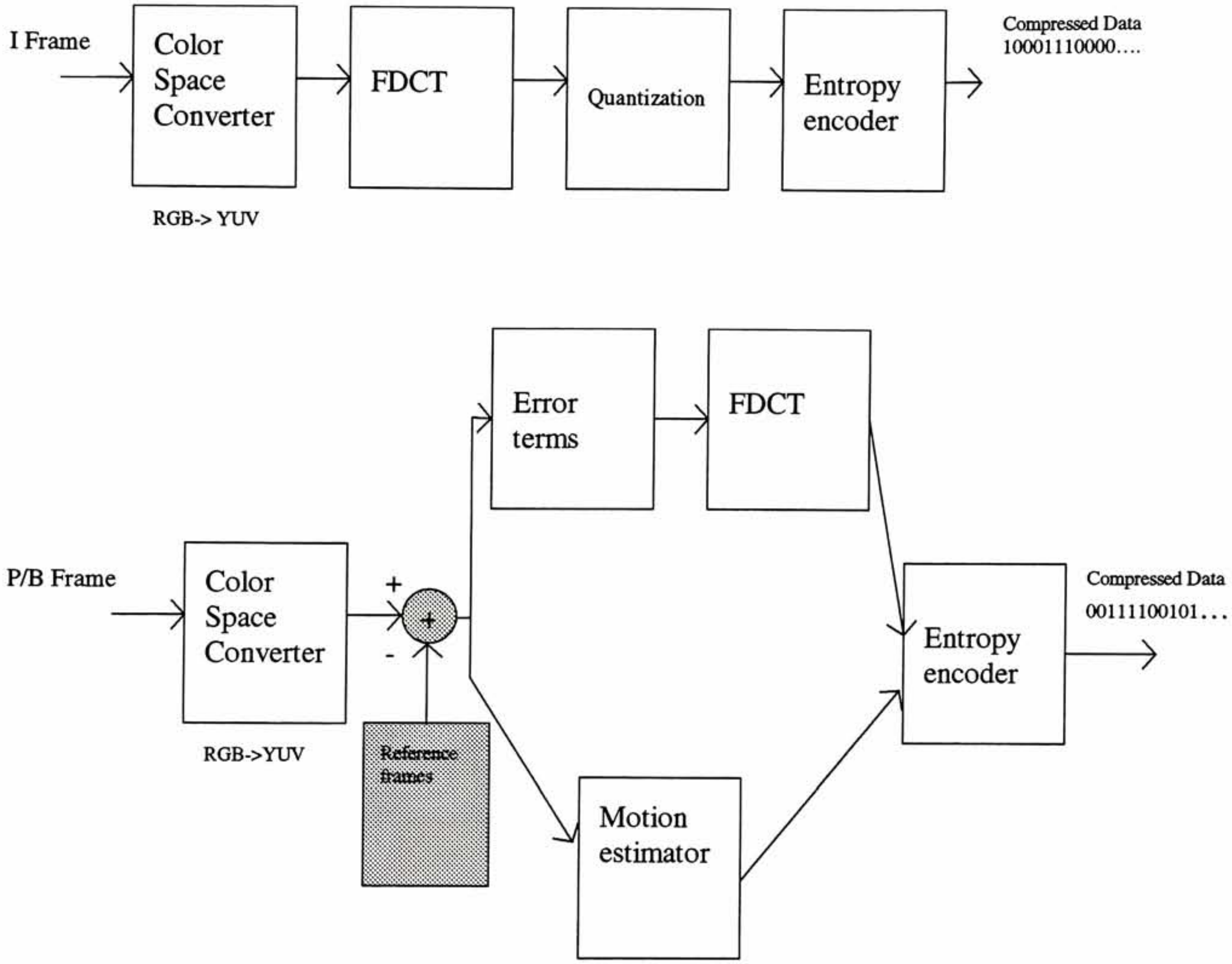


Figure 4 Block Diagram of the MPEG-1 Encoder (LAPLANTE96 152)

To compress a color image it is first transformed into the YUV format. Each image then consists of one luminance and two chrominance components. The luminance component contains twice as many samples in the X and Y direction as the other two components according to the MPEG standard. A block diagram of a typical MPEG decoder is shown as follows:

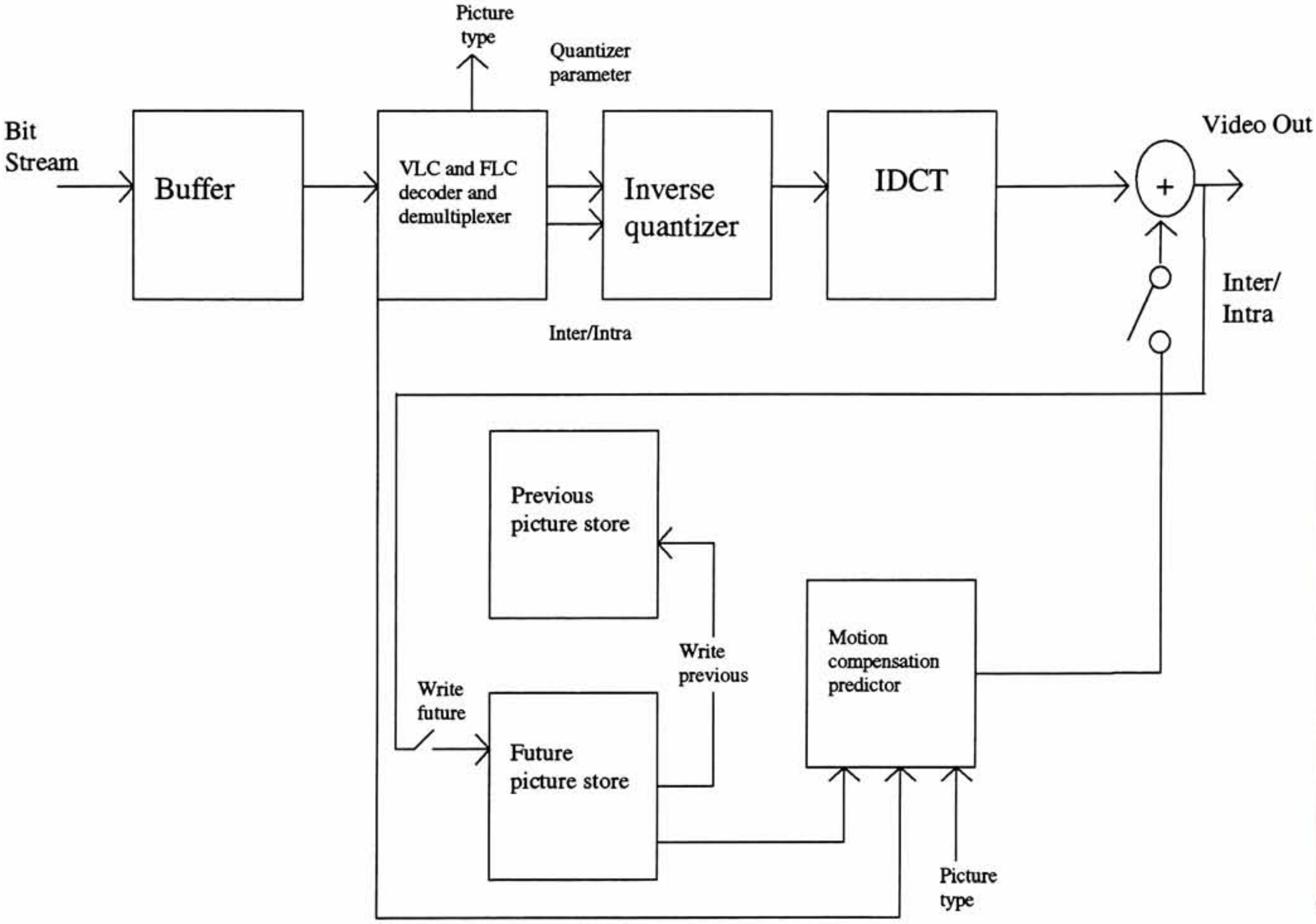


Figure 5 Block Diagram of the MPEG-1 Decoder (LAPLANTE96 153)

1.3 Detailed Explanation of MPEG Compression

1.3.1 Color Space Converter

This part of the algorithm converts the input frames into the correct color space for the MPEG-1 encoder. The encoder uses the YCbCr color space, which is a color space with one luminance channel and two chromanance channels. The chromanance channels have half the resolution of the luminance channel in both the horizontal and vertical directions. This is termed as a 4:2:0 chroma format. The following table lists different chroma formats with pixel dimensions of 720 pixels/line x 480 lines/frame:

Chroma Format	Y samples/line	Y lines/frame	C samples/line	C lines/frame	Horizontal subsampling Factor	Vertical subsampling Factor
4:4:4	720	480	720	480	none	none
4:2:2	720	480	360	480	2:1	none
4:2:0	720	480	360	240	2:1	2:1
4:1:1	720	480	180	480	4:1	none
4:1:0	720	480	180	120	4:1	4:1

1.3.2 I Frame Coding

1.3.2.1 FDCT

The first operation performed is the DC shift operation. All this operation does is subtract 128 from all the pixel values in the pixel block. This changes the range of pixel value from 0 - 255 to -128 - 127. This is done so that after the discrete cosine transform (DCT) the values will be in the correct range to be Huffman coded by the standard DC and AC table to be discussed later.

The next operation is the DCT transformation, which transform the 8x8 block of pixels into an 8x8 block of DCT coefficients. This block represents the amplitudes of various frequency components in the block of the original image. The first element of the first row is the DC coefficient, providing the average gray value of the complete 8x8 block of the original image. Other elements in the 8x8 block of DCT coefficients provide the amplitudes of increasingly higher frequencies as you go down, and to the right in the block. The DCT is a separable algorithm, so that the two- dimensional process can be divided into two one-dimensional processes, as shown in the following expressions:

$$F(u,v)=\frac{C(u)}{2}\sum_{j=0}^{7}\left\{\sum_{k=0}^{7}\frac{C(v)}{2}f(j,k)\cos\left[\frac{(2k+1)v\pi}{16}\right]\right\}\cos\left[\frac{(2j+1)u\pi}{16}\right]$$

$$F(u,v)=\frac{C(u)}{2}\sum_{j=0}^{7}g(j,v)\cos\left[\frac{(2j+1)u\pi}{16}\right]$$

where

$$g(j,v)=\sum_{k=0}^{7}\frac{C(v)}{2}f(j,k)\cos\left[\frac{(2k+1)v\pi}{16}\right]$$

The DCT procedure uses these expressions to perform the transform. The inverse DCT operation uses the following equation to perform its operation:

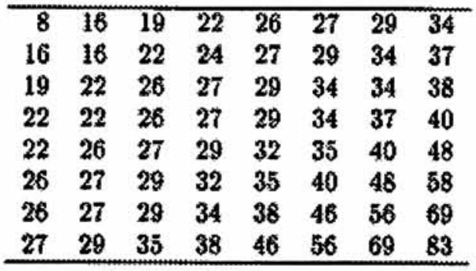
$$f(i,j)=\frac{1}{4}\sum_{u=0}^{7}\sum_{v=0}^{7}C(u)C(v)F(u,v)\cos\left[\frac{(2i+1)u\pi}{16}\right]\cos\left[\frac{(2j+1)v\pi}{16}\right]$$

1.3.2.2 Quantization

Quantization operates by dividing each of the 64 coefficients in the DCT block by the corresponding value in the quantization matrix, and then rounds the result. This has the effect of causing any result less than 0.5 to be rounded to zero. These leads to compression when these results are Huffman coded. This operation is shown by the following expression:

$$\hat{F} = \begin{cases} \left\lfloor \dfrac{F(u,v) + \left\lfloor \dfrac{Q(u,v)}{2} \right\rfloor}{Q(u,v)} \right\rfloor & \text{if F(u, v)} \geq 0 \\ \left\lfloor \dfrac{F(u,v) - \left\lfloor \dfrac{Q(u,v)}{2} \right\rfloor}{Q(u,v)} \right\rfloor & \text{if F(u, v)} < 0 \end{cases}$$

The standard quantization matrix is constructed to more heavily quantize coefficients that are not as perceptible by the human visual system. Many of the high frequency components will, as a result, be equal to zero, thus providing the opportunity for compression. The standard quantization table is shown as follows:



8	16	19	22	26	27	29	34
16	16	22	24	27	29	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	27	29	32	35	40	48	58
26	27	29	34	38	46	56	69
27	29	35	38	46	56	69	83

Figure 6 MPEG default intra quantization matrix

The values in the 8x8 matrix are then reordered in a zigzag order. This has the effect of organizing the coefficients into an order of increasing frequency. This increases the chance that list of coefficients will end in a string of zeros. The zigzag ordering of coefficients is shown as follows:

0	1	5	6	14	15	27	28
2	4	7	13	16	26	29	42
3	8	12	17	25	30	41	43
9	11	18	24	31	40	44	53
10	19	23	32	39	45	52	54
20	22	33	38	46	51	55	60
21	34	37	47	50	56	59	61
35	36	48	49	57	58	62	63

1.3.2.3 Huffman Entropy Encoding

This process takes the coefficients and compresses them in a lossless fashion. This means that these coefficients can be uncompressed without losing any information. This compressed bit stream is then sent to the output MPEG file. This process is described as follows: The DC component is encoded by first subtracting it from the DC component of the previous block (DPCM) and encoding the difference by using a DC Huffman code table. The nonzero AC values are first described by the 8-bit number: I = NNNNSSSS. The S-bits define a category from 1 to 10, which depends on the value of the coefficient. These categories are shown as follows:

Category	**AC Coefficient Range**
1	-1, 1
2	-3, -2, 2, 3
3	-7, …, -4, 4, …, 7
4	-15, …, -8, 8, …, 15
5	-31, …, -16, 16, …, 31
6	-63, …, -32, 32, …, 63
7	-127, …, -64, 64, …, 127
8	-255, …, -128, 128, …, 255
9	-511, …, -256, 256, …, 511
10	-1023, …, -512, 512, …, 1023

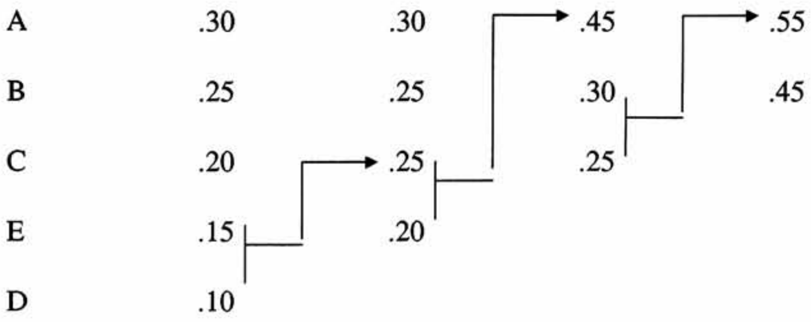
The four N-bits give the run length of zero coefficients since the last nonzero coefficient. If this number of zeros is greater than 15, a value of 240 is used for I repetitively until the number of zeros becomes less than 15. The value I = 0 represents the end of all nonzero values for the block. The value of I is then encoded by using another Huffman code table designed for AC components. This Huffman code is then followed by the value of the quantized DCT coefficient expressed by the category bits. The two Huffman codes (DC and AC) are generated by using statistics gathered which tell the frequencies of each code occurring. The corresponding Huffman code is generated so that frequently occurring codes are represented in fewer bits.

1.3.2.3.1 Discussion of Huffman Coding

The Huffman coding step mentioned above in the discussion of the MPEG compression algorithm is a lossless coding step. This means the no information is lost during the compression of the data. This step is basically a big lookup table where a certain number of input bits are translated into a certain number of output bits. This lookup table is generated by observing the probability of the different input bit patterns occurring in the data stream. The goal of Huffman coding is to code the most frequent input bit patterns with the least number of bits. As an example take a small group of input 'messages' with known probabilities of occurring in the input data stream:

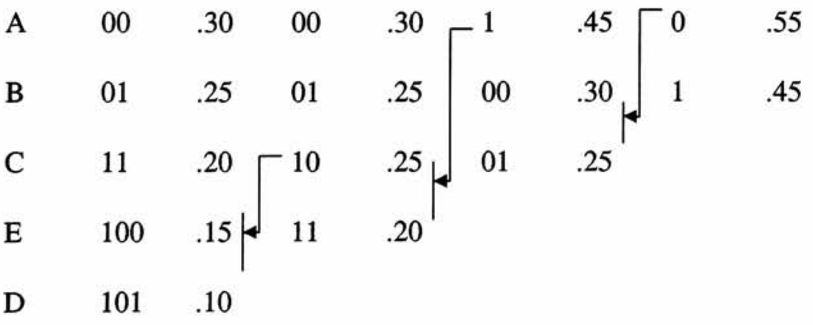
Message	Probability
A	0.30
B	0.25
C	0.20
D	0.10
E	0.15

Huffman code construction begins by summing the two least probability values, and rewriting the list. Note that the initial list is ordered with decreasing probabilities. This process is continued left to right until only two probability values remain. This is shown as follows:



A	.30	.30	.45	.55
B	.25	.25	.30	.45
C	.20	.25	.25	
E	.15	.20		
D	.10			

Huffman codes are then assign from right to left. The right most column is marked with a zero and a one. The column to the left is formed by expanding the code that resulted from the sum of the two least probability values. To do this a zero is added to the right of the present Huffman code for the greater of the two probability values, and a one is added to the right of the present Huffman code for the lower of the two probability values. The other Huffman codes are just copied as is. This process in then repeated. The final Huffman codes are shown in the left most column. This process is shown as follows:



A	00	.30	00	.30	1	.45	0	.55
B	01	.25	01	.25	00	.30	1	.45
C	11	.20	10	.25	01	.25		
E	100	.15	11	.20				
D	101	.10						

Assuming that probabilities for different inputs into the Huffman coder can be determined, the Huffman lookup table can therefore be generated. These probabilities can be determined by using a large set of images or video sequences, and generating a standard Huffman table. These probabilities can also be determined by observing the frequencies of the symbols in the data being processed. This allows an optimized Huffman table to be constructed. This may require two passes over the data, one to gather statistics and one to compress the data. This results in slower compression, but possibly a higher compression ratio.

1.3.3 P/B Frame Coding

1.3.3.1 Motion Estimator

1.3.3.1.1 The Block-Matching Method

Block matching is the most popular method for motion estimation due to its lesser hardware complexity, and it's now widely available in VLSI. Block matching finds the best motion vector estimate by a pixel-domain search procedure. The general concept of block matching is shown in the following figure:

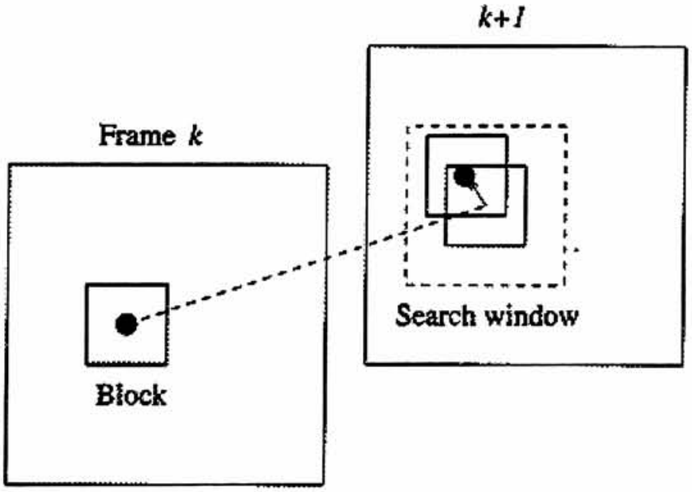


Figure 7 Block matching (TEKALP95 102)

"The displacement for a pixel (n_1, n_2) in frame k (the present frame) is determined by considering an (m x n) block centered about (n_1, n_2), and searching frame k + 1 (the search frame) for the location of the best-matching block of the same size" (TEKALP95 101). The search is typically limited to an area of (m + 2p) x (n + 2p) which is called the search window. Typically a 16x16 macroblock is used and p =6. This is shown by the following figure:

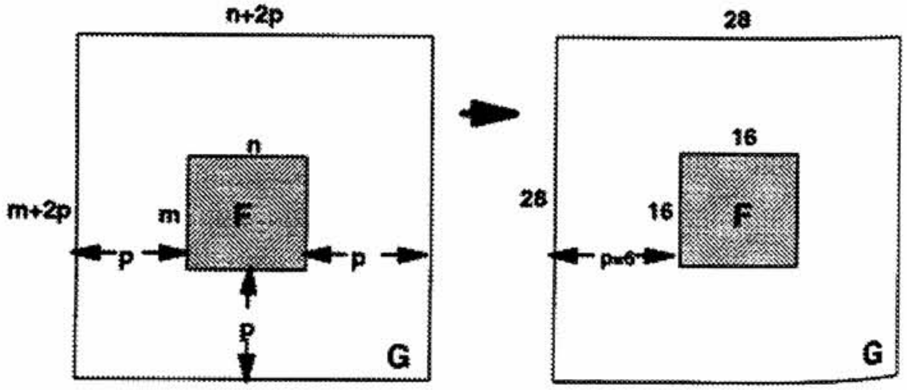


Figure 8 The search area in block-matching techniques for motion vector estimation (FURHT95 148)

Block-matching algorithms differ in the matching criteria and the search strategy. The matching criteria is a formula which gives an error value as a result, given the motion vector and necessary pixel values as inputs. The search strategy is a method that searches for the block that minimizes this error value. Once the desired block is found, the vector is encoded in the MPEG stream along with the pixel differences between the two macroblocks. These pixel differences are transformed using the DCT and quantized, like the 8x8 blocks in an I frame are. Since the error between the two macroblocks should be close to a minimum, the resulting error terms will have low values and spatial energy. This results in a high amount of compression.

1.3.3.1.2 Block Matching Criteria

1.3.3.1.2.1 The Mean-Absolute Difference (MAD) (FURHT95 148)

The Mean-Absolute Difference (MAD) is defined as:

$$MAD(dx,dy)=\frac{1}{mn}\sum_{i=-n/2}^{n/2-1}\sum_{j=-m/2}^{m/2-1}\left|F(i,j)-G(i+dx,j+dy)\right|$$

where:

F(i,j) - represents a (m x n) macroblock from the current frame,

G(i,j) - represents the same macroblock from a reference frame (past or future),

(dx,dy) - a vector representing the search location.

The search space is specified by: dx and dy in the range {-p,+p}

In typical applications m=n=16 and p=6, the MAD function becomes:

$$MAD(dx,dy)=\frac{1}{256}\sum_{i=-8}^{7}\sum_{j=-8}^{7}\left|F(i,j)-G(i+dx,j+dy)\right|$$

This cost function is the most popular choice for VLSI implementations and is used for video applications. The search strategy looks for a minimum value.

1.3.3.1.2.2 The Mean-Squared Difference (MSD) (FURHT95 149)

The Mean-Squared Difference (MSD) is defined as:

$$MAD(dx,dy) = \frac{1}{mn} \sum\nolimits_{i=-n/2}^{n/2-1} \sum\nolimits_{j=-m/2}^{m/2-1} \left[F(i,j) - G(i+dx, j+dy)\right]^2$$

The search strategy looks for a minimum value.

1.3.3.1.2.3 The Cross-Correlation Function (CCF) (FURHT95 149)

The Cross-Correlation Function (CCF) is defined as:

$$CCF(dx,dy) = \frac{\sum\limits_{i}\sum\limits_{j} F(i,j)G(i+dx, j+dy)}{(\sum\limits_{i}\sum\limits_{j} F^2(i,j))^{1/2}(\sum\limits_{i}\sum\limits_{j} G^2(i+dx, j+dy))^{1/2}}$$

The search strategy looks for a minimum value.

The MSD and CCF can be more efficient than the MAD function, but are too complex for hardware implementations.

1.3.3.1.2.4 The Maximum Matching Pel Count (MPC) (TEKALP95 103)

The Maximum Matching Pel Count is defined as:

$$T(n1,n2;dx,dy)=\begin{cases}1 & if\left|s(n1,n2,k)-s(n1+dx,n2+dy,k+1)\right|\le t\\ 0 & otherwise\end{cases}$$

where t is a predetermined threshold

$$MPC(dx,dy)=\sum_{(n1,n2)}T(n1,n2;dx,dy)$$

The search strategy looks for a maximum value.

1.3.3.1.3 Block Search Strategy

1.3.3.1.3.1 The exhaustive search algorithm (FURHT95 150)

"The exhaustive search algorithm is the simplest but computationally intensive search method, which evaluates the cost function at every location in the search area" (FURHT95 150). If the MSD cost function is used to estimate the motion vector, it would need to be evaluated 169, $(2p+1)^2$ where p=6, times for each macroblock.

1.3.3.1.3.2 The three-step-search algorithm (FURHT95 150)

The three-step search algorithm first calculates the cost function at the center and eight surrounding locations in the search area. The location that results in the smallest cost function becomes the center location for the next step. The search range is reduced by half. For p=6, the step size (distance from the center location to the surrounding locations to be tested) is 3 for the first iteration, 2 for the second, and 1 for the third. The smallest cost function result found becomes the chosen block matching location. This is shown by the following figure:

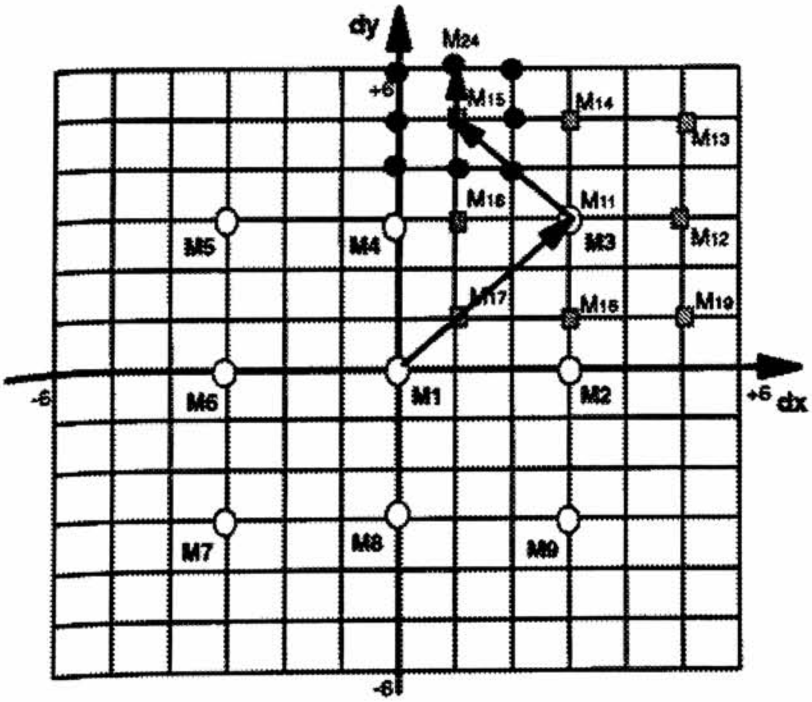


Figure 9 The three-step motion vector estimation algorithm (FURHT95 151)

The total number of computations of the cost function is: 9 x 3 - 2 = 25, which is much better than the exhaustive search algorithm.

1.3.3.1.3.3 The 2-D logarithmic search algorithm (FURHT95 152)

This algorithm uses a cost function, typically the MAD cost function, to perform a logarithmic 2-D search along a virtual direction of minimum distortion on the data within the search area. The following figure shows an example of this algorithm:

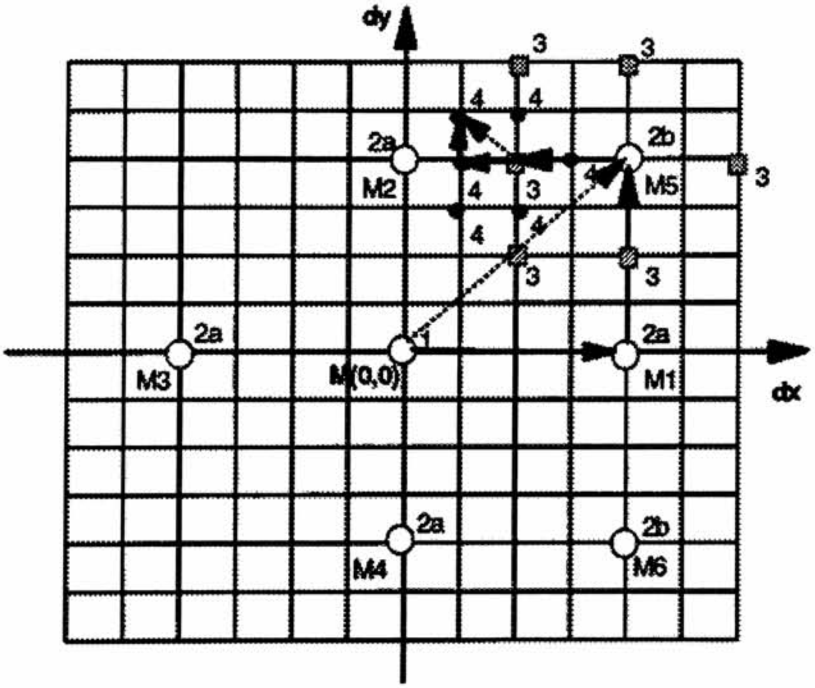


Figure 10 The 2D logarithmic search algorithm (FURHT95 152)

Step 1

The MAD function is calculated for M(0,0), and compared to a threshold. If the value is below the threshold, the desired location is found and the search is complete. Assume that this is the case any time a MAD function is calculated at a location for the remainder of a location. This means that the algorithm stops when a location is found where the MAD is below the threshold.

Step 2a

The next four cost functions, $M_1(4,0)$, $M_2(0,4)$, $M_3(-4,0)$, and $M_4(0,-4)$ are calculated. If the minimum of these 4 values is less than M(0,0) go to step 2b. Otherwise, go on to step 3.

Step 2b

Assuming that the minimum in the previous step was found at M_1, then the surrounding positions $M_5(4,4)$ and $M_6(4,-4)$ are calculated. The minimum of these to locations is used in the next step.

Step 3

Assuming that the new minimum location is $M_5(4,4)$ as shown above, steps 2a and 2b are repeated with the step size divided by 2.

Step 4

The step size is divided by 2 again, steps 2a and 2b are repeated, and the algorithm ends with the minimum location of the final tests being the result.

1.3.3.1.3.4 The conjugate direction search algorithm (FURHT95 153)

The principle of this search method is shown by the following figure:

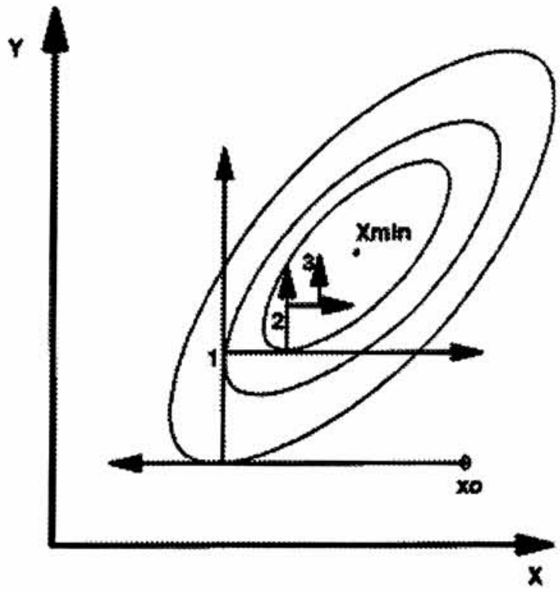


Figure 11 The principle of the conjugate direction search algorithm (FURHT95 154)

This figure shows that the basic principle is to search from a starting point along the dx direction until a minimum value is found. The algorithm than searches along the dy direction, anchored at the minimum location just found, until another minimum location is found. The direction of the search is now the vector connecting the starting point with the minimum just found. The minimum in this new direction is used as the result. An example of this is shown in the following figure:

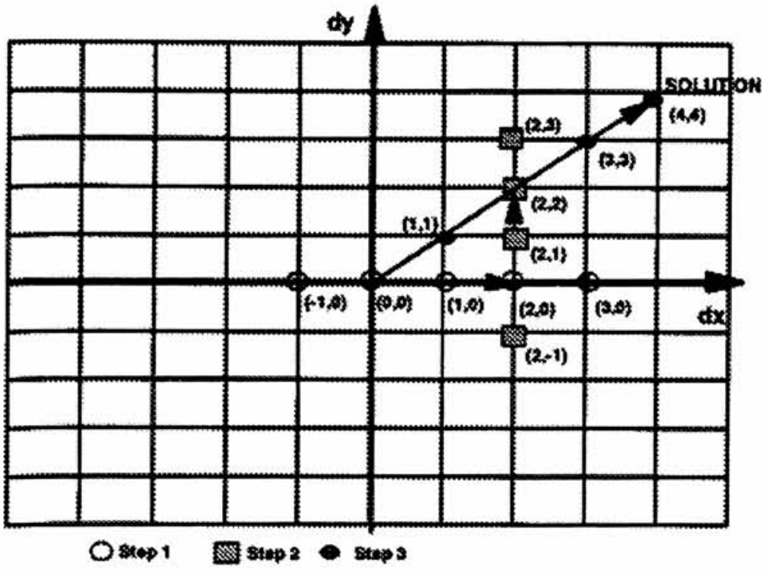


Figure 12 The conjugate direction search method for motion vector estimation

(FURHT95 155)

If the dx and dy vectors found in the first two steps do not form a square the nearest grid points along the search direction in the last step are the ones which are tested for a minimum.

1.3.3.2 Entropy Encoder

The above procedure results in motion vector(s) and error terms. The error terms DCTed and quantized. Then they are zigzag scanned to form [run, level] pairs, which are then coded using variable length codes (VLC), in other words Huffman codes. This process is described in more detail above in the section concerning I-frame coding. Motion vectors are DPCM encoded with respect to the motion vectors of the previous blocks. VLC (Huffman) tables are defined for encoding the type of macroblock, the differential motion vector, and the error terms. Separate Huffman tables exist for coding the macroblock types for P- and B- frames. The Huffman tables for specifying the motion vectors and error terms are the same for both types of frames.

1.3.4 Output Bitstream Hierarchical Data Structure

The MPEG-1 bitstream is made up of a hierarchical data structure, consisting of six layers, which allows the decoder to process the data unambiguously. The layers are as follows:

1. *Sequences* - formed by several group of pictures.
2. *Group of pictures (GOP)* - made up of pictures. Refer to figure labeled "Group of Pictures in MPEG-1".
3. *Pictures* - made up of slices. There are four types of pictures : I-pictures, P-pictures, B-pictures, and D-pictures. D-pictures store only the DC component of each block, and are useful for browsing at very low bitrates. The other three types of pictures have already been discussed.
4. *Slices* - consist of macroblocks, and are mainly for error recovery.
5. *Macroblocks* - 16x16 units. Refer to the figure labeled "Macroblock Types in MPEG-1".
6. *Blocks* - 8x8 pixel arrays, the smallest available DCT unit.

There are headers defined for sequences, GOPs, pictures, slices, and macroblock to specify the information that follows in the bitstream.

1.4 Explanation of MPEG Decompression

The decompressor performs the inverse operation of the compressor. As a result only a basic overview of its operation will be given. Refer to the figure labeled "Block diagram of the MPEG-1 Decoder" for the main steps in this process. The block labeled "VLC and FLC decoder and demultiplexer" decodes the input data stream and passes the resulting data to the correct portion of the algorithm. VLC stands for variable length codes, in other words Huffman codes. FLC stands for fixed length codes. The main pieces of data in the compressed bit stream are: quantized DCT coefficients which are either error terms from the motion compensation or stand alone blocks, the motion prediction vectors, and the macroblock types. The blocks in the decompression process labeled "inverse quantizer" and "IDCT" create the stand alone pixel block or error terms. Error terms are added to the results from the "motion compensation predictor" for inter pictures. This is indicated by the switch on the decompression block diagram. In order to decompress pictures with motion compensation the previous and future frames must be stored for reference. This is indicated by the blocks labeled "previous picture store" and "future picture store".

1.5 MPEG Variations

1.5.1 MPEG-2

The MPEG-2 standard is intended for high resolutions and supports compressed bit streams of high-quality digital video at the rate of 2-80 Mb/s. The main features of the MPEG-2 syntax are: "i) it allows for interlace inputs, higher-definition inputs, and alternative subsampling of the chroma channels, ii) it offers a scalable bitstream, and iii) it provides improved quantization and coding options" (TEKALP95 448).

1.5.1.1 MPEG-2 Macroblocks

A macroblock is defined as four 8x8 luminance blocks and their spatially associated chroma blocks. MPEG-2 has three chroma subsampling formats, 4:2:0 (same as MPEG-1), 4:2:2 (chroma subsampled in the horizontal direction only), and 4:4:4 (no chroma subsampling). The locations of the luma and chroma pixels for the 4:2:0 (label a) and 4:2:2 (label b) formats are show as follows:

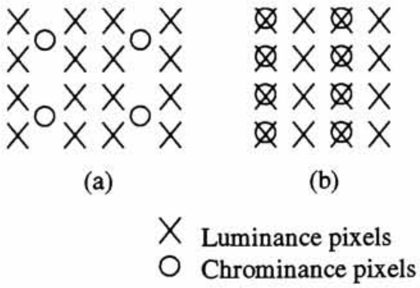


Figure 13 Chrominance subsampling options (TEKALP95 449)

Figure 13 (a) shows chrominance subsampling by two in both directions. There are 4 chrominance pixels in this diagram, 2x2 = 4, while there are 16 luminance pixels, 4x4 = 16. Figure 13 (b) shows chrominance subsampling by two in only the horizontal direction. There are 8 chrominance pixels in the diagram, 2x4 = 8, while there are 16 luminance pixels, 4x4 = 16.

1.5.1.2 Coding Interlaced Video

Interlaced video is made up of sequences of even and odd fields separated by a field period. There are two new picture types defined for interlaced video. *Frame pictures* are obtained by interleaving lines of even and odd fields. *Field pictures* are the even and odd field as separate pictures. Field pictures occur in pairs (top and bottom fields) and together make up a frame. "If the top field is a P- (B-) picture, then the bottom field must also be a P- (B-) picture. If the top field is an I-picture, then the bottom field can be an I- or P-picture" (TEKALP95 451). Pairs of field pictures are always encoded in the order they should appear at the output.

Each MB in a frame picture can be coded with a field- or frame-DCT option. Field-DCT may be selected for macroblocks containing high motion, while a frame-DCT may be used for macroblocks with little motion but high spatial activity. The internal organization of the MB for both of these types of DCTs is shown as follows:

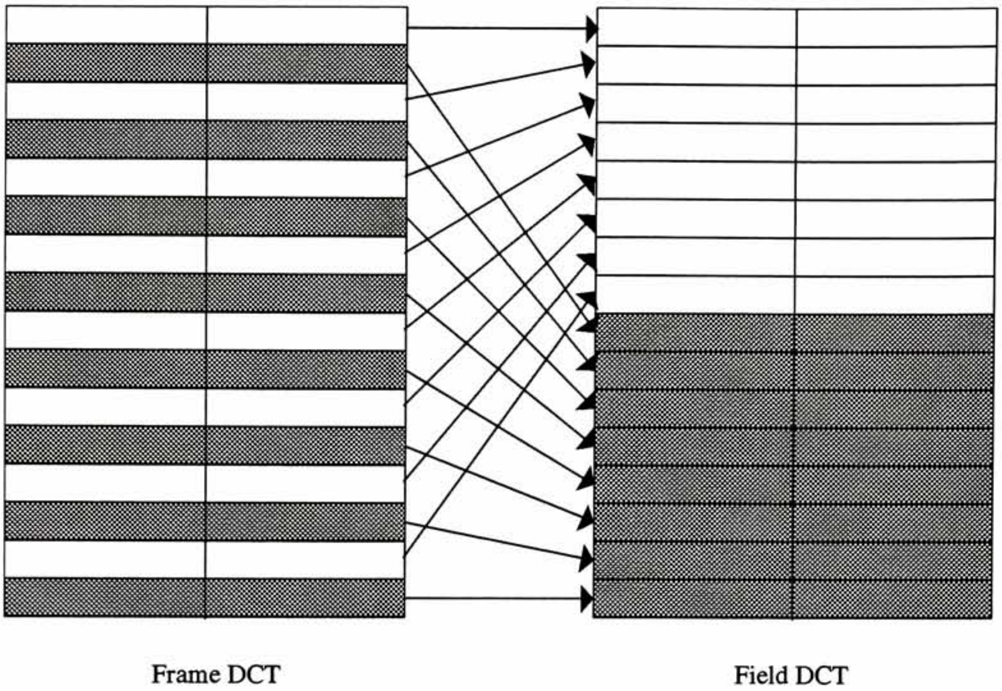


Figure 14 DCT options for interlaced frame pictures (TEKALP95 452)

There are also two major types of prediction modes for interlaced video. These are simple field and simple frame prediction. "In simple field prediction, each field is predicted independently using data from one or more previously decoded fields. Simple frame prediction forms a prediction for an entire frame based on one or more previously decoded frames" (TEKALP95 452). Field pictures can only use field predictions. Frame pictures can use either frame or field prediction on a MB-by-MB basis. When there is motion in the video stream, frame prediction has strong motion artifacts. In the absence of motion, field prediction does not use all the information available.

1.5.1.3 Scalable Bitstream Extensions

Scalability is the feature which allows only parts of the available bitstream to be decoded to obtain video at a certain resolution. Decoders with different complexities can decode and display video streams at different spatio-temporal resolutions from the same bitstream. The *base layer* is the minimum portion of a bitstream which can be decoded to produce an output video stream. The MPEG-2 syntax allows two or three layers of video to be included in the bitstream. There are three main forms of scalability:

1. *Spatial scalability* - allow the ability to decode video at different spatial resolutions without decompressing the entire frame. Enhancement layers contain increasingly higher-frequency information.

2. *SNR scalability* - decodes using different quantizer step sizes for the DCT coefficients. Enhancement layers contain the difference between the base layer and the original video.

3. *Temporal scalability* - decodes at different frame rates without decoding every available frame.

1.5.1.4 Other Additions

MPEG-2 has an optional scanning pattern in addition to zigzag scanning called "alternate scan". This pattern is was designed to fit interlaced video better, and is shown as follows:

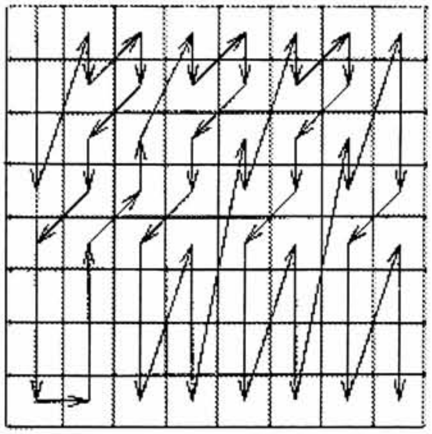


Figure 15 Alternate scan (TEKALP95 454)

A full 11-bit resolution is allowed for the DC coefficients in MPEG-2. This means that coefficients are quantized into the range of [-2048,,2047], as opposed to [-256,255] in MPEG-1.

MQUANT has also been expanded in MPEG-2. "In addition to a set of MQUANT values that are integers between 1 and 31, MPEG-2 allows for an optional set of 31 values that include real numbers ranging from 0.5 to 56" (TEKALP95 454).

MPEG-2 supports a variety of features and free parameters. There are five profiles of MPEG-2 which support different levels of the available features. There are also 4 levels of these profiles which impose constraints on the values of the free parameters for the purpose of different hardware implementations. These are shown in the following table:

Level	Max. Pixels	Max. Lines	Max. Frames/s
Low	352	288	30
Main	720	576	30
High-1440	1440	1152	60
High	1920	1152	60

(TEKALP95 455)

The 5 profiles are as follows:

1. *Simple profile* - does not allow the use of B-pictures, only supports the Main level, and has a maximum bitrate of 15 Mbps.
2. *Main profile* - does not include any scalability, and has upper bounds on the bitrates equal to 4, 15, 60, and 80 Mbps for the Low, Main, High-1440 and High levels, respectively.
3. *SNR Scalable profile* - supports Low and Main levels with maximum bitrates 4 and 15, respectively. The maximum bitrates for the base layer are 3 and 10 Mbps.
4. *Spatially Scalable profile* - supports only High-1440 level with a maximum bitrate of 60 Mbps. The maximum bitrate for the base layer is 15 Mbps.
5. *High profile* - includes Main, High-1440, and High levels with maximum bitrate of 20, 80, 100 Mbps, respectively. The maximum bitrates for the base layer is 4, 20, and 25 Mbps respectively.

1.5.2 MPEG-4

The MPEG-4 standard, which is under development, was originally intended to support very low bitrate applications. This goal has been significantly modified since its original conception. It now deals with coding audiovisual object, to be described later in this section. The standard is still under development, and is scheduled to become an international standard by November 1998. This schedule is aggressive because of the desire to provide a solution to the problems addressed by this standard before multiple proprietary solutions are created.

1.5.2.1 Goals of MPEG-4

MPEG-4 is being developed to meet changes in how audiovisual material is produced, delivered, and consumed. Some of these changes are as follows:

1. Production of audiovisual material -

   In the past content was produced by recording it with a camera and a microphone. "Artificially generated content used to be limited to movies and science, but now it is quite common to see it used in other business applications- for example architecture-, and consumer devices, such as computer games" (KOENEN97). This newer type of content is also often 3-dimensional. Pre-segmented material using blue-screen techniques is also often produced. Another change is the association of textual information with the objects in a video scene.

2. Delivery of multimedia information -

   Users are now requiring that video and other data be transported along networks which originally only transmitted audio information. Mobile users want access to the same multimedia information that is available to them in their homes and offices. Higher bandwidth networks are becoming available which promise to deliver several Megabits per second to the user. As the number of types of networks is growing , the number of connections that involve more than one network type is also increasing.

3. Consumption of multimedia information -

   More and more content is becoming audiovisual in nature. There is also a need for this information to be read, seen, and heard in interactive ways. An example of this is the world wide web, which has grown tremendously in recent years.

4. Software implementations of multimedia algorithms -

   As personal computers are becoming more powerful it is now possible to run many multimedia applications without specialized hardware.

5. Reuse of audiovisual material -

   "The digital form of storage and transmission offers the possibility to copy audiovisual scenes as many times as one would like, without the loss of quality inherent to analog re-use" (KOENEN97). Tools could also be re-used as well. Different programs running on the same machine can make use of the same audiovisual tool. For example a web browser or a video editor could both make use of the same MPEG player tool.

6. Mixing of traditional multimedia service models -

   These service models are communication, interactive, and broadcast, which can be roughly mapped to the Telecommunications, Information Technology, and Entertainment sectors respectively. The boundaries between these service models are blurring. Examples of this are interactivity being added to broadcast services, and mixed communication/interactive applications on the internet. As this mixing takes place there is a tendency for each business sector to develop its own solutions for the same types of applications. This results in difficulty in communicating this information between the business sectors. To prevent this MPEG-4 will attempt to support all of these services models, and as a result allow mixed models to be created.

1.5.2.2 Main Features of MPEG-4

The main new feature that MPEG-4 includes is the coding of audiovisual objects rather than video frames with associated audio. For example a video object of a dog could be associated with the audio object of the dog barking. This allows for versatile re-use of data, bandwidth and processing management schemes, and error protection. It also makes mixing of natural and synthetic material, and data types such as graphics and text easier. Other features are as follows:

1. A New Kind of Interactivity -

   Coding the objects in a scene separately allows a different type of interactivity than is allowed today. For example an object in a scene could be associated with additional information, through the use of a URL for example, which could be activated when the object is selected. URL stands for universal resource locator, which is used to locate information on the Internet. This is difficult to accomplish with frame based video unless the object occupies a fixed position in the scene. The ability to separately store and access objects also allows new content to be created by combining several of these objects.

   Composition is also an important part of the MPEG-4 algorithm. This is the part of the algorithm that deals with combining the objects to create a final output stream. Information about spatio-temporal information is sent along with the objects in order for the compositor to operate. This information is used to synchronize the different objects in time and space. Separating this function from the decoding of the objects allows the user to influence the reconstruction of the scene, by moving the objects or change the playback of the associated audio. Coding objects separately also allows the quality and error protection of the objects to be individually changed. The data for these objects can also be gathered from different locations.

MPEG-4 will not specify how a given scene is organized into objects. It will specify a decoding standard, and not the encoding method. This allows for competition among available encoders, and leaves room for technological innovation in segmentation and encoding methods.

The image segmentation problem is not completely solved. It is now possible to find and track a face for a videophone utility, even in real time, for example. Content produced offline using blue-screen techniques is already segmented to some degree. Leaving the problem of segmentation out of the main focus of the standard allows these problems to be solved in the future, without eliminating the usefulness of the standard.

The use of objects will also require that copyright issues be addressed. "Objects should have the option to carry copyright information, e.g. stating that re-use is not allowed, or giving a pointer to the owner or caretaker of the copyright" (KOENEN97).

2. Access to Multimedia Information -

MPEG-4 will include coding tools and a system layer that will allow for error detection and correction. The user, or the encoder itself, will also be able to decide how many bits should be spent on the different objects in the scene. This will be useful on mobile networks, which are often low bandwidth.

Another goal of MPEG-4 is to make communications across heterogeneous networks possible. This will require scalable objects which can be accessed at different bitrates, depending on the available bandwidth and computing power on the network. Important objects can be given precedence in the decoding. Less important objects can be decoded at a lower resolution, or possibly only once in the case of a stationary background. Similar quality trade-offs are also possible for the associated audio.

3. Integration of different type of Multimedia Objects -

   The object representation used by MPEG-4 allows for mixing of audiovisual material of different origin. The objects could be natural or synthetic, graphics or text. They could also be two or three dimensional. Each of these types of objects have their own efficient way of being represented. As a result each type of object would have its own decoding tool which would then pass the resulting object in local time and space coordinated to the compositor. The compositor would then perform the rendering and composition of the objects in the scene using the attached properties of the object. This would result in an audio and video frame which could be played by a presenter.

4. Flexibility -

   There are many different forms of flexibility that will be offered by the MPEG-4 standard. The object representation itself allows for flexibility in how a final multimedia sequence is presented. Configuration information could also be downloaded for the object processing tools used, but it is unclear whether this can be done in real-time. The complete tools themselves could also be loaded from the remote site. "Summarizing, flexibility will start with composition and will, when compute power allows this and a market demand exists, be extended to decoder configuration and decoding tools downloading" (KOENEN97).

1.6 Alternatives to MPEG

1.6.1 Quicktime Movies

Quicktime is a digital video format created by Apple. Video players are available for this type of format on a variety of computer platforms. The Quicktime structure is focused toward software playback. There are a variety of compression methods that can be used in the Quicktime format. These include JPEG, video compressor-RPZA-, compact video-cinepak-, animation compressor-RLE-, Indeo 3.2, and an MPEG Codec. Compared to a 30 sec, 30 frame/sec synchronized audio and video MPEG-1 file of about 1.4MB, Quicktime move files tend to be 200% to 400% larger.

1.6.2 AVI

AVI is Microsoft's digital video format. There are a variety of compression methods that can be used in the AVI format. Intel's Indeo format is the most popular of these. Indeo compression is performed in software and is, as a result, slower than compression methods that can be implemented in hardware. In encodes at about 15 frames/sec and is a proprietary method available from a single vendor. AVI files are from 100% to 200% larger than the MPEG-1 file mentioned about in the Quicktime discussion.

2. Video Stream Analysis

2.1 Description

This deliverable's goal is to analyze the effect of modifying the parameters to the MPEG algorithm on the resulting decompressed video stream. The factors of the resulting decompressed stream that are recorded and analyzed include: Overall CR (compression ratio), Playing frame rate, Average CR of I, P, and B frames separately, File percentage of I, P, and B frames, and Image quality. Image quality is rated subjectively by a group of individuals viewing the resulting video sequence, and rating it using a number scale from 1 to 5 according to various categories. These categories are defined in the section labeled "Survey Clarification of Terms":

2.1.1 Survey Video Sequence Selection

Various video sequences were used to show a range of possible applications of the MPEG algorithm, so that statements about which settings of the algorithm variables are appropriate in different cases can be made later on in this section of the thesis. The video sequences chosen are:

Name: carm4
Description: Cars moving in a stationary background

Name: folcar1
Description: Car relatively stationary in the frame while it moves along the background

Name: zoom3
Description: A zoom in and out of a street containing moving cars with no panning

Name: b5m2
Description: A computer generated planet exploding

Name: b5m3
Description: A computer generated space battle, where the background is mostly black and ships are moving around the scene

Name: toy1
Description: A computer generated rotate while zooming out of a toy figure

2.1.2 Survey Clarification of Terms

Blocking artifacts:

The appearance of blocks (solid colored squares) in the video sequence due to spatial blocks (8x8) or motion blocks (16x16).

Contouring:

Contouring is solid colored bands where there should be a smooth color sweep. This results from too few color values being encoded in the video sequence.

Sharpness of edges:

Look for blurring of what should be straight solid lines. This is especially visible in the three computer generated video sequences.

Fine detail:

Look for details in the objects in the video sequences. For example the clarity of the cars even at a distance, the structure of the space ships, and the ability to see small particles when the planet explodes. Remember to keep in mind the detail level of the original source.

Quality of motion (smoothness):

This deals with the ability to see trails when an object or the background moves.

Frame flickering:

This deals with changing levels of frame quality. For example one frame of the sequence can appear to have good image quality while the following frames decrease in quality. This pattern then repeats. This is caused by the occurrence of I frame (those with no motion estimation). I frames tend to have better image quality because they are self contained, and do not use information from other video frames.

Color shift:

For example a black background in the original could appear slightly red after it has been compressed (space scenes).

Overall rating of video sequence:

Your overall rating of the quality of the video sequence in relation to the original video sequence.

2.1.3 Obtaining Base Video Stream for Comparison

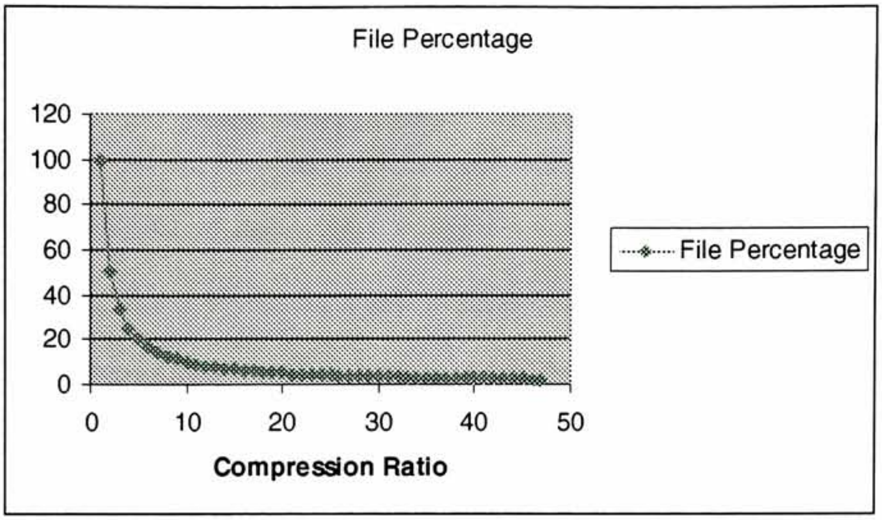
In order to properly analyze the results, a base MPEG stream for each video sequence must be obtained for comparison purposes. These base streams have storage and processing requirements that are important. The MPEG-1 standard is targeted for compression of 320x240 full-motion video at rates of 1 to 1.5 Mb/s in applications such as interactive multimedia and broadcast television. Assuming a 320x240 24-bit color image at 30 frames/sec for 5 seconds, the following would be true:

Storage Requirement: 320x240x3x30x5 = 34.56 M bytes

Processing Requirement: 320x240x3x30 = 6.9 M bytes/sec

Required Compression Ratio: (320x240x3x30x8) / (1.5 Mbits/sec) = 36.9:1

The above calculation for required compression ratio, using the 1.5 Mbits/sec target given above, shows that only a relatively small compression ratio of 36.9:1 is required to meet the specification. This corresponds to requiring only 1/36.9 = 2.7 % of the original file size. A conclusion to draw from this is that high compression ratios may appear impressive but the savings in file size diminish as the compression ratio increases. The following graph shows file percentage Vs. compression ratio:



From the concept presented in this graph:

> The gain in file percentage from compression ratio 1:1 to 10:1 is 90% (or a savings of 6.22 Mbytes/sec of video), while the gain in compression ratio from 100:1 to 200:1 is only 0.5% (or a savings of 34.6k bytes/sec of video).

These calculations indicate that it is desirable to keep the compression ratio, and therefore Qfactors, low unless a very low speed network is being used to transfer the video.

Since the storage requirements are reasonably large, some amount of compression of the initial base stream is appropriate. As a result the original video sequence consists of only I (JPEG) frames using the standard low quantization table with a Qfactor of 1, which produces no highly visible artifacts in the video stream. The compression ratio for these original video sequences are approximately 7:1. This fact is visible on the graph labeled "I frame Compression Ratio when varying I Qfactor and Frame Pattern for carm4 video" in the appendix.

2.1.4 Type of test sequences generated

Two main types of MPEG variables were modified during the creation of the MPEG testing sequence. The first was the Qfactor for the I, P, and B frames. The Qfactor is a value used to modify the standard quantization matrix. Each term in the quantization matrix is multiplied by the Qfactor. There is a different Qfactor number for each of the three types of frames. The second MPEG variable modified was the frame pattern string. This controls the frequency of the I, P, and B frames in the MPEG video stream.

2.1.4.1 Analytical Testing Sequence

There were two main types of testing sequences investigated during the qualitative portion of this deliverable. The first series of MPEG files were generated with a constant frame pattern sequence while one of the three Qfactors was varied. The constant frame pattern is as follows:

IBBPBBPBBPBBPBBP

The default values from the I, P, and B Qfactors were 8, 10, 25 respectively. Two dimensional graphs of the resulting data were then created. The x-axis shows the various values of the Qfactor used. The y-axis graphs the result of interest. These results are the numerical ones mentioned above: Overall CR (compression ratio), Playing frame rate, Average CR of the frame type whose Qfactor is being varied, and File percentage of the frame type whose Qfactor is being varied. One graph was made for each of these 4 parameters multiplied by the three types of frames. Results from all 6 original video streams are shown on each graph.

The second series of MPEG files were generated by varying both the frame pattern and one of the three types of Qfactors at the same time. This results in 3 dimensional graphs with only results from one original video stream shown on each graph. Qfactors of 1, 9, 21, and 31 were plotted along the y-axis. The following frame patterns were plotted along the x-axis:

Pattern 0: IBBPBBPBBPBBPBBP	Low Frequency I Frame
Pattern 1: IBBBIBBBIBBBIBBB	High Frequency I Frame
Pattern 2: IPPPIPPPIPPPIPPP	High Frequency I Frame
Pattern 3: IBPBIBPBIBPBIBPB	High Frequency I Frame
Pattern 4: IIIIIIIIIIIIIIII	All I Frame

The results of interest are graphed along the z-axis. Only interesting graphs of this testing sequence are included with the thesis.

2.1.4.2 Image Quality Testing Sequence

From the MPEG files generated for the above tests a select few were chosen to show a group of individual to subjectively investigate the resulting image quality as discussed above. The chosen sequences are as follows:

Video Title: carm4

Test Number	Description
2	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9
3	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 25
4	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9
5	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 25
8	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9

Video Title: folcar1

Test Number	Description
2	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9
3	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 25
4	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9
6	Pattern 1: IBBBIBBBIBBBIBBB B Qfactor = 9
7	Pattern 1: IBBBIBBBIBBBIBBB B Qfactor = 21
8	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9

Video Title: zoom3

Test Number	Description
2	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9
4	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9
6	Pattern 3: IBPBIBPBIBPBIBPB P Qfactor = 9

Video Title: b5m2

Test Number	Description
1	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9
2	Pattern 3: IBPBIBPBIBPBIBPB I Qfactor = 9
3	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9
7	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9
8	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 21

Video Title: b5m3

Test Number	Description
1	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9
3	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9
5	Pattern 1: IBBBIBBBIBBBIBBB I Qfactor = 9
7	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9

Video Title: toy1

Test Number	Description
1	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9
3	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9
5	Pattern 3: IBPBIBPBIBPBIBPB P Qfactor = 9
6	Pattern 3: IBPBIBPBIBPBIBPB P Qfactor = 21
7	Pattern 3: IBPBIBPBIBPBIBPB I Qfactor = 9

For comparison purposes a reference sequence is also viewed. This sequence contains all I frames and uses a Qfactor of 1. This gives very good image quality, but slow playback.

2.2 Discussion of Hardware/Software Setup

2.2.1 Video Capture Setup

The following section will describe the hardware and software setup used to capture video sequences off videotape and into a series of still frames which could be read and compressed by the MPEG-1 software encoder. The following lists the major pieces of hardware used:

- Power Macintosh 9500/132
- Ultra Sparc 1
- Targa 2000 Video Capture Board
- Sony Trinitron Color Video Monitor
- Panasonic SVGA Camera with Tripod
- VCR

The following lists the major pieces of software used:

- Adobe Premiere 4.0
- Image Alchemy v1.7.7 for Sun 4
- MPEG-1 Software Encoder

The following is a diagram of the video capture process:

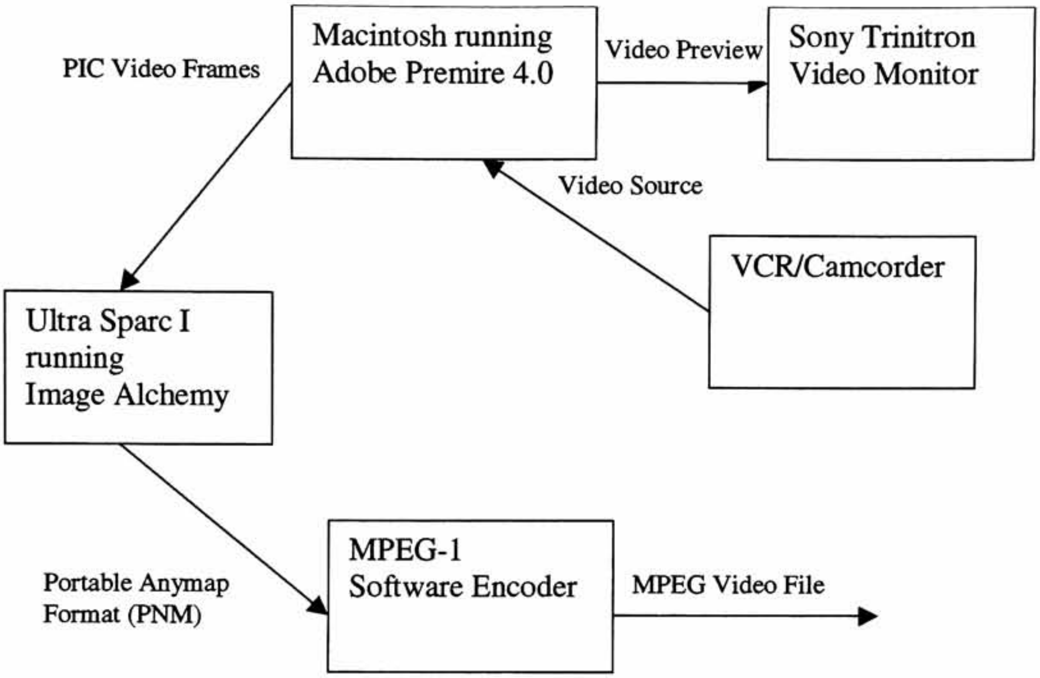


Figure 16 Video Capture Process

The video sequence was first stored on videotape using the Panasonic SVGA Camera and a tripod to keep the image stationary. A VCR, or the camera itself, was then connected to the Macintosh using the Targa 200 video capture board. This board also had an output that was connected to a Sony Trinitron color monitor. This was useful for previewing the video sequences. Adobe Premiere 4.0 was then used to capture the video sequence and save the result as a series of individual picture frames with no compression. These frames were stored in the PIC image format. The frames were then transferred over the network to an Ultra Sparc I. Image Alchemy v1.7.7 was then used to convert these files to the portable any map (PNM) format, which was the input format required by the MPEG-1 software encoder. The MPEG-1 software encoder was then used, with the desired compression options, to create an MPEG file.

2.2.2 Survey Video Creation Setup

To create the survey video used with a group of people at RIT the following procedure was followed:

1. The desired MPEG files were transferred from the Ultra Sparc to the Macintosh.
2. The Targa 2000 Video Capture Board was connected to output video to both the Sony Trinitron color monitor, for previewing, and a VCR, for recording.
3. An MPEG viewer set to display all of the frames in the MPEG file was used to play the videos.
4. Each video was played three times on the screen and recorded on the videotape.
5. Titles were used to describe each of the 6 main video sequences.

2.2.3 Processing Scripts

2.2.3.1 Survey Form Creation Script

This script takes the name of an MPEG file as input and outputs a survey form containing analytical information about the file and survey categories. The code for this script is contained in the appendix as "Survey Form Creation Script". An example of the form that results from processing an MPEG file is in the appendix section labeled "Survey Form Example". This example show that the top of the form contains file statistics like overall compression ratio, play time, and compression ratio of each of the three frame types. These statistics are gathered by calling the mpeg_stat program on the MPEG file, and then processing the resulting information. These files are used by the graph creation script to extract the required numerical information, that is then outputted in a format readable by Microsoft Excel. The image quality surveys used a reduced version of these forms, one without the numerical information, to save on the paper required.

2.2.3.2 Test Sequence Creation Script

This script generates an MPEG survey test sequence by using the survey form creation script, mpeg_encode, and a test sequence definition file. This script outputs a series of MPEG files in the requested directory, along with the associated survey forms generated by the survey form creation script. The code for this script is contained in the appendix as "Test Sequence Creation Script". Examples of the test sequence definition file are in the appendix section labeled "Test Sequence Definition File Examples". The first example labeled "Example varying only Iqscale" shows how a test sequences varying the I Qscale, but leaving the frame pattern constant, can be generated. This definition file contains a variety of information fields. The test name field gives a description of the test. The test base field gives the starting part of the name of the files that will be generated. The created files are numbered according to the test. The files end in ".mpg" or ".form". The number of tests field gives the number of test definitions that will be processed. The output dir field gives the directory name where the output files will be placed. The input dir field gives the location of the original video frames. The input string field gives a string used to read in the video frames by the MPEG algorithm. The gamma field gives a brightness correction factor that is used when creating the MPEG file. After this header part of the file a series of test definitions follow. The first line of these test definitions contains a comment string not processed by the script. This can be used to number the tests. The option string field is an additional comment string not processed by the script. This can be used to describe the particular test. The PATTERN field gives the frame pattern to be used. The IQSCALE, PQSCALE, and BQSCALE give the Qscales that are to be used. The PSEARCH_ALG, and BSEARCH_ALG give the block matching search algorithms to be used. These two parameters are not changed during the video stream analysis that is conducted in this thesis.

In the first test sequence definition file example the I Qscale is changed while the other parameters remain constant. In the next example given, labeled "Example varying Iqscale and Frame Pattern", both the I Qscale and the frame pattern are varied while the other parameters remain constant.

2.2.3.3 Graph Creation Script

This script generates a graph data file that can be loaded into Microsoft Excel. This script takes a graph definition file and a series of MPEG form files in as input. The script operates by gathering the requested information from the correct form files, which is determined by examining its content, and outputting this information in a form which is easily processed by Excel. The graph definition files contain a series of information fields. These can be seen in the example files included in the appendix section labeled "Graph Definition File Examples". The title field is a comment field useful in titling the resulting graph. The type field indicates how many parameters will be varied. Using the label 3-D indicates that two parameters will be varied, while using the label 2-D indicates that only one parameter will be varied. The test parm field gives the name of the parameter that is being tested. This is the value that will be plotted on the resulting graph. The Xnum field gives the number of locations on the X axis. The Xfield field gives the parameter represented on the X axis. A list of the X parameter values is then given. A Ynum field, Yfield field, and a Y parameter list are included for a 3-D graph. The script operated by finding the form with the correct X and, if included, Y parameter values, and recording the test parameter value. After all the required values are located, a file that can be read into Excel is generated.

Available options for the X and Y field parameters are IQSCALE, PQSCALE, BQSCALE, and PATTERN. The Yfield can also be VIDNAME that gives the video sequence name. This is useful in creating a multiple line graph, where each line represents a different video sequence. For examples of this refer to the appendix labeled "2-D Graphs". Available options for the Test Param field are CompRate, PlayRate, Ipercent, ICompRatio, Ppercent, PCompRatio, Bpercent, and PcompRatio. The CompRate option indicates the overall compression ratio is to be graphed. The PlayRate option indicated the maximum play rate is to be graphed. The (IPB)percent options indicate the file percentage used by the selected frame type is to be graphed. The (IPB)CompRatio options indicate the compression ratio of the selected frame type is to be graphed.

The example graph definition file labeled "Example of varying Iqscale and Video Sequence" show how to create a multiple line drawing plot, where each line represents a different video sequence and the X axis contained the varied parameter. In this case the varied parameter is the I Qscale and the plotted value is the overall compression ratio of the file. The example graph definition file labeled "Example of varying Iqscale and Frame Pattern for carm4 Video" shows how to create a 3-D graph where two parameters are varied, the I Qscale and the frame pattern. The value plotted in this case is the overall compression ratio. Also note that only form files from the carm4 video sequence are provided as input. The section in the appendix labeled "3-D Graphs" shows examples of the resulting graphs of this type.

2.2.4 Discussion of Limits of Playback Speeds

The playback speed for these videos is limited by the type of computer hardware used, and the size and complexity of the MPEG file. The usual playback speed for a moderately compressed MPEG file, from the six videos tested, is over the required display speed of 30 frames/sec using the Ultra Sparc I. This machine has a 167 MHz Ultra Sparc processor with a 83 MHz bus and at least 64 Mbytes of memory. The play back speed for the Power Macintosh 9500/132, used to conduct the image quality surveys, is lower than achieved for the Ultra Sparc I. The frame rate is typically over 20 frames/sec. This is lower than the desired 30 frames/sec. This machine has a 132 MHz processor with a 40 MHz bus speed and 81 Mbytes of memory. As a result a powerful machine is required to view MPEG files which have not been overly compressed, which would result in noticeable image quality loss, at the desired frame rate. An Ultra Sparc or Pentium machine running at over 100Mhz is suggested. The bus should be fast enough to handle the 1.5 Mbits/sec stated as the desired data rate for MPEG-1. The memory size should be large enough to contain the required MPEG file, or the machine must have a virtual memory system capable of keeping up with the data rate.

2.3 Conclusions and Trade off Analysis

2.3.1 Numerical Result Analysis

2.3.1.1 2-D Graphs

2.3.1.1.1 I Qfactor Graphs

For the following discussion refer to the graphs in the appendix labeled "Compression Ratio Vs. I Qfactor", "Play Rate Vs. I Qfactor", "I frame CR Vs. I Qfactor", and "I frame file % Vs. I Qfactor". The first of these graphs shows how difficult it is to compress the folcar video. The maximum compression ratio shown for this sequence is approximately 100:1. This image is difficult to compress because of the large amount of motion information that must be saved due to the panning of the background. On the other extreme, the carm4 video compresses very well. The maximum compression ratio shown for this video is close to 600:1. This video compresses well because the majority of the video is stationary. As a result very little motion information must be encoded in the P and B motion estimation frames. This video also consists of a relatively simple background made up of a solid colored sky and a green field. This graph shows that increasing the I Qfactor past 9 results in very little gained compression for all of the videos except the carm4 video. This is one of the key points gathered from this numerical result analysis. The loss in quality of this sequence is not really worth the higher compression ratio. The rest of the video sequences have compression ratios in the range of 200:1 – 300:1.

The graph labeled "Play Rate Vs. I Qfactor" shows that play rate is basically unaffected by increasing the I Qfactor. This is caused by the fact that only 1 frame out of 16 is an I frame for this frame patterns. These play rates are those obtained from the Berkeley MPEG player using an Ultra Sparc. This graph shows that folcar1 is the most difficult video to play, while carm4 is the easiest to play. The order of these results is similar to those obtained in the previous graph, and is related to the complexity of the motion in the image. Videos with contain very little motion allow for the coding of some of the macroblocks to be skipped, in the P and B frames, using a macroblock resulting from a past or future reference frame instead. This information can be quickly decoded and played. Videos with complex motion in them, like the background sweep in folcar1, do not result in high compression ratios for the P and B frames. This results in more information to read and process from the file. This causes slower playback.

The graph labeled "I Frame CR Vs. I Qfactor" shows the compression ratio of only the I frames as compared to the I Qfactor. The lines in this graph are basically straight, indicating the almost direct relationship that exists. This is understandable because the Qfactor directly controls how much information is discarded during the compression of a frame. This graph also shows that these frames typically achieve compression ratios in the 20:1 – 100:1 range. These are the lowest compression ratios achieved out of all three frame types. The maximum compression ratio of this type of frame is determined as follows:

> The original number of bits in an 8x8 block is: 8x8x8bitsx3color = 1536 bits
>
> It takes 5 bits to minimally code a luminance block (3 for DC difference of 0, and 2 for end of block code)
>
> It takes 4 bits to minimally code a chrominance block (2 for DC difference of 0, and 2 for end of block code). Since chrominance blocks are subsampled by 2 in both directions, you can effectively think that you only have to code one of them per block)
>
> This gives a total number of bits needed as 5+4 = 9. Therefore the maximum compression ratio is 1536/9 = 170.7:1.

The complexity of the background of the video sequence determines how well the I frames will compress. More complex images contain a large number of edges and color changes. Complex areas also include very few solid color regions. This graph shows that the video which achieves the least I frame compression ratio is toy1. This video contains lots of color sweeps, and sharp lines. The b5m3 image is the easiest to compress because the background is mostly a constant color (black). The video b5m2 also compresses well because it also contains a great deal one constant color, black, in the background.

The graph labeled "I frame file % Vs. I Qfactor" shows the I frame file percentage compared to the I Qfactor. The lines in this graph appear to have inverse slopes of the lines on the I frame compression ratio graph. This occurs because as the I frame compression ratio increases the file percentage of the I frames decreases. The ordering of the lines on this graph is determined by the amount of information contained in the other frame types. Since the other frame types are both motion predicted, the ordering on this graph is related to the complexity of the motion in the video sequence. For example videos with complex motion should have lower I frame percentages, because most of the information is contained in the motion estimated frame. The lowest I frame file percentages are achieved by the folcar1 video, which as discussed above, is the most complex video in terms of motion. The second lowest I frame file percentages are achieved by the b5m3 video. This is understandable because the background in that video is very simple, while the motion of the space ships is fairly complex. The highest I frame percentages occur for the carm4 video, which has very little motion in it.

2.3.1.1.2 P Qfactor Graphs

For the following discussion refer to the graphs in the appendix labeled "Compression Ratio Vs. P Qfactor", "Play Rate Vs. P Qfactor", "P frame CR Vs. P Qfactor", and "P frame file % Vs. P Qfactor". The first of these graphs shows that changing the Qfactor of the P frames does have some effect on the overall compression ratio. This effect levels off after a Qfactor of 15, so it is advisable to keep the P Qfactor at or below this value. The order of the lines on this graph gives an indication of the complexity of the motion and background in each of the video sequences. The order of these lines is as follows: carm4, b5m3, zoom3, b5m2, toy1, folcar1. This order also tracks increasing motion and background complexity.

The graph labeled "Play Rate Vs. P Qfactor" shows that play rate is basically unaffected by increasing the P Qfactor past a Qfactor of 10. This is because the compression ratios also level off at this point, indicating little change in overall file contents.

The graph labeled "P frame CR Vs. P Qfactor" shows the compression ratio of only the P frames as compared to the P Qfactor. The complexity of the motion in the image determines the order of the lines on this graph. This order is as follows: carm4, zoom3, toy1, b5m2, b5m3, folcar1. This ordering is understandable when you eliminate the complexity contained in any stationary part of the background. For example the b5m2 video contains relatively complex motion due to the particles released when the planet explodes, and the motion in the b5m3 video is even more complex than this because of the motion of the larger space ships. The graph shows that P frame typically have compression ratios in the range 100:1 – 450:1. The maximum compression ratio for P frames is very high due to the ability to skip over 16x16 macroblocks. This is coded with a very few number of bits, resulting in a high compression ratio. These high compression ratios, which are achieved by skipping macroblocks, account for the extremely high P frame compression ratios which occur after a P Qfactor of 5 for the carm4 video. After a P Qfactor of 5, the error terms left after the motion estimation and quantization are small enough that the compressor chooses to skip coding some of the macroblocks. The amount of macroblocks that are skipped increases as the P Qfactor increases past 5, resulting in high P frame compression ratios. Skipping macroblocks results in errors that appear as motion trails and increased flickering when an I frame, which contains no error due to motion compensation, is displayed. This video is the only one of the six survey videos that shows this effect so dramatically because of its stationary background and small motion content. The high compression ratio of the P frames for the carm4 video looks significant until you consider the P frame file percentage affected at these high Qfactors. For example, at a Qfactor of 25 the compression ratio of the P frames is 2000:1 but the affected file percentage is only 6.2%. Amdahl's Law states that the performance improvement gained from using some faster mode of execution is limited by the fraction of the time the faster mode can be used. This can be modified in this case to state that the overall compression of the file is limited by the amount of the file the frame type, whose compression is being modified, occupies. The Amdahl's law equation can be rewritten as:

$$CRFactor_{overall} = \frac{1}{(1 - Fraction_{enhanced}) + \frac{Fraction_{enhanced}}{CRFactor_{enhanced}}}$$

Consider the following example problem taken from this graph:

P Qfactor	Overall Compression Ratio	P Frame File %	P Frame Compression Ratio
9	370.37	20.0%	588.24
25	434.78	6.2%	2000

The $CRFactor_{enhanced}$ for the P frames when the P Qfactor changes from 9 to 25 is 2000/588.24 = 3.4 . Therefore the $CRFactor_{overall}$ is calculated as follows:

$$CRFactor_{overall} = \frac{1}{(1 - .20) + \frac{.20}{3.4}}$$

$$CRFactor_{overall} = 1.16$$

Multiplying the overall compression ratio with a P Qfactor of 9 by this factor a compression ratio of 1.116(370.37) = 413.33 is obtained. This is fairly close to the actual compression ratio of 434.78. This example shows that the improvement in P frame compression ratio is not as important as it might seem. It is important to keep in mind the percent of the file that is affected by changes in the Qfactors.

The graph labeled "P frame file % Vs. P Qfactor" shows the P frame file percentage compared to the P Qfactor. The order of the lines in this graph is based on the amount of motion in the video sequence, and is basically in the reverse order of those in the previous graph. The lines in the graph level out between a P Qfactor of 10 and 15. This indicates why the overall compression ratio of the file levels out at this point as well. For the carm4 video it is advisable to keep the P Qfactor below 10 because after this point the file percentage becomes relatively insignificant. For the folcar1 the P frame file percentage is much larger, so it is advisable to choose a larger P Qfactor because of its effect on the overall compression ratio.

2.3.1.1.3 B Qfactor Graphs

For the following discussion refer to the graphs in the appendix labeled "Compression Ratio Vs. B Qfactor", "Play Rate Vs. B Qfactor", "B frame CR Vs. B Qfactor", and "B frame file % Vs. B Qfactor". The first of these graphs shows that the B Qfactor has very little effect on the overall compression ratio of the file. This means that nothing is gained by increasing the B Qfactor past 10, and the B Qfactor should be kept even lower than this if possible. Since B frames are capable of the highest compression ratios of the three types, it is more important to the overall compression ratio of the file how many B frames are in the frame pattern than what the B Qfactor is.

The graph labeled "Play Rate Vs. B Qfactor" shows that play rate is basically unaffected by increasing the B Qfactor. The play rate is affected more by the complexity of the content in the video.

The graph labeled "B frame CR Vs. B Qfactor" shows the compression ratio of only the B frames as compared to the B Qfactor. These lines are basically straight after a B Qfactor of 10. This adds more support to the belief that B Qfactors should be kept below 10. This graph shows that B frames typically have compression ratios in the range of 500:1 – 1000:1. 1. The maximum compression ratio for B frames is very high due to the ability to skip over 16x16 macroblocks. This is coded with a very few number of bits, resulting in a high compression ratio. These are the highest compression ratios achieved for all three frame types. One feature of this graph that stands out is that the b5m3 video has the lowest B frame compression ratio for any of the videos when the B Qfactor is 1, but has the highest compression ratio for any of the videos when the B Qfactor is past 9. This affect is caused by the two features of this video sequence. The first is the use of a constant background color, black, in this video sequence. When this video was captured, noise was introduced into the image due to the sampling. This means that a constant color may appear to be one solid color on the screen, but may contain many slightly different color values in the actual file. This was checked by looking at the pixel values for this video. This noise makes it very difficult for the block matching algorithm to operate effectively at low B (or P) Qfactors. As the B Qfactor is increased the effect of the noise is reduced by the fact that the error between the average of the past and future reference frame macroblocks and the current frame macroblock is being coded. This error may then be so low that the macroblock is skipped, resulting is extremely high B frame compression ratios. B frames are more effective than P frames in reducing spatial noise due to video sampling. As a result, frame patterns with a high number of B frame should be used for video sequences with a lot of areas of solid color. This average greatly reduces the effect of the noise in the image, especially when the resulting error is further quantized by a high B Qfactor. The second feature of this video is that the objects in the video tend to move in straight lines, appearing in both past and future reference frames. This make it easier for the block matching algorithm to locate closely matching blocks, which results in better compression.

The graph labeled "B frame file % Vs. B Qfactor" shows the B frame file percentage compared to the B Qfactor. This graph shows that B frame file percent becomes basically constant after a B Qfactor of 10. It is also interesting to note how the B frame file percentage is below 30% most of the time, even though 10 out of every 16 frames (62.5%) in the tested frame pattern are B frames. The B5m3 B frame compression ratio effect described above also has an effect on the B frame file percent for the b5m3 video. The B frame file percent is above 50% when the Qfactor is 1, which is the highest for any of the videos at that B Qfactor. After a B Qfactor of 9, the B frame file percent for the b5m3 video becomes the second lowest of the six videos. This shows the affect that compression ratio of a particular frame type can have on that frame's file percentage.

2.3.1.2 3-D Graphs

2.3.1.2.1 I Qfactor Graphs

For the following discussion refer to the graphs in the appendix labeled "Compression Ratio when varying I Qfactor and Frame Pattern for carm4 video", "Play Rate when varying I Qfactor and Frame Pattern for carm4 video", "I frame Compression Ratio when varying I Qfactor and Frame Pattern for carm4 video", and "I Frame Percentage when varying I Qfactor and Frame Pattern for carm4 video". The first graph shows that the low frequency I frame pattern results in the highest overall compression ratios, while the frame pattern consisting of only I frames results in the lowest overall compression ratios. This indicates that the frequency of I frames is very important to overall compression ratio. This is due to the relatively small compression ratios I frames are capable of achieving. For this video the three frame patterns with a higher number of I frames all have similar compression ratios for a given I Qfactor. This occurs because this video contains very little motion, so the choice between using P or B frames affects a relatively small part of the overall file size. This is not always true for the other video sequences, because they contain different amounts of motion in them. The compression ratios for the low frequency I frame patterns can also be compared to the compression ratios for the high frequency I frame patterns. For the same Qfactor the low frequency I frame pattern compresses a maximum of 4 times better than the high frequency I frame pattern. This happens because the high frequency I frame pattern contains 4 times as many I frames as the low frequency I frame pattern. Result for the other five video sequences were also observed. The graphs for the zoom3, b5m2, and toy1 video appear similar to the carm4 one except the results are scaled to a maximum of 300:1 instead of a maximum of 600:1. This is a result of the higher motion content of these three videos as compared to the carm4 video. In the folcar1 video, the frame pattern IBBIBB.. results in the highest overall compression ratios, with a maximum of 180:1. This is shown in the graph labeled "Compression Ratio when varying I Qfactor and Frame Pattern for folcar1 video" in the appendix. Panning the background results in every block in the background being in motion. Since these blocks almost always exist in both a future and a previous frame, this video is well suited to the use of B frames. The IPPPIPPP.. pattern does not achieve as high compression ratios, which is further evidence of the benefits of B frames for this video. In the b5m3 video, the number of I frames in the frame pattern does not affect the overall compression ratio as much as in the other videos. This is due to the basically constant color (black) background in this video. The IPPPIPPP.. pattern also does not compress as well as those with B frames, which supports the use of B frames in this video.

The graph labeled "Play Rate when varying I Qfactor and Frame Pattern for carm4 video" shows the play rate results obtained. This graph looks similar to the graph obtained for overall compression ratio, except that it is scaled down by a factor less then 7 to 1. This shows that there is a direct relationship between the video play rate and the overall compression ratio. To play a video faster on a given machine you need to increase the compression of the file. The peaks on this graph do not appear as high as those in the overall compression ratio graph. This is due to the speed limitations of the machine. There is also an amount of work that must be done to display the image, which is not greatly affected by decreasing the file size. This includes displaying the resulting pixels, and parsing the input file. The results from the play rate graphs for the variance of the other frame type for all other videos show the same type of relationship between play rate and overall compression ratio. As a result this will be the only mention of the 3D graphs of the video play rate.

The graph labeled "I frame Compression Ratio when varying I Qfactor and Frame Pattern for carm4 video" clearly shows the linear relationship between the I frame compression ratio and the I Qfactor. The most noticeable aspect of this graph is that the frame pattern has no effect on the compression ratio of the I frames. Since this frame type does not depend on the motion estimation technique, varying the motion estimation frames has no effect. Any variation in the spatial complexity of the background is averaged out over the course of the video, so changing the number of I frames also has no effect. This graph type for the other 5 videos also shows the same effect. The maximum compression ratio for the I frames varies from a maximum of 140:1 for the b5m3 to a minimum of 80:1 for the toy1 video. The b5m3 contains very little background information, while the toy1 video contains a lot of sweeps and sharp edges in its background.

The graph labeled "I Frame Percentage when varying I Qfactor and Frame Pattern for carm4 video" shows the I frame file percentage when varying the I Qfactor and the frame pattern for the carm4 video. This graph shows that I frames typically occupy 70-90% of the total file size. This holds true for the other videos as well, with the lowest I frame percentage being 50%. This indicates that the compression of the I frames is very important to the overall compression ratio of the file. Therefore the I Qfactor and the number of I frames in the frame pattern must be chosen carefully.

2.3.1.2.2 P Qfactor Graphs

For the following discussion refer to the graphs in the appendix labeled "Compression Ratio when varying P Qfactor and Frame Pattern for carm4 video", "Play Rate when varying P Qfactor and Frame Pattern for carm4 video", "P frame Compression Ratio when varying P Qfactor and Frame Pattern for carm4 video", and "P Frame Percentage when varying P Qfactor and Frame Pattern for carm4 video". The first graph shows that changing the P Qfactor does not have nearly the affect on overall compression ratio that the number of I frames in the frame pattern does. The higher frequency I frame patterns containing P frames have similar overall compression ratios. There is typically a slightly higher compression ratio for the IPPPIPP... pattern than the IBPBI… pattern. For the other videos, the amount of this increase depends on the file percentage that P frames account for. This is affected by the motion content of the video. This will be explained more during the discussion of the P frame compression ratio graph. This graph for the other 5 videos shows similar results.

The graph labeled "P frame Compression Ratio when varying P Qfactor and frame Pattern for carm4 video" shows the P frame compression ratio when varying the P Qfactor and the frame pattern for the carm4 video. The most significant thing to notice on this graph is that the compression ratios for the IPPPI… pattern are slightly higher than the IBPBI… pattern. P frames can use either I or P frames as forward prediction reference frames. Since the P frames in the

IBPBI... frame pattern are always followed by an I frame before the next P frame, the prediction must always be based on an I frame. This is not the case for the other frame pattern because some P frames can be referenced to another P frame. Since P frames contain less information than a corresponding I frame, due to the motion estimation, referencing a P frame will on average compress more than referencing an I frame. This explains why the IPPPI... pattern compresses slightly more than the IBPBI... pattern. The graphs for the other 5 videos show a similar relationship. The scale of the graphs does vary for these other videos, however, as shown by the maximum P frame compression ratio obtained. The highest of these is 5000:1 P frame compression ratio for the carm4 video. This video contains very little motion. The smallest of these is 400:1 for the folcar video, which contains a great deal of motion. This is shown in the graph labeled "P frame Compression Ratio when varying P Qfactor and Frame Pattern for folcar1 video" in the appendix. The order of increasing P frame compression ratio is as follows: folcar1, b5m3, b5m2, toy1, zoom3, and carm4.

The graph labeled "P Frame Percentage when varying P Qfactor and Frame Pattern for carm4 video" shows the P frame file percentage when varying the P Qfactor and the frame pattern for the carm4 video. The most important thing to note from this graph is that the P frames are responsible for a very small percentage of the overall file, 10-20%, unless the P Qfactor is low and the frame pattern contains mostly P frames. These observations are also true for the other 5 videos.

2.3.1.2.3 B Qfactor Graphs

For the following discussion refer to the graphs in the appendix labeled "Compression Ratio when varying B Qfactor and Frame Pattern for carm4 video", "Play Rate when varying B Qfactor and Frame Pattern for carm4 video", "B frame Compression Ratio when varying B

Qfactor and Frame Pattern for carm4 video", and "B Frame Percentage when varying B Qfactor and Frame Pattern for carm4 video". The first graph shows that increasing the B Qfactor has a negligible affect on the overall compression ratio. This is due to the low percentage of the overall file size that B frames are responsible for. As a result the B Qfactor should be kept low, below 10, so that image quality is not degraded for negligible benefit in overall compression ratio. The inclusion of B frames and their frequency in the frame pattern have more effect on overall compression ratio than the B Qfactor. The results obtained for the other five videos are similar. There is far less variance in the maximum compression ratios achieved. The highest compression ratio achieved on this graph is approximately 400:1 for the carm4 video, while it is only 110:1 for the folcar1 video. This is shown in the graph labeled "Compression Ratio when varying B Qfactor and Frame Pattern for folcar1 video" in the appendix.

The graph labeled "B frame Compression Ratio when varying B Qfactor and frame Pattern for carm4 video" shows the B frame compression ratio when varying the B Qfactor and the frame pattern for the carm4 video. The most interesting thing to note about this graph is that the IBPBI... pattern tends to compress better than the IBBBI... pattern for the same B Qfactor. B frames can only have reference frames that are I or P frames. This means that in the IBBBI... pattern B frames can only reference the I frames. In the IBPBI... pattern the B frames can reference an I or a P frame. Since P frames contain less information than the corresponding I frames, the IBPBI.. frame pattern should and does have a higher compression ratio.

The graph labeled "B Frame Percentage when varying B Qfactor and Frame Pattern for carm4 video" shows the B frame file percentage when varying the B Qfactor and the frame pattern for the carm4 video. The most important thing to note from this graph is that the B frames are responsible for a very small percentage of the overall file, 10-20%, unless the B Qfactor is low and the frame pattern contains mostly B frames. These observations are also true for the other 5 videos.

2.3.1.3 Summary of Graph Results

The following is a list of the major points obtained for each of the frame types during the numerical result analysis:

Frame Type:

I Frames

- Low frequency I frame pattern results in highest overall compression ratios
- I frames have small compression ratios as compared to the other frame types, in the range of 20:1 – 100:1 for the low frequency I frame pattern
- The maximum compression ratio for this frame type is 170:1, which would be a solid colored block.
- The effect of I frames on the overall compression ratio of the file is reduced with a decrease in the background's content in terms of sharp edges and color sweeps.
- Play rate is directly related to overall compression ratio of the file, and a large number of I frames results in slow playback due to the difficulty in compressing I frames.
- A linear relationship exists between I frame compression ratio and the I Qfactor
- The frame pattern choice does not affect the I frame compression ratio
- B5m3 has the highest I frame compression ratio due to lack of background information, while the toy1 video has the lowest I frame compression ratio due to the large number of sharp edges and color sweeps in this video
- I frames typically occupy 70-90% of the total file size, with a minimum near 50%
- Increasing the I Qfactor past 9 results in very little gain in compression ratio, when compared to the loss in video quality
- I frame file percentages are lower for videos with complex motion

P Frames

- Play rate is related to the motion complexity of the video, which affects the overall compression ratio of the file
- Varying the P Qfactor does not affect the overall compression ratio as much as the number of I frames in the frame pattern does
- P frames which are allowed to use other P frames as reference frames compress better than P frames that have to use I frames as a reference
- The compression ratio of the P frames is very dependant on the amount of motion in the video
- P frames are only responsible for 10-20% of the total file size unless the P Qfactor is really low and the frame pattern contains mostly P frames
- P frames have medium level compression ratios, in the range of 100:1 – 450:1 for the low frequency I frame pattern
- P frame file percentages are high for videos with complex motion and little background spatial activity
- Effect of P Qfactor on overall compression ratio levels off after a Qfactor of 15, so it advisable to keep the P Qfactor below or at this value
- It is important to remember the affected file percentage when considering raising the P Qfactor

B Frames

- B frames should be used when blocks are likely to exist in both previous and future frames

- B frames should be used when the frames contain a lot of solid color areas. B frames will help to reduce the spatial noise in the image.
- The B Qfactor should be kept below 10, because raising it further does not help the overall compression ratio of the file
- Play rate is related to the motion complexity of the video, which affects the overall compression ratio of the file
- B frames are only responsible for 10-20% of the file size unless the Qfactor is really low and the frame pattern consists of mostly B frames
- B frames which are allowed to use P frames as reference frames compress better than B frames that have to use I frames as a reference
- B frames have the highest compression ratios, in the range of 500:1 – 1000:1 for the low I frequency I frame pattern
- It is important to remember the affected file percentage when considering raising the B Qfactor
- The choice of how many B frames to include in the frame pattern has more effect on overall compression ratio than the B Qfactor
- B frames make up a very small amount of the file, even though the number of B frames in the pattern might be high (10 out of 16 = 62.5%)

2.3.2 Survey Result Analysis

2.3.2.1 Quality of original reference video sequences

The following statements are gathered by observing the results obtained for the reference videos during the first video survey. All of the original sequences are found to play far below the desired frame rate of 30 frames/sec. This made the motion appear jerky. As a result many of the more heavily compressed video streams appear better because they playback more smoothly, even though they suffer from a loss in image quality.

2.3.2.2 Overall Ranking of Video Sequence Survey Results

The following shows a ranking of the compressed video sequence results in order of preference for both surveys based on the overall rating category of the survey. A short description of how the video sequence was created is also included:

Video Title: carm4

Survey 1		Survey 2	
Test Number	Description	Test Number	Description
8	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9	2	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9
2	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9	8	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9
4	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9	4	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9
5	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 25	5	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 25
3	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 25	3	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 25

Video Title: folcar1

Survey 1		Survey 2	
Test Number	Description	Test Number	Description
6	Pattern 1: IBBBIBBBIBBBIBBB B Qfactor = 9	6	Pattern 1: IBBBIBBBIBBBIBBB B Qfactor = 9
8	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9	8	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9
2	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9	7	Pattern 1: IBBBIBBBIBBBIBBB B Qfactor = 21
7	Pattern 1: IBBBIBBBIBBBIBBB B Qfactor = 21	4	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9
4	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9	2	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9
3	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 25	3	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 25

Video Title: zoom3

Survey 1		Survey 2	
Test Number	Description	Test Number	Description
4	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9	6	Pattern 3: IBPBIBPBIBPBIBPB P Qfactor = 9
6	Pattern 3: IBPBIBPBIBPBIBPB P Qfactor = 9	4	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9
2	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9	2	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9

Video Title: b5m2

Survey 1		Survey 2	
Test Number	Description	Test Number	Description
7	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9	7	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9
2	Pattern 3: IBPBIBPBIBPBIBPB I Qfactor = 9	2	Pattern 3: IBPBIBPBIBPBIBPB I Qfactor = 9
1	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9	1	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9
3	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9	3	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9
8	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 21	8	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 21

Video Title: b5m3

Survey 1		Survey 2	
Test Number	Description	Test Number	Description
7	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9	3	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9
3	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9	1	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9
1	Pattern 0: IBBPBBPBBPBBPBBP I Qfactor = 9	7	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9
5	Pattern 1: IBBBIBBBIBBBIBBB I Qfactor = 9	5	Pattern 1: IBBBIBBBIBBBIBBB I Qfactor = 9

Video Title: toy1

Survey 1		Survey 2	
Test Number	Description	Test Number	Description
7	Pattern 3: IBPBIBPBIBPBIBPB I Qfactor = 9	7	Pattern 3: IBPBIBPBIBPBIBPB I Qfactor = 9
6	Pattern 3: IBPBIBPBIBPBIBPB P Qfactor = 21	3	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9
5	Pattern 3: IBPBIBPBIBPBIBPB P Qfactor = 9	5	Pattern 3: IBPBIBPBIBPBIBPB P Qfactor = 9
3	Pattern 2: IPPPIPPPIPPPIPPP P Qfactor = 9	6	Pattern 3: IBPBIBPBIBPBIBPB P Qfactor = 21
1	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9	1	Pattern 0: IBBPBBPBBPBBPBBP P Qfactor = 9

For the following discussion refer to the above list and the table in the appendix labeled "Weighted Average of Survey Category Ratings Table". This table shows the results sorted by the weighted average of the category ratings. This was obtained as follows:

1. Each of the rating category results was modified to be $(5-x)^2$. Therefore:
   5 = 0
   4 = 1
   3 = 4
   2 = 9
   1 = 16
2. All eight categories are summed for each person's survey result
3. The average of these sums is taken

The value therefore is low for good video results, and high for a bad video result. The weighting causes a 1 (poor quality) to count more heavily in the sum than a 4 or 5. The following shows the weighted average that would result if all response in each category were the given number:

5 = 0
4 = 8
3 = 32
2 = 72
1 = 128

This is not surprisingly 8 (categories) times the answers from the list above.

For the video labeled carm4 people like the quality of the frame pattern with only 1/16 of the frames being I frames especially when the I Qfactor is low (9). This is shown by the overall ratings of 3.6 for both surveys. The weighted average results of 23 and 17.40, respectively, are also low indicating good quality. This indicates that for this video sequence people are more tolerant to bad motion artifacts, like long motion trails, than poor quality in the background. Having a low I Qfactor causes a higher quality background image to be stored. Since this image contains a stationary background this is desirable because people have a long time to notice problems contained in the stationary background image. This would not be the case if the background were moving. Encoding only one I frame for each 16 frames is acceptable in this case because the background contains very little motion, and therefore will not become corrupted as frequently as objects move across it. The main background flaws in this image are noticeable when the cars move across it. Since this only occurs on a small portion of the total background people are able to accept the loss in quality. This video sequence one of the few in the series where this frame pattern is acceptable. It is also interesting to note that the lowest rated test is the one with a high I Qfactor value, and therefore bad background quality. The test with a high P Qfactor value, and therefore bad motion quality is rated as the second worst.

For the video labeled folcar1 the IBBBI... pattern with the B Qfactor = 9 rates above the IPPPI pattern with the P Qfactor = 9. This indicates that people prefer bi-directional prediction other than forward prediction for this video sequence. This video sequence contains a moving background and a relatively stationary car. This means that most of the 16x16 blocks in the image are in motion. Bi-directional prediction does a better jobs of motion estimation in this case because most of the blocks in the image are moving in a relatively straight line across the screen. As a result the forward and backward motion vectors are easy to find, and result in pixel blocks whose average is likely to be very similar to the desired block. If P frame encoding is used instead only half the available motion information is encoded, resulting in lower video quality. Therefore, for videos that contain moving non-rotating objects appearing in a sequence of consecutive frames, B frames are beneficial to the resulting image quality. Another conclusion is that videos containing a lot of objects disappearing would not benefit from the backward frame information encoded by B frames. The pattern with only one I frame per 16 frames has the lowest survey results. This is due to the fact that the background becomes highly corrupted due to the motion in the video. The I frame causes a noticeable flicker in image quality. This effect is less noticeable with the higher I frame frequency of the other frame patterns (one I frame every 4 frames).

For the video labeled zoom3 the IBPBI... frame pattern with a P Qfactor of 9 rates the best in the weighted average category for both surveys. This indicates that B frames are beneficial in the compression of this video sequence. The pattern with a reduced number of I frames rates poorly because of the high amount of motion in this image caused by the zoom, and the resulting quality flicker, which is apparent, when an I frame is reached.

For the video labeled b5m2 the IPPPI.. pattern with a P Qfactor of 9 results in better image quality than the patterns with B frames. This video shows a planet exploding into a bunch of small particles. Since objects are being created in this video sequence, which did not exist in a previous frame, it is understandable why B frames might result in a lower quality video sequence. The worst rated test occurs with a frame pattern of IPPPI and P Qfactor = 21. The amount of motion in this image makes it undesirable, in terms of video quality, to increase the P Qfactor.

For the video labeled b5m3 the frame pattern with 1 I frame for every 16 frames gives a good result when the P Qfactor is 9. This frame pattern usually does not give a good result in terms of images quality because of the dependence of the background quality on the frequency of I frames. This video gives an acceptable result, however, because of the basically constant color, black, background. In this video there really is no background because the space ships are all moving. The speed of the motion also cuts down on the viewer's ability to notice the frame flickering usually associated with this frame pattern. Also notice that the overall category is scored higher when the P Qfactor is equal to 9 than when the I Qfactor is equal to 9. This is because of the high amount of motion in this video, and the relationship between the P Qfactor and the quality of the motion.

For the video labeled toy1 the results indicate that a good frequency of both I and B frames are needed. This image contains a computer generated background with a lot of color sweeps and sharp edges. This type of background cannot be quantized very much without the loss in quality becoming noticeable. This explains why the pattern with a low frequency of I frames receives the worst video quality rating. B frames are desirable for this video sequence because objects appear in both previous and future reference frames. Another observation that can be made is that the MPEG algorithm has a difficult time encoding rotations. This is shown by the fact that the lines in the tiled floor in this video become jagged as the image is rotated. This is most likely caused by the fact that the motion estimation technique works on translations of blocks, and not rotation. This causes difficulty in finding a correct block to match with, and more error terms to encode as a result.

2.3.2.3 Compression Ratio vs. Video Quality

For the following discussion refer to the table in the appendix labeled "Compression Ratio Table". This table shows the results for each video sequence sorted by overall compression ratio. The general trend for this table is for the overall rating category to decrease as compression ratio increases. The weighted average, which measures the perceived loss in quality in the video sequence, increases as compression ratio increases. There is also a relationship between the frame pattern and the compression ratio given constant Qfactors. The following table shows the percentages of I, P, and B frames in each of the four chosen frame patterns:

Frame Type	Pattern 0 Frames/Seq.	Pattern 0 Percentage	Pattern 1 Frames/Seq.	Pattern 1 Percentage	Pattern 3 Frames/Seq.	Pattern 3 Percentage	Pattern 2 Frames/Seq.	Pattern 2 Percentage
I	1	6.25	4	25	4	25	4	25
P	5	31.25	0	0	12	75	4	25
B	10	62.5	12	75	0	0	8	50

It is a feature of the algorithm that B frames compress more than P frames, and P frames compress more than I frames under normal situations, given constant Qfactors. Therefore based on the above table the order of the frame patterns for increasing compression ratio is: 2, 3, 1, and 0. Another feature of the algorithm is that higher Qfactors result in higher compression ratios. The order of the results on the compression ratio table follows these two trends. Each of the video sequences will not be examined for lack of correlation between compression ratio and image quality ratings.

For the video labeled carm4 there is one noticeable deviation from the general patterns mentioned above. In the first survey the IBBPBB.. pattern with an I Qfactor of 9 has a better overall rating than the same pattern with a P Qfactor of 9. This occurs despite the fact that an I Qfactor of 9 results in a higher compression ratio, and therefore less information saved, than a P Qfactor of 9. In the second survey the IBBPBB.. pattern with an I Qfactor of 9 has a better weighted average result than all of the other test sequences for this video. This indicates that people are more concerned with the quality of the background, than the quality of the motion. This is understandable given the small amount of motion and stationary background in the video sequence.

For the video labeled folcar1 there are two noticeable variations in the ratings. In both surveys the IBBI.. pattern with a B Qfactor of 9 has a better video quality rating than the IPPPI.. pattern with a P Qfactor of 9. This occurs even though the compression ratio for the IBBBI.. pattern is slightly higher. The motion and flicker for the IBBPBB.. pattern with an I Qfactor of 9 was pretty noticeable, but people still give the sequence relatively good ratings. The compression ratio for this sequence is 108.70:1, which is pretty high. This indicates that people are willing to put up with motion artifacts in this sequence, especially in survey 1. Survey 1 was the videotaped survey, which made the artifacts in the video harder to see.

For the video labeled zoom3 the IBPBI.. pattern with P Qfactor of 9 has the best video quality ratings of the sequence even though its compression ratio of 119.05:1 is not the lowest one obtained. This indicates that using B frames in this sequence could be beneficial in terms of overall compression.

For the video labeled b5m2 the pattern IBBPBBP.. with an I Qfactor of 9 gives reasonable video quality results considering the 243.9:1 compression ratio of this sequence. Image quality could be improved if a lower Qfactor for the I frames is chosen. The compression ratio would still be high because of the infrequency of I frames. The compression ratio of 136.99:1 achieved with the IPPPI pattern and a P Qfactor = 9 is still relatively high. This sequence gives the best video quality results for this video. The compression ratio could be improved if the number of I frames in this sequence was cut in half (1 I frame every 8 frames). This would most likely give acceptable results due to people's response to the sequence with only 1 I frame every 16 frames.

For the video labeled b5m3 the IBBPBBP.. pattern with a P Qfactor = 9 has a good overall rating of 4.2 from survey 2, while still providing an impressive 263.16:1 compression ratio. Given the lack of a significant background in this video this frame pattern with a low number of I frames is able to provide acceptable video quality, and a high compression ratio.

For the video labeled toy1 the IBPBIBPB.. pattern with an I Qfactor = 9 overall ratings of 3.8 and 4 results from the two surveys, respectively. This sequence also has very low weighted average results of 17.33 and 15.0, respectively. This combined with the reasonably high compression ratio of 107.53 makes this sequence a good choice in terms of image quality and compression ratio.

2.3.2.4 Full Compression Ratio Sort Analysis

For the following discussion refer to the table in the appendix labeled "Full Sort on Compression Ratio Table". This table shows the results from each of the two surveys sorted by overall compression ratio. The carm4 video sequence has the highest four compression ratios on the list. The IBBPBBP pattern with an I Qfactor of 9 gives the best video quality of these, having a compression ratio of 400:1 and an overall rating of 3.6 for both surveys. This frame pattern with a low number of I frames dominates the higher compression ratios. Three sequences from the folcar1 video are found to have the lowest overall compression ratios. This is not surprising given the complexity of the motion in this video sequence. The overall ratings and weighted average scores for these sequences, however, indicate very good video quality. The general order of the video sequences in term of increasing compression ratio is: folcar1, toy1, zoom3, b5m2, b5m3, and carm4. This order appears to follow the complexity of the motion and background in the video sequences. Folcar1 and toy1 are complex sequences due to the background motion and level of detail. B5m3 and carm4 are relatively simple to compress because of either the lack of background or lack of motion, respectively.

2.3.2.5 Modified Compression Ratio Sort Analysis

For the following discussion refer to the table in the appendix labeled "Modified Compression Ratio Table". This table shows the results for each video sequence sorted by the compression ratio of frame type whose Qfactor is modified. This table shows that P and B frames are capable of some very high compression ratios. For the carm4 video with a P Qfactor = 25 the compression ratio of the P frames is 2000:1. This is not as high as it sounds overall because the P frames only account for 25% of the frames, and even less of the compressed file's total size. I frames have a much lower compression ratio, the maximum from the tests being 91.74:1 when the I Qfactor is 25 for the carm4 video. The weighted averages for the two surveys are 52.61 and 61.80 respectively. These are the worst weighted averages received for the entire survey. Typical P and B frame compression ratios are in the 100:1 - 400:1 range.

2.3.2.6 Survey Category Full Sort Analysis

2.3.2.6.1 Blocking Artifacts

For the following discussion refer to the table in the appendix labeled "Blocking Artifacts". This table shows the results for each video sequence sorted by the blocking artifacts rating. The worst blocking ratings occur when the I Qfactor = 25. This setting makes the spatial blocks in the background very noticeable in both the folcar1 and carm4 video sequences. Low blocking ratings also occur when the P Qfactor is set to 21. These blocks are results of the motion and appear as long motion trails behind a moving object. These are especially visible in the carm4 and b5m2 videos. Surprisingly for the toy1 video with the P Qfactor set to 21 the block rating received are above average for the two surveys, 4.33 and 3.6 respectively. A possible explanation for this is that since this is a computer generated sequence the block matching algorithm is able to locate blocks that more closely match the original block. This requires less information to be saved, and therefore lessens the effect of increasing the P Qfactor. Another possible explanation for all of the results for blocking artifacts in the toy1 video being 3.6 or above is that the sweeps in color in the majority of the background (the reddish floor tile) might have been difficult to see. This was especially true in the first survey that was viewed from video tape. All of these results are 4 or above.

2.3.2.6.2 Contouring

For the following discussion refer to the table in the appendix labeled "Contouring". This table shows the results for each video sequence sorted by the contouring rating. Contouring is especially visible in the carm4 and b5m3 videos. In survey 1 some of the sequences from these videos receive ratings as low as 2.6. Both surveys agree that the worst sequence in terms of contouring is carm4 with a frame pattern of IBBPBBP.. and an I Qfactor of 25, scoring 2.6 and 2.4 respectively. Contouring is highly visible in this image because the background was stationary, giving the viewers time to notice the banding in the color sweeps contained in the grass. B5m3 has contouring visible in the fire coming from the engines of the ships. This is marked down in survey one, but in survey 2 people are more tolerant. Given the faster motion in this video it is possible to miss this effect, or not be bothered by it.

2.3.2.6.3 Sharpness of Edges

For the following discussion refer to the table in the appendix labeled "Sharpness of Edges". This table shows the results for each video sequence sorted by the sharpness of edges rating. The most noticeable feature from this table is that high I Qfactors result in fuzzy edges. This is shown by the sequences with the I Qfactor = 25 having the lowest sharpness of edges ratings. To a lesser degree sequences with the P Qfactor = 25 show the same effect, but its visibility is related to the amount of motion in the video. For example in the first survey the carm4 video with a P Qfactor of 25 receives a 2.6 rating, while in the second survey it receives a 4. This variance in response shows that viewing condition can affect responses. People could have also been affected by the poor quality in the motion of this sequence. This sequence receives the lowest rating in the quality of motion category in both surveys.

2.3.2.6.4 Fine Detail

For the following discussion refer to the table in the appendix labeled "Fine Detail". This table shows the results for each video sequence sorted by the fine detail rating. The results in this category are very close to the results obtained for the above category "Sharpness of Edges". Given that the ability to see edges affects how well you can see detail, this correlation is understandable.

2.3.2.6.5 Quality of Motion

For the following discussion refer to the table in the appendix labeled "Quality of Motion". This table shows the results for each video sequence sorted by the quality of motion rating. The lowest rated test for this category in both surveys is the carm4 video with a P Qfactor of 25. This is understandable because the cars, which are the only moving object in this video, have very long motion trails. These are caused by quantization errors in the motion prediction because the P Qfactor is so large. This allows for high compression, but poor motion quality. Videos with high P Qfactor values in general have low quality of motion ratings on this table. This table also shows a tendency for pattern 0, which is the low frequency I frame pattern, to have low quality of motion values. This is due to the relationship between the noticeable frame flicker, the next category to be discussed, and the perceived motion quality.

2.3.2.6.6 Frame Flickering

For the following discussion refer to the table in the appendix labeled "Frame Flickering". This table shows the results for each video sequence sorted by the frame flickering rating. It is noticeable that for both surveys the frame pattern with the low frequency of I frames receives low ratings for this category. This occurs because there is a noticeable change in image quality when an I frame is encountered. I frames do not suffer from error introduced during the motion prediction, and therefore have higher relative image quality. The low number of I frames allows the video quality to degrade significantly before an I frame is encountered. The noticeable exception to this is the b5m3 receives the highest ratings for this category in survey 2. The video has no real background because it is a series of moving space ships shown against a black background. As a result there is no background to degrade, and flicker is not as noticeable.

2.3.2.6.7 Color Shift

For the following discussion refer to the table in the appendix labeled "Color Shift". This table shows the results for each video sequence sorted by the color shift rating. This category in general receives high marks, indicating that it is difficult to see. The lowest ratings for this category in survey 1 are received by the b5m3 video. This occurs because the black background appears slightly red in color after it is compressed. This is hard to see on a TV monitor, but the effect on the computer screen was noticeable while developing the testing sequence.

2.3.2.7 Recommendations

Based on the above discussion considering both video quality and overall compression ratio the following videos are chosen as the best ones from each video test sequence:

Video Title	Pattern	Qfactor	Weighted Avg. 1	Weighted Avg. 2	Compression Ratio
carm4	0:	I Qfactor = 9	23.0	17.40	400.00
folcar1	1:	B Qfactor = 9	19.51	7.82	72.46
zoom3	3:	P Qfactor = 9	14.80	17.20	119.05
b5m2	2:	P Qfactor = 9	12.60	11.20	136.99
b5m3	0:	P Qfactor = 9	29.67	7.22	263.16
toy1	3:	I Qfactor = 9	17.33	15.00	107.53

Where,

The weighted avg. is determined as follows:

1. The numbers 1 and 2 refer to the survey the results are taken from
2. Each of the survey rating category results was modified to be $(5-x)^2$. Therefore:
   $5 = 0$
   $4 = 1$
   $3 = 4$
   $2 = 9$
   $1 = 16$
3. All eight categories are summed for each person's survey result
4. The average of these sums is taken

For more information refer to the above thesis section labeled "Overall Ranking of Video Sequence Survey Results"

2.3.2.8 Summary of Survey Results

The following is a list of the major points obtained for each of the video sequences from the image quality survey:

<u>Video Title</u>

carm4 - Cars moving in a stationary background

- Encoding only one I frame for each 16 frames is acceptable because the background contains very little motion
- High I Qfactors cause a highly noticeable loss in background quality
- People are more concerned with the quality of the background than the quality of the motion
- The ability to lose motion information allows for compression of the P and B frames
- This video is capable of the highest compression ratio of the videos tested
- The compression ratios of the P frames when the P Qfactor = 25 is 2000:1
- Contouring is highly visible
- High P Qfactor sequences receive the lowest quality of motion ratings, due to long motion trails behind the cars

folcar1 - Car relatively stationary in the frame while it moves along the background

- People prefer bi-directional prediction over forward prediction for this video sequence
- The use of B frames allows for more compression of the video than using P frames
- Motion artifacts in the videotaped survey are harder to see
- This video has the lowest compression ratio of the videos tested

zoom3 - A zoom in and out of a street containing moving cars with no panning

- B frames are beneficial in the compression of this video sequence
- Frame flickering is highly noticeable when the pattern with a reduced number of I frames is used

b5m2 - A computer generated planet exploding

- B frames do not appear to create good video quality in this case
- The amount of motion in this video requires a low P Qfactor
- One I frame for every 4 frames is suggested
- If low frequency I frame pattern is chosen, use a very low I Qfactor to reduce frame flickering

b5m3 - A computer generated space battle, where the background is mostly black and ships are moving around the scene

- Encoding only one I frame for each 16 frames is acceptable because the background is basically black
- The I Qfactor can be raised because the background contains very little information
- The P Qfactor should remain low due to the motion of the space ships
- The lack of a background allows for significant compression of the I frames in terms of both their content and frequency
- This video has the second highest compression ratio due to its lack of background information

- Contouring is visible in the fire coming from the engines of the ships, but fast motion allows people to neglect this effect
- This video receives a high frame flickering rating despite the use of the low frequency I frame pattern because of the lack of a visible background
- A reddish color shift is somewhat visible in the black space background

toy1 - A computer generated rotate while zooming out of a toy figure

- A good frequency of both I and B frames are needed due to the complexity of the background and motion
- B frames are desirable for this video because objects appear in both previous and future reference frames
- Edges become jagged during a rotation due to the motion estimation technique's dependence on translations, but not rotations, of blocks
- Solid areas appear to be able to handle higher P Qfactors, due to the computer generated nature of this sequence which allows solid areas to be matched more closely
- I Qfactor must be kept low due to problems with motion estimation that will cause significant frame flickering otherwise
- Motion blocking problems are especially hard to see in the videotaped survey

2.3.3 Final Trade off Analysis

The following lists the major conclusions and trade-offs that can be made from a combination of the results from the analytical and survey analyses:

Overall Recommendations and observations

- The I Qfactor should only be increased past 9 when compressing videos with low spatial content
- The number of I frames in the frame pattern should be decreased for videos with low spatial content in the video or a very small amount of motion in the video
- People can tolerate slight motion trails or background blocking, if the result is to make the motion look less jerky
- B Qfactor should be kept below 10
- P Qfactor should be kept below 15
- B frames should be used in videos where the objects in motion stay visible for a series of frames
- B frames should be used in videos with a lot of constant color areas
- Sequence which allow P frames, instead of I frames, to be used as a reference should be preferred because of their benefit to the overall compression ratio
- Qfactors can be higher for videos that are to be shown on TV monitors rather than computer screens
- Rotations of the background will cause problems with the motion estimation, requiring low P and B Qfactors. These problems are especially visible along sharp edges in the video.

- If a low frequency I frame pattern is chosen, use a lower I Qfactor to reduce the frame flickering
- It is important to remember the affected file percentage when considering raising the P or B Qfactor
- The choice of how many B frames to include in the frame pattern has more effect on overall compression ratio than the B Qfactor

Recommendations for video with little or no background spatial content

- These videos allow for higher I Qfactors, which greatly benefits the overall compression ratio
- These videos also allow for encoding only one I frame for each 16 frames because of their little background content

Recommendations for videos with high background content

- I Qfactors below 9 must be used in order for the video to appear acceptable
- High frequency I frame patterns must be used if there is any motion of the whole background
- Compress the P and B frames as much as possible, since people will focus on the background quality

Recommendations for videos with little or no motion

- These videos allow for encoding only one I frame for each 16 frames because the background contains very little motion

- Low I Qfactors should be used since artifacts in the background are highly visible
- People are more concerned with the quality of the background than the quality of the motion, allowing for P and B Qfactors in the range of 15-20

Recommendations for videos with high motion content

- If objects move across the video in a series of frames, use B frames rather than P frames for motion prediction
- These videos will result in low compression ratios
- Do not make more than 25% of the frames in the pattern I frames, because doing so will lose the possible motion estimation benefits to the overall compression ratio

Recommendations for natural (videotaped) videos

- I Qfactors can be kept slightly higher for these type of videos, in the range of 9-15, because of the lack of sharp edges in the typical scene.
- P and B Qfactors can also be raised because of the typical viewer's inability to see errors

Recommendations for computer generated videos

- The sharp edges and color sweeps in these video will require the use of lower I Qfactors (below 9)
- A video with a lot of solid color areas will be able to handle a high P or B Qfactor because of the success of the block matching technique

- Video with a lot of areas solid color areas should use more B frames in the frame pattern because of their ability to reduce spatial noise introduced during recording and compression of the resulting constant color area
- A video with a lot of sharp edges that are in motion will require low P or B Qfactors, because the error will be noticeable

3. Suggested Areas of Continued Research

3.1 Other MPEG-1 Parameters to Modify (Parallel MPEG-1 Video Encoding 4-5)

The analytical testing and image quality survey conducted during this thesis concentrated on the effects of modifying the I, P, and B Qfactors and the frame pattern. There exist a few other parameters which can be modified during the encoding of an MPEG file. The major remaining parameter is the motion vector search techniques. Some of the possible search techniques were discussed in the background section of this thesis. There are search techniques for the P frame motion vectors and search techniques for the B frame motion vectors. The choice of which search techniques to use for the P and B frames are options in the test sequence definition files used by the test sequence creation script developed for the thesis. See the section labelled "Test Sequence Definition File Examples" in the appendix for an example of this.

The search techniques implemented for P frames are : exhaustive, subsample, two-level, and logarithmic. The mean absolute difference (MAD) is used as a cost function while conducting these block search techniques. This cost function was described in the background section of the thesis. The exhaustive search tests all possible motion vectors in the search window. The subsample search computes the cost function based on fewer pixels. Only half of the 256 (16x16 macroblock) pixels are used to calculate the cost function. The two-level search consists of two parts which rely on the fact that the MPEG-1 encoder calculates motion vectors to the half pixel. First the search space is search exhaustively for the best full-pixel motion vector, then the best vector from this vector and the surrounding 8 half pixel vectors is chosen. The logarithmic search operates by reducing the number of motion vectors to test. First nine vectors in the search window are tested. Next it tests eight vectors centered on the best of the original 9 vectors. This process is repeated with decreasing motion vector lengths until a single best vector is located. The logarithmic search is similar to the three-step search method described in the background section of this thesis. The figure included with the discussion of the three-step search method is also helpful in understanding the logarithmic search. Assuming a *n* by *m* pixel rectangular search window, where $n > m$, the following table gives the theoretical number of pixel to pixel comparisons for each of these search techniques:

Theoretical Comparison of P Frame Search Technique

Search Technique	Pixel to Pixel Comparisons
Exhaustive	256(2n+1)(2m+1)
Subsample	64(2n+1)(2m+1)
Two-Level	256((n+1)(m+1)+8)
Logarithmic	$256(6\log_2 2m + 2\log_2 2n + 1)$

(Parallel MPEG-1 Video Encoding 4-5)

The search techniques for B-frames have to examine both the past and future reference frames. The one implemented in this version of the MPEG-1 software encoder are: exhaustive, simple, and cross2. All methods use the chosen P frame search method to find the best forward (V_f) and backward vectors (V_b). If using one of these motion vectors is better than using a combination of a forward vector and a backward vector, then the single vector is used. The exhaustive search finds the best matching backward vector for each tested forward vector using an exhaustive search. This method is very slow. The simple search only considers the combination of the best forward and backward vectors found by the P frame search technique. The search method as a result takes approximately twice as long as the chosen P frame search technique. The cross2 technique searches for the best backward vector to match V_f and the best forward vector to match V_b. The best of the four resulting alternatives (V_f, V_b, V_f+match, or V_b+match) is chosen. This search method takes approximately twice as long as the simple search.

Modifying the chosen motion vector search method and performing a similar analytical and/or image quality survey may prove interesting. The analytical tests would probably result in more useful information than an image quality survey when varying these particular encoding parameters. Comparing the resulting compressor execution times may also prove interesting. The MPEG-1 encoder could also be modified to support the other search methods and cost function described in the background section of this thesis. Tests could then be run to compare the result obtained from these algorithms to the existing search methods and cost functions.

3.2 Execution Time Analysis

A timing analysis of the execution of the MPEG-1 compressor could be conducted to locate the computationally complex pieces of the code. After the bottlenecks are discovered, suggestions for improving the algorithm could be made and tested. Each of the major blocks of the MPEG-1 compressor and decompressor could be examined. For the compressor these pieces include:

1. Color space conversion
2. Forward Discrete Cosine Transform (FDCT)
3. Quantization
4. Entropy Encoding
5. Motion Estimation

For decompressor these pieces include:

1. Inverse quantization
2. Inverse Discrete Cosine Transform (IDCT)
3. Motion compensation predictor
4. Future/Previous picture store
5. Dithering

One possible method for determining these execution time percentages is by using the UNIX gprof command which produces an execution profile of a program that has been compiled with the -pg option. A function call graph is created which gives the number of call to a particular procedure, along with the percentage of time spent in that procedure. The following shows an example of the procedure hierarchy results obtained for the MPEG-1 compressor using the carm4 video: (only significant time percentages are shown)

I. mpegVidRsrc 99.7 %
    A. DoDitherImage 52.6%
    B. ParseReconBlock 33.2 %
        1. j_rev_dct 21.4 %
        2. j_rev_dct_sparse 0.3%
    C. ComputeForwVector 0.2%
    D. ComputeBackVector 0.2%
    E. ExecuteDisplay 0.2%
II. InitColorDither 0.3 %

The following shows an example of the procedure hierarchy results obtained for the MPEG-1 decompressor using the carm4 video: (only significant time percentages are shown)

- I. GenMPEGStream 100%
  - A. SetFrameRate 96.7%
    - 1. GenBFrame 77.9%
      - a) EstimateSecondsPerBFrame 4.5%
        - (1) ComputeDiffDCTBlock 2.4%
      - b) BMotionSearch 72.4%
        - (1) LumAddMotionError 44.0%
        - (2) PLogarithmicSearch 34.3%
          - (a) LumMotionError 34.0%
      - c) ComputeHalfPixelData 2.7%
        - (1) LumBlockMAD 0.7%
    - 2. GenPFrame 12.7%
      - a) PMotionSearch 6.8%
        - (1) PLogarithmicSearch 34.3%
          - (a) LumMotionError 34.0%
      - b) ComputeDiffDCTs 0.8 %
    - 3. GenIFrame .7%
    - 4. ReadFrame 8.6%
      - a) PNMtoYUV 7.8%

The percentages sometimes add up to more that 100% because more than one function is calling a given function. This is shown by a function name appearing more than once in the above list.

The analytical results obtained could be compared to code complexity information obtained by analysis the actual program code.

3.3 Matrix of Parameter Limits Vs. Video Content Type for MPEG-1 and MPEG-2

Another area for further work would be in performing a similar experimental analysis using a MPEG-2 software encoder. The analysis could include both a numerical analysis and a image quality analysis. This would provide information on how the MPEG-2 algorithm compares to the MPEG-1 algorithm. There are also additional parameters which can be modified with the MPEG-2 algorithm. These include the coding for interlaced video, the scalable bitstream extensions, the alternate to zigzag scanning, and the extension to MQUANT. Once this study is completed a set of limits for the different parameter value, like the Qfactors and the frame pattern, could be determined. These limits would be based on the content type of the video and different limits would exist for the MPEG-1 and MPEG-2 algorithms. The limits for the MPEG-1 algorithm have already been investigated by this thesis.

3.4 Procedure for Guaranteeing Image Quality by Observing Video Content

A systematic procedure for observing the content of a particular video and then determining the best parameter values to use for that particular video to guarantee acceptable image quality and video playback could be developed. This procedure would also have to take into account the computer hardware being used to encode and display the video, along with the network bandwidth if a network is being used. This procedure should also take into account any realtime encoding and viewing constraints. These would exist in a video conferencing application for example. This procedure would make it easier for someone new to the MPEG algorithm to obtain good results in terms of image quality, speed of playback, and compression. Many of the trade-offs that exist for different types of video sequences have already been examined by this thesis.

4. Bibliography

4.1 General MPEG background and information

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[LEGALL91] D. LeGall, “MPEG: A Video Compression Standard for Multimedia Applications,” *Comm. ACM*, Vol. 34, No. 4, Apr. 1991, pp. 45-68.

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4.2 General information on multimedia systems and requirements.

[FURHT94] B. Furht, "Multimedia systems: an overview," *IEEE Multimedia*, vol. 1, no. 1, 1994, pp. 47-59.

4.3 From WWW

4.3.1 General MPEG algorithm information

From: http://www.powerweb.de./mpeg/mpegfaq/

MPEG-1 Faq..

MPEG-2 Faq.

MPEG-4 Faq.

4.3.2 Information about the MPEG source code used to complete this project

From: ftp://mm-ftp.cs.berkeley.edu/pub/multimedia/mpeg/

Berkeley's MPEG-1 Video Encoder User's Guide

Berkeley's Parallel MPEG-1 Video Encoding

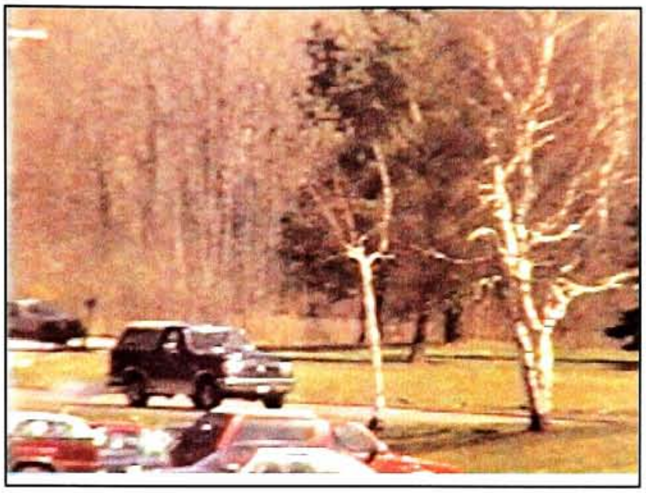
Unix manual pages for Berkeley's mpeg_play, mpeg_encode, mpeg_stat, mpeg_blocks, and mpeg_bits programs

5. Appendices

5.1 Appendix A: Video Sequence Clips

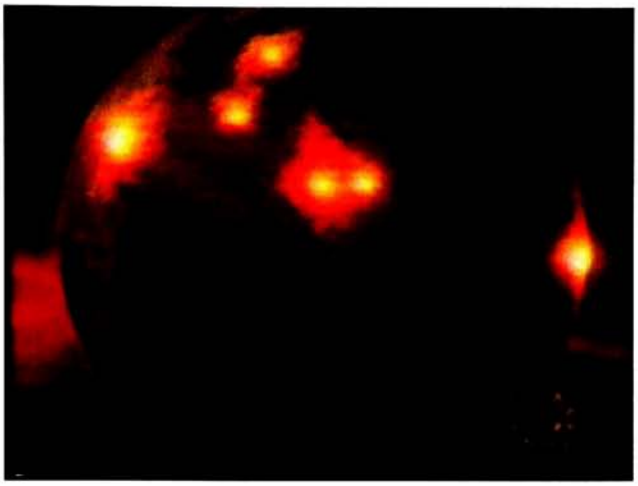
Carm4 Video Sequence:

Folcar1 Video Sequence:

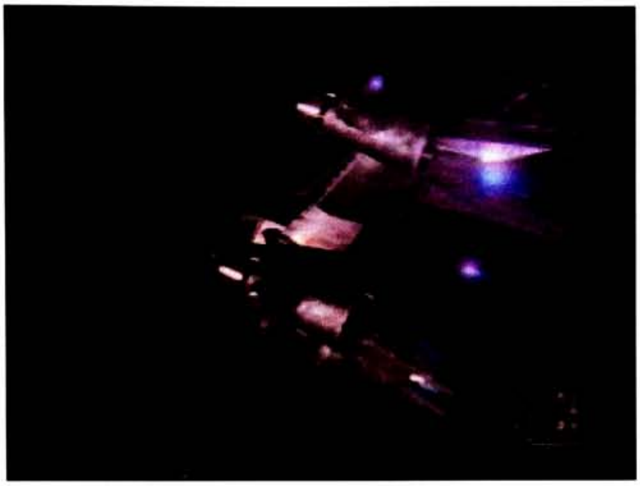


Zoom3 Video Sequence:

B5m2 Video Sequence:



B5m3 Video Sequence:



Toy1 Video Sequence:

5.2 *Appendix B: Survey Results*

The following table show the results of the first video survey which was conducted at RIT using a video tape of the required video sequences:

MPEG Survey Results:

Title: carm4-test-num1.mpg

						Min	Max	Avg.
Blocking Artifacts	5	5	5	3	5	3	5	4.60
Contouring	3	3	5	4	5	3	5	4.00
Sharpness of Edges	4	3	4	4	5	3	5	4.00
Fine Detail	4	2	4	2	4	2	4	3.20
Quality of motion	2	3	2	1	2	1	3	2.00
Frame Flickering	4	4	3	2		2	4	3.25
Color shift from original	5		5	4		4	5	4.67
Overall rating of video sequence	4	3	3	2	4	2	4	3.20

Title: carm4-test-num2.mpg

						Min	Max	Avg.
Blocking Artifacts	4	5	4	3	5	3	5	4.20
Contouring	3	3	5	4	5	3	5	4.00
Sharpness of Edges	3	3	4	4	5	3	5	3.80
Fine Detail	3	2	4	2	4	2	4	3.00
Quality of motion	2	3	3	1	3	1	3	2.40
Frame Flickering	3	4	4	2	4	2	4	3.40
Color shift from original	4	5	5	4	5	4	5	4.60
Overall rating of video sequence	3	4	4	3	4	3	4	3.60

Title: carm4-test-num3.mpg

						Min	Max	Avg.
Blocking Artifacts	2	5	2	2		2	5	2.75
Contouring	2	3	2	3	3	2	3	2.60
Sharpness of Edges	3	2	2	1	3	1	3	2.20
Fine Detail	2	2	2	2	3	2	3	2.20
Quality of motion	2	3	2	1	2	1	3	2.00
Frame Flickering	2	3	3	1	4	1	4	2.60
Color shift from original	4	5	4	4	5	4	5	4.40
Overall rating of video sequence	2	3	3	2	2	2	3	2.40

Title: carm4-test-num4.mpg

						Min	Max	Avg.
Blocking Artifacts	4	5	4	4	5	4	5	4.40
Contouring	4	4	4	4	5	4	5	4.20
Sharpness of Edges	4	3	3	3	5	3	5	3.60
Fine Detail	3	3	3	2	4	2	4	3.00
Quality of motion	2	4	4	1	3	1	4	2.80
Frame Flickering	3	4	3	2	4	2	4	3.20
Color shift from original	4	5	4	3	5	3	5	4.20
Overall rating of video sequence	3	4	3	3	4	3	4	3.40

Title: carm4-test-num5.mpg

						Min	Max	Avg.
Blocking Artifacts	3	5	4	1	5	1	5	3.60
Contouring	3	3	4	4	5	3	5	3.80
Sharpness of Edges	3	2	3	2	3	2	3	2.60
Fine Detail	3	2	2	2	2	2	3	2.20
Quality of motion	2	2	2	1	2	1	2	1.80
Frame Flickering	2	3	2	1	2	1	3	2.00
Color shift from original	4	4	4	4	5	4	5	4.20
Overall rating of video sequence	2	2	4	2	3	2	4	2.60

Title: carm4-test-num8.mpg

						Min	Max	Avg.
Blocking Artifacts	4	5	5	4	5	4	5	4.60
Contouring	4	4	5	4	3	3	5	4.00
Sharpness of Edges	4	3	4	3	3	3	4	3.40
Fine Detail	3	3	4	2	3	2	4	3.00
Quality of motion	3	4	5	1	4	1	5	3.40
Frame Flickering	3	4	4	1	4	1	4	3.20
Color shift from original	4	5	5	3	5	3	5	4.40
Overall rating of video sequence	4	4	4	3	4	3	4	3.80

Title: folcar1-test-num1.mpg

						Min	Max	Avg.
Blocking Artifacts	5	4	5	2	5	2	5	4.20
Contouring	4	3	5	1	5	1	5	3.60
Sharpness of Edges	4	3	3	3	5	3	5	3.60
Fine Detail	3	3	3	4	4	3	4	3.40
Quality of motion	3	4	2	2	2	2	4	2.60
Frame Flickering	5	4	2	2	5	2	5	3.60
Color shift from original			5	4	4	4	5	4.33
Overall rating of video sequence	4	3	3	3	4	3	4	3.40

Title: folcar1-test-num2.mpg

						Min	Max	Avg.
Blocking Artifacts	4	4	3	2	4	2	4	3.40
Contouring	4	4	4	1	4	1	4	3.40
Sharpness of Edges	3	3	3	3	4	3	4	3.20
Fine Detail	3	3	4	4	3	3	4	3.40
Quality of motion	2	4	3	2	3	2	4	2.80
Frame Flickering	2	4	3	2	4	2	4	3.00
Color shift from original	3	5	4	3	4	3	5	3.80
Overall rating of video sequence	3	4	4	3	4	3	4	3.60

Title: folcar1-test-num3.mpg

						Min	Max	Avg.
Blocking Artifacts	2	4	2	2	3	2	4	2.60
Contouring	3	3	4	1	3	1	4	2.80
Sharpness of Edges	2	3	4	3	3	2	4	3.00
Fine Detail	2	3	4	3	3	2	4	3.00
Quality of motion	2	4	2	2	2	2	4	2.40
Frame Flickering	2	4	2	2	4	2	4	2.80
Color shift from original	2	4	4	3	4	2	4	3.40
Overall rating of video sequence	2	4	3	2	2	2	4	2.60

Title: folcar1-test-num4.mpg

						Min	Max	Avg.
Blocking Artifacts	2	4	3	2	3	2	4	2.80
Contouring	3	3	4	2	3	2	4	3.00
Sharpness of Edges	3	3	4	3	3	3	4	3.20
Fine Detail	3	3	4	3	4	3	4	3.40
Quality of motion	3	4	4	1	3	1	4	3.00
Frame Flickering	2	4	4	2	4	2	4	3.20
Color shift from original	2	4	4	3	4	2	4	3.40
Overall rating of video sequence	3	4	5	2	3	2	5	3.40

Title: folcar1-test-num6.mpg

						Min	Max	Avg.
Blocking Artifacts	3	4	4	4	4	3	4	3.80
Contouring	2	3	4	2	4	2	4	3.00
Sharpness of Edges	4	3	4	4	4	3	4	3.80
Fine Detail	4	3	3	4	3	3	4	3.40
Quality of motion	3	3	5	2	4	2	5	3.40
Frame Flickering	4	4	5	2	4	2	5	3.80
Color shift from original	4		5	4	4	4	5	4.25
Overall rating of video sequence	4	3	5	4	3	3	5	3.80

Title: folcar1-test-num7.mpg

						Min	Max	Avg.
Blocking Artifacts	2	4	3	4	4	2	4	3.40
Contouring	3	3	3	4	4	3	4	3.40
Sharpness of Edges	4	3	3	4	4	3	4	3.60
Fine Detail	4	3	3	4	2	2	4	3.20
Quality of motion	2	4	4	2	4	2	4	3.20
Frame Flickering	3	3	3	2	4	2	4	3.00
Color shift from original	3	4	4	4	4	3	4	3.80
Overall rating of video sequence	3	3	3	4	4	3	4	3.40

Title: folcar1-test-num8.mpg

						Min	Max	Avg.
Blocking Artifacts	4	4	4	3	3	3	4	3.60
Contouring	4	3	4	5	4	3	5	4.00
Sharpness of Edges	3	3	4	3	3	3	4	3.20
Fine Detail	3	3	4	4	3	3	4	3.40
Quality of motion	3	4	5	2	4	2	5	3.60
Frame Flickering	3	3	5	2	4	2	5	3.40
Color shift from original	4	4	4	4	4	4	4	4.00
Overall rating of video sequence	4	3	4	4	3	3	4	3.60

Title: zoom3-test-num1.mpg

						Min	Max	Avg.
Blocking Artifacts	5	5	5	2	5	2	5	4.40
Contouring	5	4	5	2	5	2	5	4.20
Sharpness of Edges	4	3	5	5	4	3	5	4.20
Fine Detail	4	3	5	4	4	3	5	4.00
Quality of motion	3	3	3	2	2	2	3	2.60
Frame Flickering	5	4	2	2	5	2	5	3.60
Color shift from original	5		5	5	4	4	5	4.75
Overall rating of video sequence	5	3	3	3	4	3	5	3.60

Title: zoom3-test-num2.mpg

						Min	Max	Avg.
Blocking Artifacts	4	5	4	2	5	2	5	4.00
Contouring	4	4	4	2	3	2	4	3.40
Sharpness of Edges	4	3	4	4	3	3	4	3.60
Fine Detail	3	3	3	4	3	3	4	3.20
Quality of motion	3	4	4	3	3	3	4	3.40
Frame Flickering	2	4	3	2	4	2	4	3.00
Color shift from original	4	5	4	5	4	4	5	4.40
Overall rating of video sequence	4	4	4	4	3	3	4	3.80

Title: zoom3-test-num4.mpg

						Min	Max	Avg.
Blocking Artifacts	4	5	5	3	4	3	5	4.20
Contouring	4	4	5	2	3	2	5	3.60
Sharpness of Edges	3	3	5		3	3	5	3.50
Fine Detail	2	3	4	4	4	2	4	3.40
Quality of motion	3	3	4	4	4	3	4	3.60
Frame Flickering	3	4	4	2		2	4	3.25
Color shift from original	4	5	5	5	4	4	5	4.60
Overall rating of video sequence	3	4	5	4	4	3	5	4.00

Title: zoom3-test-num6.mpg

						Min	Max	Avg.
Blocking Artifacts	5	5	5	3	4	3	5	4.40
Contouring	5	4	5	2	4	2	5	4.00
Sharpness of Edges	4	3	5	4	4	3	5	4.00
Fine Detail	4	3	4	4	3	3	4	3.60
Quality of motion	4	4	5	3	2	2	5	3.60
Frame Flickering	4	4	3	3	3	3	4	3.40
Color shift from original	5	5	5	5	4	4	5	4.80
Overall rating of video sequence	4	4	5	3	3	3	5	3.80

Title: b5m2-test-num0.mpg

						Min	Max	Avg.
Blocking Artifacts	5	5	5	5	3	3	5	4.60
Contouring	3	4	5	4	4	3	5	4.00
Sharpness of Edges	5	4	4	4	3	3	5	4.00
Fine Detail	5	4	3	4	4	3	5	4.00
Quality of motion	4	4	2	3	3	2	4	3.20
Frame Flickering	5	4	2	3	4	2	5	3.60
Color shift from original	5		5	4	4	4	5	4.50
Overall rating of video sequence	5	4	2	4	4	2	5	3.80

Title: b5m2-test-num1.mpg

						Min	Max	Avg.
Blocking Artifacts	3	5	3	3	3	3	5	3.40
Contouring	3	4	3	4	3	3	4	3.40
Sharpness of Edges	3	4	3	3	3	3	4	3.20
Fine Detail	4	4	3	4	3	3	4	3.60
Quality of motion	3	4	4	4	3	3	4	3.60
Frame Flickering	3	4	2	3	3	2	4	3.00
Color shift from original	5	5	4	4	4	4	5	4.40
Overall rating of video sequence	3	4	3	4	3	3	4	3.40

Title: b5m2-test-num2.mpg

						Min	Max	Avg.
Blocking Artifacts	2	5	4	4	3	2	5	3.60
Contouring	3	4	4	4	3	3	4	3.60
Sharpness of Edges	3	4	4	4	3	3	4	3.60
Fine Detail	4	4	3	4	3	3	4	3.60
Quality of motion	4	4	4	4	4	4	4	4.00
Frame Flickering	3	4	4	3	4	3	4	3.60
Color shift from original	5	5	4	3	4	3	5	4.20
Overall rating of video sequence	3	4	4	4	3	3	4	3.60

Title: b5m2-test-num3.mpg

						Min	Max	Avg.
Blocking Artifacts	2	5	5	3	2	2	5	3.40
Contouring	3	4	5	4	3	3	5	3.80
Sharpness of Edges	3	3	4	4	3	3	4	3.40
Fine Detail	2	4	4	4	4	2	4	3.60
Quality of motion	3	4	4	3	3	3	4	3.40
Frame Flickering	4	4	2	2	3	2	4	3.00
Color shift from original	2	5	5	4	4	2	5	4.00
Overall rating of video sequence	3	4	3	3	3	3	4	3.20

Title: b5m2-test-num7.mpg

						Min	Max	Avg.
Blocking Artifacts	4	5	4	4	4	4	5	4.20
Contouring	4	4	4	4	3	3	4	3.80
Sharpness of Edges	3	4	4	3	4	3	4	3.60
Fine Detail	3	4	4	4	4	3	4	3.80
Quality of motion	3	4	4	3	4	3	4	3.60
Frame Flickering	4	4	3	3	3	3	4	3.40
Color shift from original	5	5	4	5	4	4	5	4.60
Overall rating of video sequence	4	4	4	4	4	4	4	4.00

Title: b5m2-test-num8.mpg

				Min	Max	Avg.
Blocking Artifacts	2	5	2	2	5	3.00
Contouring	3	3	2	2	3	2.67
Sharpness of Edges	3	3	3	3	3	3.00
Fine Detail	3	3	3	3	3	3.00
Quality of motion	4	4	3	3	4	3.67
Frame Flickering	3	3	2	2	3	2.67
Color shift from original	5	4	4	4	5	4.33
Overall rating of video sequence	3	3	3	3	3	3.00

Title: b5m3-test-num0.mpg

				Min	Max	Avg.
Blocking Artifacts	4	5	5	4	5	4.67
Contouring	5	3	5	3	5	4.33
Sharpness of Edges	5	3	4	3	5	4.00
Fine Detail	5	3	4	3	5	4.00
Quality of motion	3	4	2	2	4	3.00
Frame Flickering	5	3	2	2	5	3.33
Color shift from original	5		5	5	5	5.00
Overall rating of video sequence	5	3	3	3	5	3.67

Title: b5m3-test-num1.mpg

				Min	Max	Avg.
Blocking Artifacts	2	5	4	2	5	3.67
Contouring	3	3	4	3	4	3.33
Sharpness of Edges	3	3	4	3	4	3.33
Fine Detail	3	3	3	3	3	3.00
Quality of motion	3	3	3	3	3	3.00
Frame Flickering	4	3	2	2	4	3.00
Color shift from original	4	4	2	2	4	3.33
Overall rating of video sequence	3	3	3	3	3	3.00

Title: b5m3-test-num3.mpg

				Min	Max	Avg.
Blocking Artifacts	3	5	3	3	5	3.67
Contouring	3	3	2	2	3	2.67
Sharpness of Edges	3	3	3	3	3	3.00
Fine Detail	4	3	3	3	4	3.33
Quality of motion	4	4	2	2	4	3.33
Frame Flickering	3	3	2	2	3	2.67
Color shift from original	4	4	4	4	4	4.00
Overall rating of video sequence	3	3	3	3	3	3.00

Title: b5m3-test-num5.mpg

				Min	Max	Avg.
Blocking Artifacts	4	4	2	2	4	3.33
Contouring	3	3	2	2	3	2.67
Sharpness of Edges	2	3	2	2	3	2.33
Fine Detail	3	3	2	2	3	2.67
Quality of motion	4	4	4	4	4	4.00
Frame Flickering	4	3	4	3	4	3.67
Color shift from original	3	4	3	3	4	3.33
Overall rating of video sequence	3	3	2	2	3	2.67

Title: b5m3-test-num7.mpg

				Min	Max	Avg.
Blocking Artifacts	3	4	4	3	4	3.67
Contouring	3	2	4	2	4	3.00
Sharpness of Edges	3	2	4	2	4	3.00
Fine Detail	2	3	4	2	4	3.00
Quality of motion	3	4	4	3	4	3.67
Frame Flickering	2	3	4	2	4	3.00
Color shift from original	3	4	4	3	4	3.67
Overall rating of video sequence	3	3	4	3	4	3.33

Title: toy1-test-num0.mpg

				Min	Max	Avg.
Blocking Artifacts	5	5	5	5	5	5.00
Contouring	5	3	5	3	5	4.33
Sharpness of Edges	5	3	5	3	5	4.33
Fine Detail	5	4	5	4	5	4.67
Quality of motion	3	4	2	2	4	3.00
Frame Flickering	5	3	2	2	5	3.33
Color shift from original	5	4	5	4	5	4.67
Overall rating of video sequence	4	4	2	2	4	3.33

Title: toy1-test-num1.mpg

				Min	Max	Avg.
Blocking Artifacts	3	5	4	3	5	4.00
Contouring	3	3	4	3	4	3.33
Sharpness of Edges	4	3	3	3	4	3.33
Fine Detail	3	3	4	3	4	3.33
Quality of motion	4	3	3	3	4	3.33
Frame Flickering	2	3	2	2	3	2.33
Color shift from original	4	4	5	4	5	4.33
Overall rating of video sequence	3	3	3	3	3	3.00

Title: toy1-test-num3.mpg

				Min	Max	Avg.
Blocking Artifacts	4	5	5	4	5	4.67
Contouring	2	4	5	2	5	3.67
Sharpness of Edges	3	4	4	3	4	3.67
Fine Detail	4	3	4	3	4	3.67
Quality of motion	3	4	2	2	4	3.00
Frame Flickering	4	3	4	3	4	3.67
Color shift from original	3	4	5	3	5	4.00
Overall rating of video sequence	3	4	3	3	4	3.33

Title: toy1-test-num5.mpg

				Min	Max	Avg.
Blocking Artifacts	4	5	5	4	5	4.67
Contouring	4		5	4	5	4.50
Sharpness of Edges	3	3	5	3	5	3.67
Fine Detail	3	3	4	3	4	3.33
Quality of motion	4	3	2	2	4	3.00
Frame Flickering	3	3	4	3	4	3.33
Color shift from original	3	4	4	3	4	3.67
Overall rating of video sequence	3	3	4	3	4	3.33

Title: toy1-test-num6.mpg

				Min	Max	Avg.
Blocking Artifacts	4	5	4	4	5	4.33
Contouring	3	4	4	3	4	3.67
Sharpness of Edges	3	3	4	3	4	3.33
Fine Detail	3	3	4	3	4	3.33
Quality of motion	4	4	5	4	5	4.33
Frame Flickering	2	3	4	2	4	3.00
Color shift from original	4	4	4	4	4	4.00
Overall rating of video sequence	3	4	4	3	4	3.67

Title: toy1-test-num7.mpg

				Min	Max	Avg.
Blocking Artifacts	3	5	4	3	5	4.00
Contouring	3	3	4	3	4	3.33
Sharpness of Edges	3	3	3	3	3	3.00
Fine Detail	3	4	4	3	4	3.67
Quality of motion	3	4	4	3	4	3.67
Frame Flickering	4	3	4	3	4	3.67
Color shift from original	4	4	4	4	4	4.00
Overall rating of video sequence	3	4	5	3	5	4.00

The following table shows the results of the second video survey which was conducted using a Macintosh Power PC connected to a video monitor:

MPEG Survey2 Results:

Title: carm4-test-num1.mpg

			Min	Max	Avg.
Blocking Artifacts	5	4	4	5	4.50
Contouring	5	4	4	5	4.50
Sharpness of Edges	5	3	3	5	4.00
Fine Detail	5	4	4	5	4.50
Quality of motion	2	4	2	4	3.00
Frame Flickering	2	2	2	2	2.00
Color shift from original	5	4	4	5	4.50
Overall rating of video sequence	2	4	2	4	3.00

Title: carm4-test-num2.mpg

						Min	Max	Avg.
Blocking Artifacts	4	3	3	4	3	3	4	3.40
Contouring	4	4	4	5	5	4	5	4.40
Sharpness of Edges	3	4	3	5	4	3	5	3.80
Fine Detail	4	4	4	5	3	3	5	4.00
Quality of motion	2	2	4	5	4	2	5	3.40
Frame Flickering	3	2	4	5	3	2	5	3.40
Color shift from original	4	4	5	5	5	4	5	4.60
Overall rating of video sequence	3	3	4	5	3	3	5	3.60

Title: carm4-test-num3.mpg

						Min	Max	Avg.
Blocking Artifacts	2	1	2	2	1	1	2	1.60
Contouring	2	1	2	2	5	1	5	2.40
Sharpness of Edges	2	1	2	2	2	1	2	1.80
Fine Detail	2	1	2	2	2	1	2	1.80
Quality of motion	2	2	4	5	5	2	5	3.60
Frame Flickering	3	2	3	5	3	2	5	3.20
Color shift from original	4	2	3	3	5	2	5	3.40
Overall rating of video sequence	2	2	2	2	2	2	2	2.00

Title: carm4-test-num4.mpg

						Min	Max	Avg.
Blocking Artifacts	3	2	4	3	3	2	4	3.00
Contouring	3	3	4	5	5	3	5	4.00
Sharpness of Edges	4	3	4	5	4	3	5	4.00
Fine Detail	3	4	4	5	4	3	5	4.00
Quality of motion	2	3		5	4	2	5	3.50
Frame Flickering	4	3	3	5	4	3	5	3.80
Color shift from original	4	3	4	5	5	3	5	4.20
Overall rating of video sequence	3	3	4	5	3	3	5	3.60

Title: carm4-test-num5.mpg

						Min	Max	Avg.
Blocking Artifacts	3	2	3	2	2	2	3	2.40
Contouring	4	2	3	5	5	2	5	3.80
Sharpness of Edges	4	3	4	5	4	3	5	4.00
Fine Detail	4	4	4	5	3	3	5	4.00
Quality of motion	1	1	2	2	4	1	4	2.00
Frame Flickering	3	2	1	5	3	1	5	2.80
Color shift from original	4	3	3	4	5	3	5	3.80
Overall rating of video sequence	3	3	3	3	3	3	3	3.00

Title: carm4-test-num8.mpg

						Min	Max	Avg.
Blocking Artifacts	3	3	3	4	4	3	4	3.40
Contouring	4	3	3	5	5	3	5	4.00
Sharpness of Edges	4	3	4	5	4	3	5	4.00
Fine Detail	4	3	3	5	3	3	5	3.60
Quality of motion	4	4	4	4	4	4	4	4.00
Frame Flickering	2	3	3	5	4	2	5	3.40
Color shift from original	3	4	2	5	5	2	5	3.80
Overall rating of video sequence	4	3	3	5	4	3	5	3.80

Title: folcar1-test-num1.mpg

			Min	Max	Avg.
Blocking Artifacts	5	4	4	5	4.50
Contouring	5	4	4	5	4.50
Sharpness of Edges	4	4	4	4	4.00
Fine Detail	3	4	3	4	3.50
Quality of motion	5	4	4	5	4.50
Frame Flickering	2	5	2	5	3.50
Color shift from original	5	5	5	5	5.00
Overall rating of video sequence	3	4	3	4	3.50

Title: folcar1-test-num2.mpg

						Min	Max	Avg.
Blocking Artifacts	3	3	3	4	3	3	4	3.20
Contouring	4	3	4	5	5	3	5	4.20
Sharpness of Edges	3	4	3	4	4	3	4	3.60
Fine Detail	2	3	3	5	4	2	5	3.40
Quality of motion	4	3	4	5	4	3	5	4.00
Frame Flickering	2	2	3	4	4	2	4	3.00
Color shift from original	4	3	4	5	5	3	5	4.20
Overall rating of video sequence	4	3	3	5	3	3	5	3.60

Title: folcar1-test-num3.mpg

						Min	Max	Avg.
Blocking Artifacts	2	2	1	4	3	1	4	2.40
Contouring	2	2	2	3	5	2	5	2.80
Sharpness of Edges	2	2	2	4	4	2	4	2.80
Fine Detail	3	1	2	4	3	1	4	2.60
Quality of motion	4	2	3	3	3	2	4	3.00
Frame Flickering	1	2	3	3	3	1	3	2.40
Color shift from original	4	3	4	5	5	3	5	4.20
Overall rating of video sequence	2	2	2	4	3	2	4	2.60

Title: folcar1-test-num4.mpg

						Min	Max	Avg.
Blocking Artifacts	4	3	3	4	3	3	4	3.40
Contouring	4	4	3	5	5	3	5	4.20
Sharpness of Edges	4	3	4	5	4	3	5	4.00
Fine Detail	3	4	3	5	3	3	5	3.60
Quality of motion	4	3	4	5	4	3	5	4.00
Frame Flickering	1	4	4	5	3	1	5	3.40
Color shift from original	4	4	3	5	5	3	5	4.20
Overall rating of video sequence	4	4	3	5	3	3	5	3.80

Title: folcar1-test-num6.mpg

						Min	Max	Avg.
Blocking Artifacts	5	3	4	5	4	3	5	4.20
Contouring	5	4	4	5	5	4	5	4.60
Sharpness of Edges	4	4	4	5	4	4	5	4.20
Fine Detail	4	4	4	5	3	3	5	4.00
Quality of motion	5	5	4	5	3	3	5	4.40
Frame Flickering	4	4	3	5	3	3	5	3.80
Color shift from original	4	5	4	5	5	4	5	4.60
Overall rating of video sequence	5	4	4	5	4	4	5	4.40

Title: folcar1-test-num7.mpg

						Min	Max	Avg.
Blocking Artifacts	4	3	3	4	2	2	4	3.20
Contouring	5	4	3	5	5	3	5	4.40
Sharpness of Edges	4	4	3	5	4	3	5	4.00
Fine Detail	3	3	3	5	2	2	5	3.20
Quality of motion	5	5	4	5	3	3	5	4.40
Frame Flickering	4	3	3	5	2	2	5	3.40
Color shift from original	4	4	4	5	5	4	5	4.40
Overall rating of video sequence	4	4	3	5	2	2	5	3.60

Title: folcar1-test-num8.mpg

						Min	Max	Avg.
Blocking Artifacts	5	4	3	5	4	3	5	4.20
Contouring	5	4		5	5	4	5	4.75
Sharpness of Edges	5	4	3	4	3	3	5	3.80
Fine Detail	4	5	3	4	3	3	5	3.80
Quality of motion	5	5	4	5	4	4	5	4.60
Frame Flickering	4	4	4	5	3	3	5	4.00
Color shift from original	5	5	2	5	5	2	5	4.40
Overall rating of video sequence	5	5	3	4	3	3	5	4.00

Title: zoom3-test-num1.mpg

			Min	Max	Avg.
Blocking Artifacts	5	5	5	5	5.00
Contouring	5	5	5	5	5.00
Sharpness of Edges	5	5	5	5	5.00
Fine Detail	5	5	5	5	5.00
Quality of motion	2	5	2	5	3.50
Frame Flickering	5	5	5	5	5.00
Color shift from original	5	5	5	5	5.00
Overall rating of video sequence	2	5	2	5	3.50

Title: zoom3-test-num2.mpg

						Min	Max	Avg.
Blocking Artifacts	2	3	3	5	3	2	5	3.20
Contouring	2	3	3	4	5	2	5	3.40
Sharpness of Edges	3	4	3	4	4	3	4	3.60
Fine Detail	3	3	3	4	3	3	4	3.20
Quality of motion	3	3	4	5	4	3	5	3.80
Frame Flickering	2	4	2	4	3	2	4	3.00
Color shift from original	2	4	2	5	5	2	5	3.60
Overall rating of video sequence	2	3	3	4	3	2	4	3.00

Title: zoom3-test-num4.mpg

						Min	Max	Avg.
Blocking Artifacts	3	3	4	5	2	2	5	3.40
Contouring	3	4	2	4	5	2	5	3.60
Sharpness of Edges	4	4	3	4	3	3	4	3.60
Fine Detail	4	4	3	4	2	2	4	3.40
Quality of motion	3	4	4	5	2	2	5	3.60
Frame Flickering	3	4	4	5	3	3	5	3.80
Color shift from original	4	4	4	5	5	4	5	4.40
Overall rating of video sequence	3	4	3	4	2	2	4	3.20

Title: zoom3-test-num6.mpg

						Min	Max	Avg.
Blocking Artifacts	3	3	4	5	3	3	5	3.60
Contouring	3	2	4	5	5	2	5	3.80
Sharpness of Edges	4	2	3	4	4	2	4	3.40
Fine Detail	4	3	3	5	3	3	5	3.60
Quality of motion	4	4	3	5	3	3	5	3.80
Frame Flickering	4	3	4	5	4	3	5	4.00
Color shift from original	4	4	4	5	5	4	5	4.40
Overall rating of video sequence	4	3	4	5	3	3	5	3.80

Title: b5m2-test-num0.mpg

			Min	Max	Avg.
Blocking Artifacts	5	5	5	5	5.00
Contouring	5	5	5	5	5.00
Sharpness of Edges	5	5	5	5	5.00
Fine Detail	5	4	4	5	4.50
Quality of motion	1	5	1	5	3.00
Frame Flickering	5	5	5	5	5.00
Color shift from original	5	5	5	5	5.00
Overall rating of video sequence	2	5	2	5	3.50

Title: b5m2-test-num1.mpg

						Min	Max	Avg.
Blocking Artifacts	3	3	2	3	3	2	3	2.80
Contouring	2	4	2	3	5	2	5	3.20
Sharpness of Edges	4	4	2	4	4	2	4	3.60
Fine Detail	4	3	2	4	3	2	4	3.20
Quality of motion	3	4	3	3	3	3	4	3.20
Frame Flickering	2	4	3	4	4	2	4	3.40
Color shift from original	4	3	2	5	5	2	5	3.80
Overall rating of video sequence	3	4	2	3	4	2	4	3.20

Title: b5m2-test-num2.mpg

						Min	Max	Avg.
Blocking Artifacts	4	4	3	4	4	3	4	3.80
Contouring	4	4	3	4	5	3	5	4.00
Sharpness of Edges	4	3	3	5	4	3	5	3.80
Fine Detail	3	5	3	4	4	3	5	3.80
Quality of motion	4	4	4	4	4	4	4	4.00
Frame Flickering	3	5	4	4	3	3	5	3.80
Color shift from original	4	4	4	5	5	4	5	4.40
Overall rating of video sequence	4	4	3	4	4	3	4	3.80

Title: b5m2-test-num3.mpg

						Min	Max	Avg.
Blocking Artifacts	3	3	2	2	3	2	3	2.60
Contouring	3	2	2	2	5	2	5	2.80
Sharpness of Edges	3	4	2	3	4	2	4	3.20
Fine Detail	3	3	3	3	4	3	4	3.20
Quality of motion	3	4	4	2	3	2	4	3.20
Frame Flickering	2	3	3	3	3	2	3	2.80
Color shift from original	4	3	3	4	5	3	5	3.80
Overall rating of video sequence	3	3	3	2	3	2	3	2.80

Title: b5m2-test-num7.mpg

						Min	Max	Avg.
Blocking Artifacts	4	4	4	4	3	3	4	3.80
Contouring	4	4	4	4	5	4	5	4.20
Sharpness of Edges	3	4	4	5	4	3	5	4.00
Fine Detail	3	3	5	4	3	3	5	3.60
Quality of motion	4	4	5	5	3	3	5	4.20
Frame Flickering	4	4	4	5	3	3	5	4.00
Color shift from original	4	4	4	5	5	4	5	4.40
Overall rating of video sequence	4	4	4	4	3	3	4	3.80

Title: b5m2-test-num8.mpg

						Min	Max	Avg.
Blocking Artifacts	2	2	1	3	3	1	3	2.20
Contouring	2	3	2	3	5	2	5	3.00
Sharpness of Edges	2	3	2	4	3	2	4	2.80
Fine Detail	2	2	2	4	3	2	4	2.60
Quality of motion	3	3	4	3	3	3	4	3.20
Frame Flickering	1	3		3	3	1	3	2.50
Color shift from original	4	2	3	4	5	2	5	3.60
Overall rating of video sequence	2	3	2	3	3	2	3	2.60

Title: b5m3-test-num0.mpg

			Min	Max	Avg.
Blocking Artifacts	5	5	5	5	5.00
Contouring	5	5	5	5	5.00
Sharpness of Edges	5	5	5	5	5.00
Fine Detail	5	5	5	5	5.00
Quality of motion	2	5	2	5	3.50
Frame Flickering	5	5	5	5	5.00
Color shift from original	5	5	5	5	5.00
Overall rating of video sequence	2	5	2	5	3.50

Title: b5m3-test-num1.mpg

						Min	Max	Avg.
Blocking Artifacts	4	4	4	5	3	3	5	4.00
Contouring	4	3	4	5	5	3	5	4.20
Sharpness of Edges	4	5	4	5	4	4	5	4.40
Fine Detail	4	4	4	5	3	3	5	4.00
Quality of motion	5	3	5	5	4	3	5	4.40
Frame Flickering	5	4	5	4	4	4	5	4.40
Color shift from original	4	3	3	5	5	3	5	4.00
Overall rating of video sequence	4	4	4	5	3	3	5	4.00

Title: b5m3-test-num3.mpg

						Min	Max	Avg.
Blocking Artifacts	4	4	4	5	3	3	5	4.00
Contouring	4	5	5	5	4	4	5	4.60
Sharpness of Edges	3	4	5	5	4	3	5	4.20
Fine Detail	4	5	4	5	3	3	5	4.20
Quality of motion	5	4	5	5	4	4	5	4.60
Frame Flickering	5	5	4	5	3	3	5	4.40
Color shift from original	4	5	4	5	5	4	5	4.60
Overall rating of video sequence	4	5	4	5	3	3	5	4.20

Title: b5m3-test-num5.mpg

						Min	Max	Avg.
Blocking Artifacts	1	2	2	3	3	1	3	2.20
Contouring	2	3	3	3	4	2	4	3.00
Sharpness of Edges	2	2	3	4	4	2	4	3.00
Fine Detail	3	2	4	4	4	2	4	3.40
Quality of motion	5	2	4	3	3	2	5	3.40
Frame Flickering	2	3	3	3	3	2	3	2.80
Color shift from original	4	4	3	5	5	3	5	4.20
Overall rating of video sequence	3	2	3	4	3	2	4	3.00

Title: b5m3-test-num7.mpg

						Min	Max	Avg.
Blocking Artifacts	4	4	3	5	4	3	5	4.00
Contouring	4	4	4	5	5	4	5	4.40
Sharpness of Edges	4	4	3	5	4	3	5	4.00
Fine Detail	4	4	3	5	4	3	5	4.00
Quality of motion	5	5	4	5	4	4	5	4.60
Frame Flickering	5	4	4	5	3	3	5	4.20
Color shift from original	4	5	3	5	5	3	5	4.40
Overall rating of video sequence	5	4	3	5	4	3	5	4.20

Title: toy1-test-num0.mpg

			Min	Max	Avg.
Blocking Artifacts	5	5	5	5	5.00
Contouring	5	5	5	5	5.00
Sharpness of Edges	5	5	5	5	5.00
Fine Detail	5	5	5	5	5.00
Quality of motion	1	5	1	5	3.00
Frame Flickering	5	5	5	5	5.00
Color shift from original	5	5	5	5	5.00
Overall rating of video sequence	2	5	2	5	3.50

Title: toy1-test-num1.mpg

						Min	Max	Avg.
Blocking Artifacts	2	2	3	4	4	2	4	3.00
Contouring	3	3	2	5	5	2	5	3.60
Sharpness of Edges	2	2	2	3	3	2	3	2.40
Fine Detail	4	3	2	4	3	2	4	3.20
Quality of motion	3	3	3	4	3	3	4	3.20
Frame Flickering	2	3	2	4	4	2	4	3.00
Color shift from original	5	3	4	5	5	3	5	4.40
Overall rating of video sequence	3	3	2	3	3	2	3	2.80

Title: toy1-test-num3.mpg

						Min	Max	Avg.
Blocking Artifacts	3	4	3	5	4	3	5	3.80
Contouring	4	4	3	5	5	3	5	4.20
Sharpness of Edges	2	4	3	4	3	2	4	3.20
Fine Detail	4	4	3	4	3	3	4	3.60
Quality of motion	4	5	3	5	4	3	5	4.20
Frame Flickering	5	4	3	5	4	3	5	4.20
Color shift from original	4	5	4	5	5	4	5	4.60
Overall rating of video sequence	4	4	3	4	3	3	4	3.60

Title: toy1-test-num5.mpg

						Min	Max	Avg.
Blocking Artifacts	4	3	3	5	3	3	5	3.60
Contouring	4	3	3	5	5	3	5	4.00
Sharpness of Edges	2	3	4	4	3	2	4	3.20
Fine Detail	4	3	3	4	3	3	4	3.40
Quality of motion	5	4	4	5	3	3	5	4.20
Frame Flickering	5	4	3	4	4	3	5	4.00
Color shift from original	5	5	4	5	5	4	5	4.80
Overall rating of video sequence	4	3	3	4	3	3	4	3.40

Title: toy1-test-num6.mpg

						Min	Max	Avg.
Blocking Artifacts	3	3	4	5	3	3	5	3.60
Contouring	4	4	3	4	5	3	5	4.00
Sharpness of Edges	4	4	3	3	3	3	4	3.40
Fine Detail	3	4	3	4	3	3	4	3.40
Quality of motion	3	4	4	5	3	3	5	3.80
Frame Flickering	2	5	3	5	3	2	5	3.60
Color shift from original	4	5	4	5	5	4	5	4.60
Overall rating of video sequence	3	4	3	3	3	3	4	3.20

Title: toy1-test-num7.mpg

						Min	Max	Avg.
Blocking Artifacts	4	4	3	5	3	3	5	3.80
Contouring	2	4	3	5	5	2	5	3.80
Sharpness of Edges	4	4	4	4	3	3	4	3.80
Fine Detail	3	4	4	5	2	2	5	3.60
Quality of motion	4	4	4	5	3	3	5	4.00
Frame Flickering	3	4	4	5	3	3	5	3.80
Color shift from original	4	4	4	5	5	4	5	4.40
Overall rating of video sequence	4	4	4	4	3	3	4	3.80

5.3 Appendix C: Survey Tables

5.3.1 Weighted Average of Survey Category Ratings Table

Video Title	Survey	Test	Pattern	Qfactor	Overall	Weighted Avg.	Compression Ratio
carm4	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	20.60	151.52
carm4	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	22.40	370.37
carm4	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.6	23.00	400.00
carm4	1	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	2.6	47.20	434.78
carm4	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2.4	52.61	555.56
folcar1	1	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	3.8	19.51	72.46
folcar1	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	19.60	70.42
folcar1	1	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.4	25.00	91.74
folcar1	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.6	27.80	108.70
folcar1	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	32.20	98.04
folcar1	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.6	43.80	121.95
zoom3	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.8	14.80	119.05
zoom3	1	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	17.86	117.65
zoom3	1	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	20.80	222.22
b5m2	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	12.60	136.99
b5m2	1	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.6	16.20	156.25
b5m2	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.4	21.60	243.90
b5m2	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	25.00	217.39
b5m2	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	3	32.00	161.29
b5m3	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.33	27.67	169.49
b5m3	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3	29.67	294.12
b5m3	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	29.67	263.16
b5m3	1	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	2.67	34.00	208.33
toy1	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.67	17.00	105.26
toy1	1	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4	17.33	107.53
toy1	1	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.33	19.00	96.15
toy1	1	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.33	19.08	97.09
toy1	1	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	25.67	200.00
carm4	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.6	17.40	400.00
carm4	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	18.00	151.52
carm4	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.6	18.05	370.37
carm4	2	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	3	35.40	434.78
carm4	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2	61.80	555.56
folcar1	2	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	4.4	7.82	72.46
folcar1	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	10.81	70.42
folcar1	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	17.00	98.04
folcar1	2	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.6	18.60	91.74
folcar1	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.6	20.40	108.70
folcar1	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.6	46.00	121.95
zoom3	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.8	17.20	119.05
zoom3	2	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.2	21.40	117.65
zoom3	2	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	28.40	222.22
b5m2	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	11.20	136.99
b5m2	2	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	12.20	156.25
b5m2	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.2	29.20	243.90
b5m2	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	35.20	217.39
b5m2	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	2.6	48.40	161.29
b5m3	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.2	7.22	263.16
b5m3	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	8.62	169.49
b5m3	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4	9.40	294.12
b5m3	2	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	3	35.00	208.33
toy1	2	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	14.20	96.15
toy1	2	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	15.00	107.53
toy1	2	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.4	16.60	97.09
toy1	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.2	18.80	105.26
toy1	2	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	33.20	200.00

5.3.2 Compression Ratio Table

Video Title	Survey	Test	Pattern	Qfactor	Overall Rating	Weighted Avg.	Compression Ratio
carm4	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2.4	52.61	555.56
carm4	1	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	2.6	47.20	434.78
carm4	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.6	23.00	400.00
carm4	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	22.40	370.37
carm4	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	20.60	151.52
folcar1	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.6	43.80	121.95
folcar1	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.6	27.80	108.70
folcar1	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	32.20	98.04
folcar1	1	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.4	25.00	91.74
folcar1	1	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	3.8	19.51	72.46
folcar1	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	19.60	70.42
zoom3	1	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	20.80	222.22
zoom3	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.8	14.80	119.05
zoom3	1	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	17.86	117.65
b5m2	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.4	21.60	243.90
b5m2	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	25.00	217.39
b5m2	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	3	32.00	161.29
b5m2	1	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.6	16.20	156.25
b5m2	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	12.60	136.99
b5m3	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3	29.67	294.12
b5m3	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	29.67	263.16
b5m3	1	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	2.67	34.00	208.33
b5m3	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.33	27.67	169.49
toy1	1	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	25.67	200.00
toy1	1	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4	17.33	107.53
toy1	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.67	17.00	105.26
toy1	1	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.33	19.08	97.09
toy1	1	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.33	19.00	96.15
carm4	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2	61.80	555.56
carm4	2	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	3	35.40	434.78
carm4	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.6	17.40	400.00
carm4	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.6	18.05	370.37
carm4	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	18.00	151.52
folcar1	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.6	46.00	121.95
folcar1	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.6	20.40	108.70
folcar1	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	17.00	98.04
folcar1	2	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.6	18.60	91.74
folcar1	2	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	4.4	7.82	72.46
folcar1	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	10.81	70.42
zoom3	2	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	28.40	222.22
zoom3	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.8	17.20	119.05
zoom3	2	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.2	21.40	117.65
b5m2	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.2	29.20	243.90
b5m2	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	35.20	217.39
b5m2	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	2.6	48.40	161.29
b5m2	2	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	12.20	156.25
b5m2	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	11.20	136.99
b5m3	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4	9.40	294.12
b5m3	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.2	7.22	263.16
b5m3	2	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	3	35.00	208.33
b5m3	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	8.62	169.49
toy1	2	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	33.20	200.00
toy1	2	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	15.00	107.53
toy1	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.2	18.80	105.26
toy1	2	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.4	16.60	97.09
toy1	2	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	14.20	96.15

5.3.3 Full Sort on Compression Ratio Table

Video Title	Survey	Test	Pattern	Qfactor	Overall	Weighted Avg.	Compression Ratio
carm4	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2.4	52.61	555.56
carm4	1	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	2.6	47.20	434.78
carm4	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.6	23.00	400.00
carm4	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	22.40	370.37
b5m3	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3	29.67	294.12
b5m3	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	29.67	263.16
b5m2	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.4	21.60	243.90
zoom3	1	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	20.80	222.22
b5m2	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	25.00	217.39
b5m3	1	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	2.67	34.00	208.33
toy1	1	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	25.67	200.00
b5m3	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.33	27.67	169.49
b5m2	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	3	32.00	161.29
b5m2	1	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.6	16.20	156.25
carm4	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	20.60	151.52
b5m2	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	12.60	136.99
folcar1	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.6	43.80	121.95
zoom3	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.8	14.80	119.05
zoom3	1	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	17.86	117.65
folcar1	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.6	27.80	108.70
toy1	1	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4	17.33	107.53
toy1	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.67	17.00	105.26
folcar1	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	32.20	98.04
toy1	1	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.33	19.08	97.09
toy1	1	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.33	19.00	96.15
folcar1	1	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.4	25.00	91.74
folcar1	1	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	3.8	19.51	72.46
folcar1	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	19.60	70.42
carm4	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2	61.80	555.56
carm4	2	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	3	35.40	434.78
carm4	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.6	17.40	400.00
carm4	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.6	18.05	370.37
b5m3	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4	9.40	294.12
b5m3	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.2	7.22	263.16
b5m2	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.2	29.20	243.90
zoom3	2	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	28.40	222.22
b5m2	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	35.20	217.39
b5m3	2	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	3	35.00	208.33
toy1	2	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	33.20	200.00
b5m3	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	8.62	169.49
b5m2	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	2.6	48.40	161.29
b5m2	2	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	12.20	156.25
carm4	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	18.00	151.52
b5m2	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	11.20	136.99
folcar1	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.6	46.00	121.95
zoom3	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.8	17.20	119.05
zoom3	2	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.2	21.40	117.65
folcar1	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.6	20.40	108.70
toy1	2	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	15.00	107.53
toy1	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.2	18.80	105.26
folcar1	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	17.00	98.04
toy1	2	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.4	16.60	97.09
toy1	2	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	14.20	96.15
folcar1	2	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.6	18.60	91.74
folcar1	2	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	4.4	7.82	72.46
folcar1	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	10.81	70.42

5.3.4 Modified Compression Ratio Table

Video Title	Survey	Test	Pattern	Qfactor	Overall R	Weighted Average	Modified Frame CR
carm4	1	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	2.6	47.20	2000.00
carm4	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	20.60	1428.57
carm4	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	22.40	588.24
carm4	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2.4	52.61	91.74
carm4	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.6	23.00	46.08
folcar1	1	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.4	25.00	270.27
folcar1	1	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	3.8	19.51	131.58
folcar1	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	19.60	120.48
folcar1	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.6	43.80	73.53
folcar1	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	32.20	42.55
folcar1	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.6	27.80	35.21
zoom3	1	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	17.86	400.00
zoom3	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.8	14.80	204.08
zoom3	1	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	20.80	142.86
b5m2	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	3	32.00	833.33
b5m2	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	12.60	357.14
b5m2	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	25.00	135.14
b5m2	1	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.6	16.20	52.91
b5m2	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.4	21.60	52.36
b5m3	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.33	27.67	357.14
b5m3	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	29.67	131.58
b5m3	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3	29.67	73.53
b5m3	1	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	2.67	34.00	72.46
toy1	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.67	17.00	625.00
toy1	1	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.33	19.00	384.62
toy1	1	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.33	19.08	208.33
toy1	1	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	25.67	149.25
toy1	1	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4	17.33	32.68
carm4	2	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	3	35.40	2000.00
carm4	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	18.00	1428.57
carm4	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.6	18.05	588.24
carm4	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2	61.80	91.74
carm4	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.6	17.40	46.08
folcar1	2	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.6	18.60	270.27
folcar1	2	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	4.4	7.82	131.58
folcar1	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	10.81	120.48
folcar1	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.6	46.00	73.53
folcar1	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	17.00	42.55
folcar1	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.6	20.40	35.21
zoom3	2	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.2	21.40	400.00
zoom3	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.8	17.20	204.08
zoom3	2	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	28.40	142.86
b5m2	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	2.6	48.40	833.33
b5m2	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	11.20	357.14
b5m2	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	35.20	135.14
b5m2	2	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	12.20	52.91
b5m2	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.2	29.20	52.36
b5m3	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	8.62	357.14
b5m3	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.2	7.22	131.58
b5m3	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4	9.40	73.53
b5m3	2	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	3	35.00	72.46
toy1	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.2	18.80	625.00
toy1	2	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	14.20	384.62
toy1	2	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.4	16.60	208.33
toy1	2	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	33.20	149.25
toy1	2	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	15.00	32.68

5.3.5 Survey Category Full Sort Tables

5.3.5.1 Blocking Artifacts

Video Title	Survey	Test	Pattern	Qfactor	Block	Weighted Avg.	Compression Ratio
folcar1	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.6	43.80	121.95
carm4	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2.75	52.61	555.56
folcar1	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	32.20	98.04
b5m2	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	3	32.00	161.29
b5m3	1	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	3.33	34.00	208.33
b5m2	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.4	21.60	243.90
b5m2	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	25.00	217.39
folcar1	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.4	27.80	108.70
folcar1	1	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.4	25.00	91.74
folcar1	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	19.60	70.42
carm4	1	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	3.6	47.20	434.78
b5m2	1	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.6	16.20	156.25
b5m3	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.67	27.67	169.49
b5m3	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.67	29.67	294.12
b5m3	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.67	29.67	263.16
folcar1	1	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	3.8	19.51	72.46
toy1	1	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4	17.33	107.53
zoom3	1	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4	20.80	222.22
toy1	1	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4	25.67	200.00
b5m2	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	12.60	136.99
zoom3	1	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	17.86	117.65
carm4	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4.2	23.00	400.00
toy1	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	4.33	17.00	105.26
carm4	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.4	22.40	370.37
zoom3	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4.4	14.80	119.05
carm4	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.6	20.60	151.52
toy1	1	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.67	19.00	96.15
toy1	1	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4.67	19.08	97.09
carm4	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	1.6	61.80	555.56
b5m3	2	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	2.2	35.00	208.33
b5m2	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	2.2	48.40	161.29
carm4	2	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	2.4	35.40	434.78
folcar1	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.4	46.00	121.95
b5m2	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.6	35.20	217.39
b5m2	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	2.8	29.20	243.90
carm4	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	18.05	370.37
toy1	2	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	33.20	200.00
folcar1	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.2	20.40	108.70
folcar1	2	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.2	18.60	91.74
zoom3	2	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	28.40	222.22
carm4	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.4	18.00	151.52
folcar1	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	17.00	98.04
zoom3	2	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.4	21.40	117.65
carm4	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.4	17.40	400.00
zoom3	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.6	17.20	119.05
toy1	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.6	18.80	105.26
toy1	2	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.6	16.60	97.09
toy1	2	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	15.00	107.53
toy1	2	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	14.20	96.15
b5m2	2	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	12.20	156.25
b5m2	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	11.20	136.99
b5m3	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	8.62	169.49
b5m3	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4	9.40	294.12
b5m3	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4	7.22	263.16
folcar1	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	10.81	70.42
folcar1	2	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	4.2	7.82	72.46

5.3.5.2 Contouring

Video Title	Survey	Test	Pattern	Qfactor	Contouring	Weighted Avg.	Compression Ratio
carm4	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2.6	52.61	555.56
b5m2	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	2.67	32.00	161.29
b5m3	1	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	2.67	34.00	208.33
b5m3	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.67	29.67	263.16
folcar1	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.8	43.80	121.95
folcar1	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	32.20	98.04
folcar1	1	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	3	19.51	72.46
b5m3	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3	27.67	169.49
toy1	1	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.33	25.67	200.00
toy1	1	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.33	17.33	107.53
b5m3	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.33	29.67	294.12
b5m2	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.4	21.60	243.90
zoom3	1	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	20.80	222.22
folcar1	1	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.4	25.00	91.74
folcar1	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.4	27.80	108.70
zoom3	1	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	17.86	117.65
b5m2	1	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.6	16.20	156.25
toy1	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.67	17.00	105.26
toy1	1	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.67	19.00	96.15
b5m2	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	12.60	136.99
carm4	1	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	3.8	47.20	434.78
b5m2	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	25.00	217.39
carm4	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	20.60	151.52
folcar1	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	19.60	70.42
zoom3	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4	14.80	119.05
carm4	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4	23.00	400.00
carm4	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.2	22.40	370.37
toy1	1	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4.5	19.08	97.09
carm4	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2.4	61.80	555.56
b5m2	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	35.20	217.39
folcar1	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.8	46.00	121.95
b5m3	2	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	3	35.00	208.33
b5m2	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	3	48.40	161.29
b5m2	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.2	29.20	243.90
zoom3	2	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	28.40	222.22
toy1	2	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.6	33.20	200.00
zoom3	2	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	21.40	117.65
toy1	2	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	15.00	107.53
zoom3	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.8	17.20	119.05
carm4	2	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	3.8	35.40	434.78
b5m2	2	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4	12.20	156.25
toy1	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	4	18.80	105.26
carm4	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	18.00	151.52
carm4	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4	18.05	370.37
toy1	2	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4	16.60	97.09
b5m2	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	11.20	136.99
toy1	2	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	14.20	96.15
folcar1	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.2	17.00	98.04
folcar1	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	4.2	20.40	108.70
b5m3	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4.2	9.40	294.12
b5m3	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.4	8.62	169.49
carm4	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4.4	17.40	400.00
folcar1	2	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	4.4	18.60	91.74
folcar1	2	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	4.6	7.82	72.46
b5m3	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.6	7.22	263.16
folcar1	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.75	10.81	70.42

5.3.5.3 Sharpness of Edges

Video Title	Survey	Test	Pattern	Qfactor	Sharpness	Weighted Avg.	Compression Ratio
carm4	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2.2	52.61	555.56
b5m3	1	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	2.33	34.00	208.33
carm4	1	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	2.6	47.20	434.78
toy1	1	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3	17.33	107.53
folcar1	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	3	43.80	121.95
b5m2	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	3	32.00	161.29
b5m3	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	29.67	263.16
b5m3	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3	27.67	169.49
folcar1	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.2	27.80	108.70
folcar1	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	32.20	98.04
folcar1	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.2	19.60	70.42
b5m2	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.2	21.60	243.90
b5m3	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.33	29.67	294.12
toy1	1	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.33	25.67	200.00
toy1	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.33	17.00	105.26
b5m2	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	25.00	217.39
carm4	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.4	20.60	151.52
zoom3	1	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.5	17.86	117.65
b5m2	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	12.60	136.99
zoom3	1	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.6	20.80	222.22
carm4	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.6	22.40	370.37
folcar1	1	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.6	25.00	91.74
b5m2	1	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.6	16.20	156.25
toy1	1	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.67	19.08	97.09
toy1	1	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.67	19.00	96.15
folcar1	1	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	3.8	19.51	72.46
carm4	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.8	23.00	400.00
zoom3	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4	14.80	119.05
carm4	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	1.8	61.80	555.56
toy1	2	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.4	33.20	200.00
b5m2	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	2.8	48.40	161.29
folcar1	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.8	46.00	121.95
b5m3	2	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	3	35.00	208.33
toy1	2	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.2	14.20	96.15
toy1	2	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.2	16.60	97.09
b5m2	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	35.20	217.39
zoom3	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.4	17.20	119.05
toy1	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.4	18.80	105.26
zoom3	2	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	21.40	117.65
b5m2	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.6	29.20	243.90
folcar1	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.6	20.40	108.70
zoom3	2	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.6	28.40	222.22
toy1	2	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	15.00	107.53
carm4	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.8	17.40	400.00
folcar1	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	10.81	70.42
b5m2	2	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	12.20	156.25
b5m3	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	8.62	169.49
b5m2	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	11.20	136.99
carm4	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4	18.05	370.37
carm4	2	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	4	35.40	434.78
carm4	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	18.00	151.52
folcar1	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4	17.00	98.04
folcar1	2	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	4	18.60	91.74
b5m3	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.2	7.22	263.16
folcar1	2	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	4.2	7.82	72.46
b5m3	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4.4	9.40	294.12

5.3.5.4 Fine Detail

Video Title	Survey	Test	Pattern	Qfactor	Fine D	Weighted Avg.	Compression Ratio
carm4	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2.2	52.61	555.56
carm4	1	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	2.2	47.20	434.78
b5m3	1	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	2.67	34.00	208.33
b5m2	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	3	32.00	161.29
carm4	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3	23.00	400.00
b5m3	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3	27.67	169.49
b5m3	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3	29.67	294.12
folcar1	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	3	43.80	121.95
carm4	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3	20.60	151.52
carm4	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	22.40	370.37
zoom3	1	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	20.80	222.22
folcar1	1	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.2	25.00	91.74
toy1	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.33	17.00	105.26
toy1	1	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.33	19.08	97.09
toy1	1	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.33	25.67	200.00
b5m3	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.33	29.67	263.16
folcar1	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.4	27.80	108.70
folcar1	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	32.20	98.04
folcar1	1	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	3.4	19.51	72.46
folcar1	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.4	19.60	70.42
zoom3	1	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.4	17.86	117.65
zoom3	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.6	14.80	119.05
b5m2	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.6	21.60	243.90
b5m2	1	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.6	16.20	156.25
b5m2	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.6	25.00	217.39
toy1	1	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.67	17.33	107.53
toy1	1	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.67	19.00	96.15
b5m2	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	12.60	136.99
carm4	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	1.8	61.80	555.56
b5m2	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	2.6	48.40	161.29
folcar1	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.6	46.00	121.95
b5m2	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.2	29.20	243.90
b5m2	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	35.20	217.39
zoom3	2	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	28.40	222.22
toy1	2	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	33.20	200.00
folcar1	2	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.2	18.60	91.74
zoom3	2	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.4	21.40	117.65
toy1	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.4	18.80	105.26
toy1	2	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.4	16.60	97.09
b5m3	2	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	3.4	35.00	208.33
folcar1	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.4	20.40	108.70
toy1	2	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	14.20	96.15
folcar1	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.6	17.00	98.04
zoom3	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.6	17.20	119.05
carm4	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	18.00	151.52
toy1	2	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.6	15.00	107.53
b5m2	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	11.20	136.99
folcar1	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	10.81	70.42
b5m2	2	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	12.20	156.25
b5m3	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4	9.40	294.12
carm4	2	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	4	35.40	434.78
folcar1	2	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	4	7.82	72.46
carm4	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4	18.05	370.37
b5m3	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	8.62	169.49
carm4	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4	17.40	400.00
b5m3	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.2	7.22	263.16

5.3.5.5 Quality of Motion

Video Title	Survey	Test	Pattern	Qfactor	M Qual of	Weighted Avg.	Compression Ratio
carm4	1	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	1.8	47.20	434.78
carm4	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2	52.61	555.56
carm4	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	2.4	23.00	400.00
folcar1	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.4	43.80	121.95
carm4	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	22.40	370.37
folcar1	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	2.8	27.80	108.70
toy1	1	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3	19.00	96.15
folcar1	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	32.20	98.04
toy1	1	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3	19.08	97.09
b5m3	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3	29.67	294.12
folcar1	1	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.2	25.00	91.74
toy1	1	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.33	25.67	200.00
b5m3	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.33	29.67	263.16
folcar1	1	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	3.4	19.51	72.46
carm4	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.4	20.60	151.52
b5m2	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	25.00	217.39
zoom3	1	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	20.80	222.22
zoom3	1	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	17.86	117.65
b5m2	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	12.60	136.99
zoom3	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.6	14.80	119.05
folcar1	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	19.60	70.42
b5m2	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.6	21.60	243.90
b5m2	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	3.67	32.00	161.29
b5m3	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.67	27.67	169.49
toy1	1	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.67	17.33	107.53
b5m2	1	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4	16.20	156.25
b5m3	1	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	4	34.00	208.33
toy1	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	4.33	17.00	105.26
carm4	2	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	2	35.40	434.78
folcar1	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	3	46.00	121.95
toy1	2	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	33.20	200.00
b5m2	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	3.2	48.40	161.29
b5m2	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	35.20	217.39
b5m2	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.2	29.20	243.90
carm4	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.4	17.40	400.00
b5m3	2	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	3.4	35.00	208.33
carm4	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.5	18.05	370.37
zoom3	2	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.6	21.40	117.65
carm4	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	3.6	61.80	555.56
toy1	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.8	18.80	105.26
zoom3	2	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	28.40	222.22
zoom3	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.8	17.20	119.05
folcar1	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	4	20.40	108.70
carm4	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	18.00	151.52
b5m2	2	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4	12.20	156.25
toy1	2	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4	15.00	107.53
folcar1	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4	17.00	98.04
toy1	2	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4.2	16.60	97.09
toy1	2	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	14.20	96.15
b5m2	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	11.20	136.99
folcar1	2	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	4.4	18.60	91.74
folcar1	2	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	4.4	7.82	72.46
b5m3	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4.4	9.40	294.12
b5m3	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.6	7.22	263.16
b5m3	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.6	8.62	169.49
folcar1	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.6	10.81	70.42

5.3.5.6 Frame Flickering

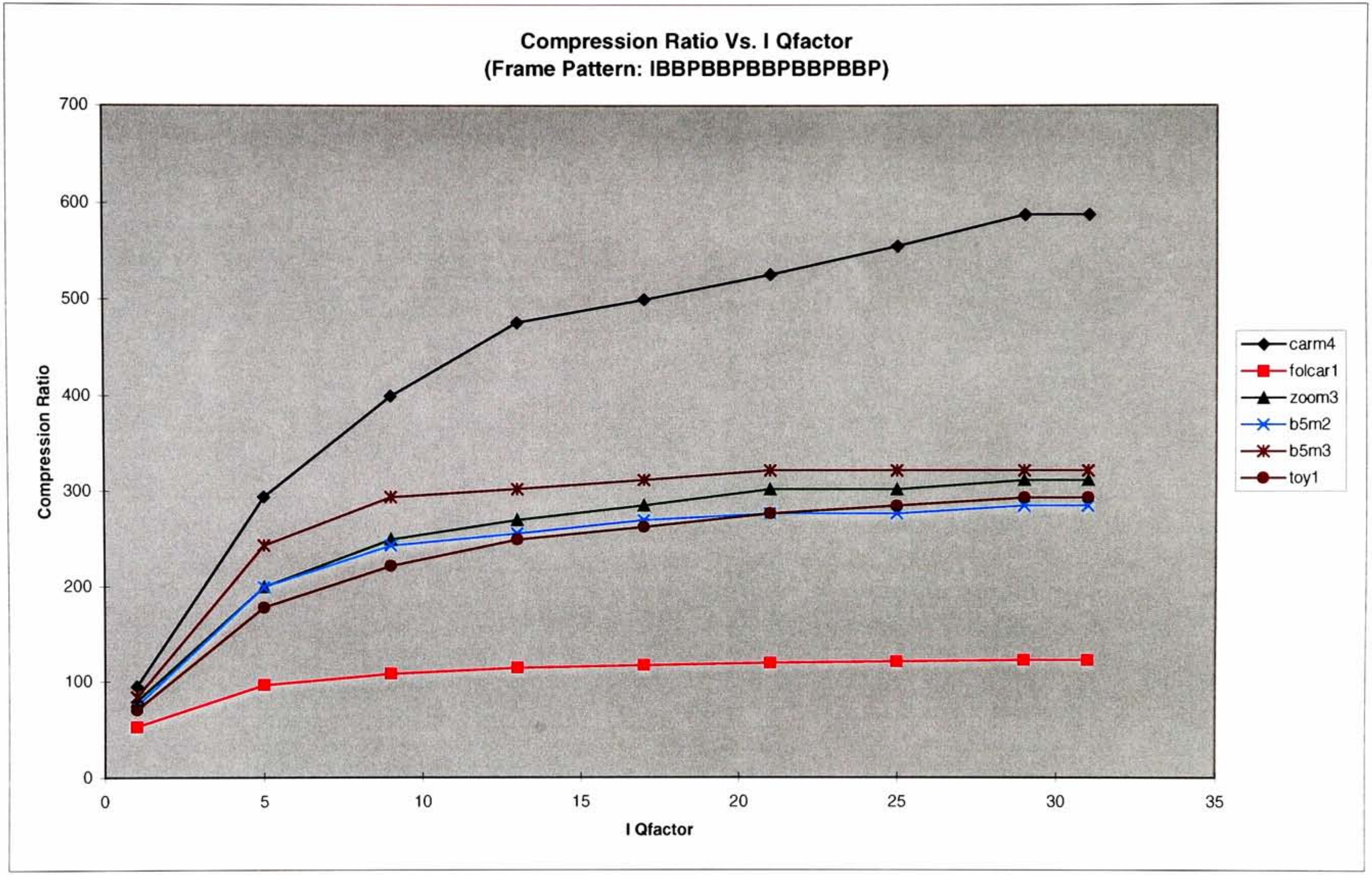
Video Title	Survey	Test	Pattern	Qfactor	Flicker	Weighted Avg.	Compression Ratio
carm4	1	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	2	47.20	434.78
toy1	1	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.33	25.67	200.00
carm4	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	2.6	52.61	555.56
b5m3	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.67	29.67	263.16
b5m2	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	2.67	32.00	161.29
folcar1	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.8	43.80	121.95
zoom3	1	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	20.80	222.22
b5m3	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3	27.67	169.49
b5m3	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3	29.67	294.12
b5m2	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	25.00	217.39
b5m2	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3	21.60	243.90
toy1	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3	17.00	105.26
folcar1	1	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3	25.00	91.74
folcar1	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3	27.80	108.70
folcar1	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	32.20	98.04
carm4	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.2	20.60	151.52
carm4	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.2	22.40	370.37
zoom3	1	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.25	17.86	117.65
toy1	1	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.33	19.08	97.09
zoom3	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.4	14.80	119.05
carm4	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.4	23.00	400.00
b5m2	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.4	12.60	136.99
folcar1	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.4	19.60	70.42
b5m2	1	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.6	16.20	156.25
toy1	1	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.67	19.00	96.15
b5m3	1	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	3.67	34.00	208.33
toy1	1	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.67	17.33	107.53
folcar1	1	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	3.8	19.51	72.46
folcar1	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	2.4	46.00	121.95
b5m2	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	2.5	48.40	161.29
b5m3	2	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	2.8	35.00	208.33
carm4	2	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	2.8	35.40	434.78
b5m2	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	2.8	35.20	217.39
folcar1	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3	20.40	108.70
toy1	2	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	33.20	200.00
zoom3	2	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3	28.40	222.22
carm4	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	3.2	61.80	555.56
b5m2	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.4	29.20	243.90
carm4	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.4	18.00	151.52
folcar1	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	17.00	98.04
folcar1	2	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.4	18.60	91.74
carm4	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.4	17.40	400.00
toy1	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	3.6	18.80	105.26
b5m2	2	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	12.20	156.25
carm4	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	18.05	370.37
folcar1	2	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	3.8	7.82	72.46
toy1	2	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	3.8	15.00	107.53
zoom3	2	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	21.40	117.65
b5m2	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	11.20	136.99
folcar1	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	10.81	70.42
toy1	2	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4	16.60	97.09
zoom3	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4	17.20	119.05
b5m3	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	8.62	169.49
toy1	2	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.2	14.20	96.15
b5m3	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4.4	9.40	294.12
b5m3	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.4	7.22	263.16

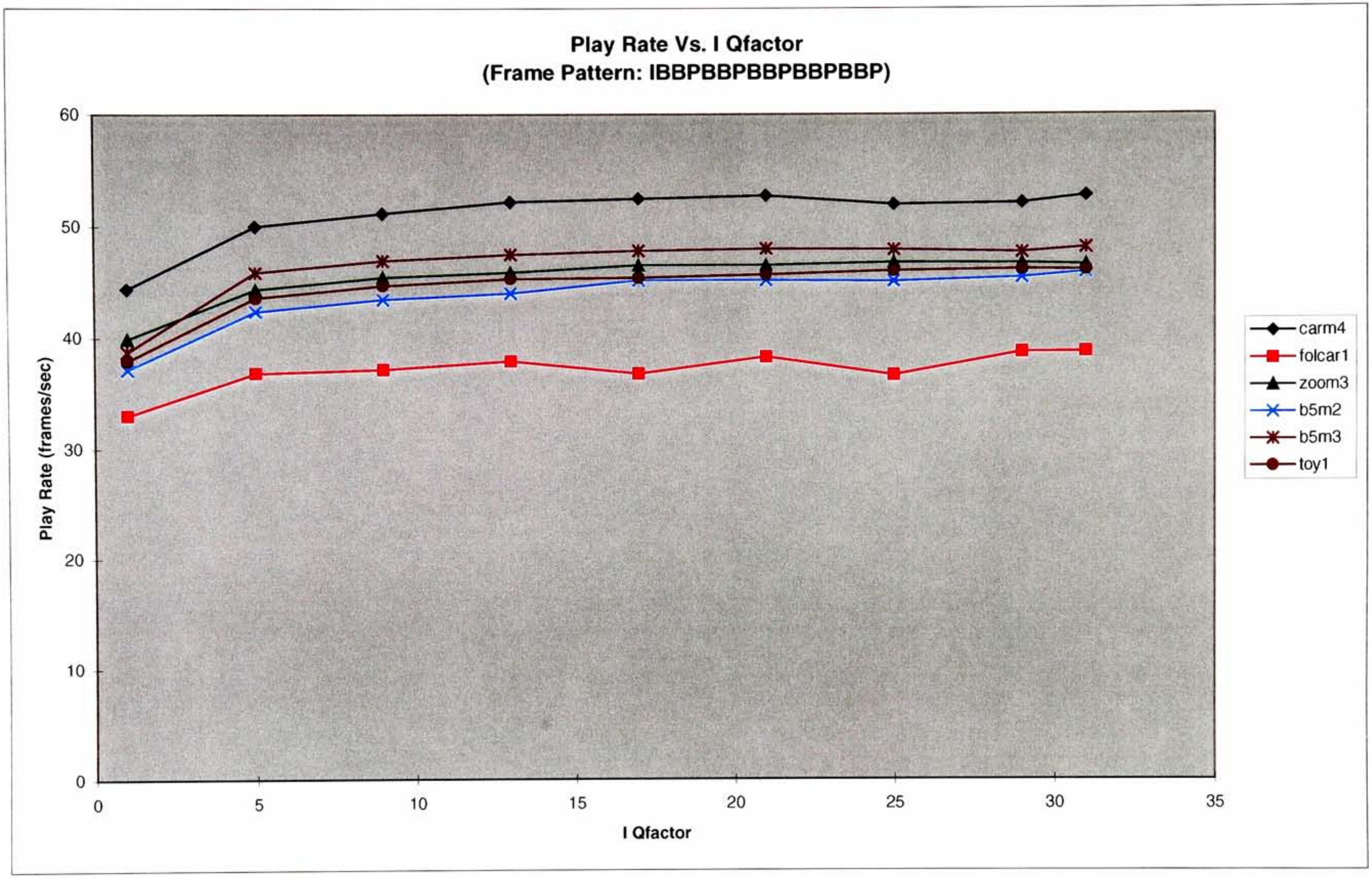
5.3.5.7 Color Shift

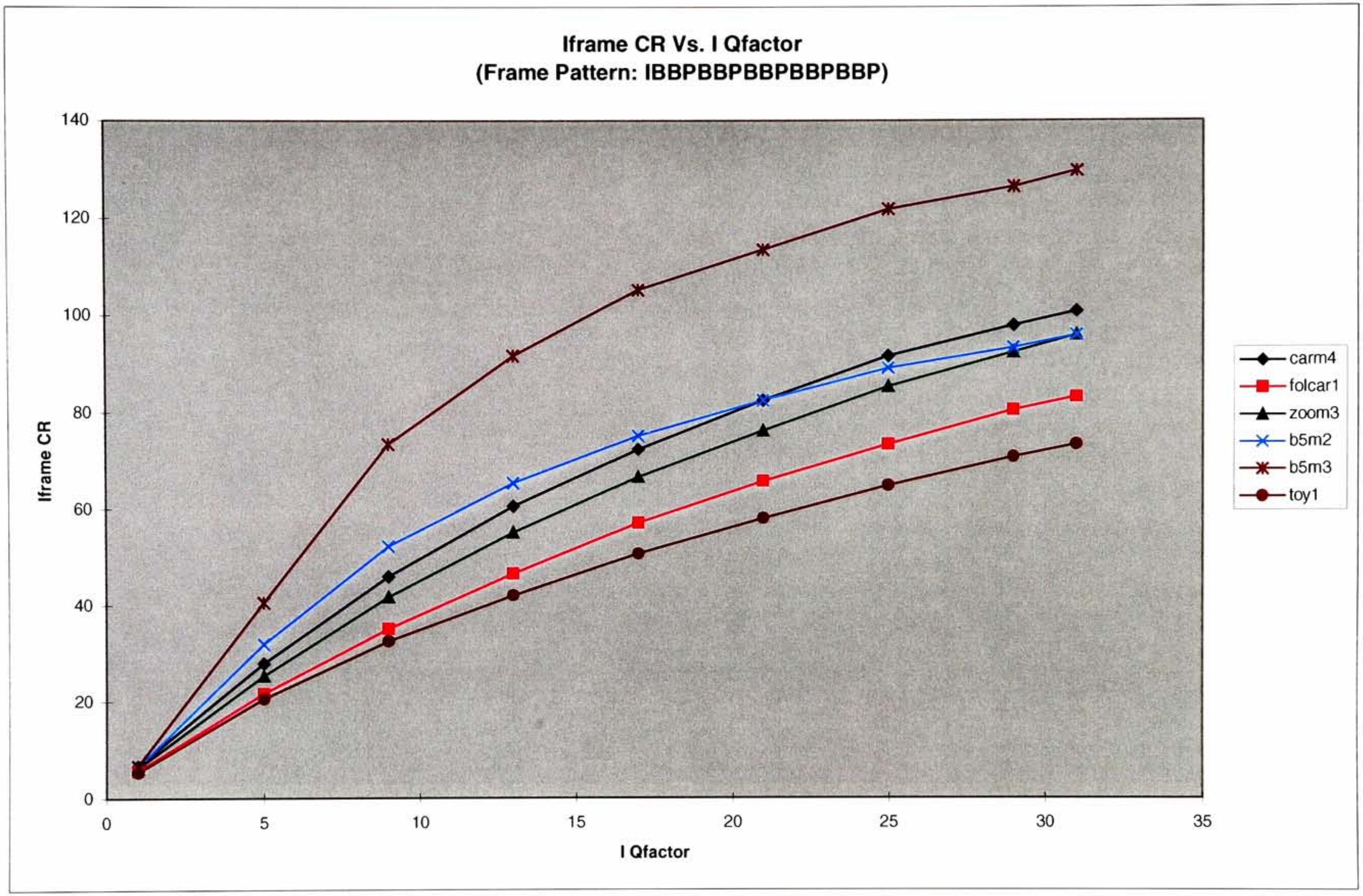
Video Title	Survey	Test	Pattern	Qfactor	C Shift	Weighted Avg.	Compression Ratio
b5m3	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.33	29.67	294.12
b5m3	1	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	3.33	34.00	208.33
folcar1	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	3.4	43.80	121.95
folcar1	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.4	32.20	98.04
toy1	1	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	3.67	19.08	97.09
b5m3	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.67	27.67	169.49
folcar1	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	3.8	27.80	108.70
folcar1	1	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	3.8	25.00	91.74
folcar1	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	19.60	70.42
b5m2	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4	25.00	217.39
b5m3	1	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4	29.67	263.16
toy1	1	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4	19.00	96.15
toy1	1	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4	17.33	107.53
toy1	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	4	17.00	105.26
carm4	1	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.2	22.40	370.37
carm4	1	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	4.2	47.20	434.78
b5m2	1	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4.2	16.20	156.25
folcar1	1	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	4.25	19.51	72.46
toy1	1	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.33	25.67	200.00
b5m2	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	4.33	32.00	161.29
b5m2	1	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4.4	21.60	243.90
carm4	1	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	4.4	52.61	555.56
carm4	1	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.4	20.60	151.52
zoom3	1	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.4	20.80	222.22
zoom3	1	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.6	17.86	117.65
carm4	1	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4.6	23.00	400.00
b5m2	1	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.6	12.60	136.99
zoom3	1	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4.8	14.80	119.05
carm4	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor = 25	3.4	61.80	555.56
b5m2	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 21	3.6	48.40	161.29
zoom3	2	2	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.6	28.40	222.22
b5m2	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	3.8	29.20	243.90
b5m2	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	3.8	35.20	217.39
carm4	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	3.8	18.00	151.52
carm4	2	5	0: IBBPBBPBBPBBPBBP	P Qfactor =25	3.8	35.40	434.78
b5m3	2	1	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4	9.40	294.12
b5m3	2	5	1: IBBBIBBBIBBBIBBB	I Qfactor = 9	4.2	35.00	208.33
carm4	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.2	18.05	370.37
folcar1	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor =9	4.2	20.40	108.70
folcar1	2	3	0: IBBPBBPBBPBBPBBP	I Qfactor =25	4.2	46.00	121.95
folcar1	2	4	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.2	17.00	98.04
b5m3	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.4	8.62	169.49
zoom3	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4.4	17.20	119.05
zoom3	2	4	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.4	21.40	117.65
folcar1	2	8	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.4	10.81	70.42
folcar1	2	7	1: IBBBIBBBIBBBIBBB	B Qfactor =21	4.4	18.60	91.74
toy1	2	1	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.4	33.20	200.00
toy1	2	7	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4.4	15.00	107.53
b5m2	2	2	3: IBPBIBPBIBPBIBPB	I Qfactor = 9	4.4	12.20	156.25
b5m2	2	7	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.4	11.20	136.99
b5m3	2	3	0: IBBPBBPBBPBBPBBP	P Qfactor = 9	4.6	7.22	263.16
toy1	2	3	2: IPPPIPPPIPPPIPPP	P Qfactor = 9	4.6	14.20	96.15
toy1	2	6	3: IBPBIBPBIBPBIBPB	P Qfactor = 21	4.6	18.80	105.26
carm4	2	2	0: IBBPBBPBBPBBPBBP	I Qfactor = 9	4.6	17.40	400.00
folcar1	2	6	1: IBBBIBBBIBBBIBBB	B Qfactor =9	4.6	7.82	72.46
toy1	2	5	3: IBPBIBPBIBPBIBPB	P Qfactor = 9	4.8	16.60	97.09

5.4 Appendix D: Numerical Results

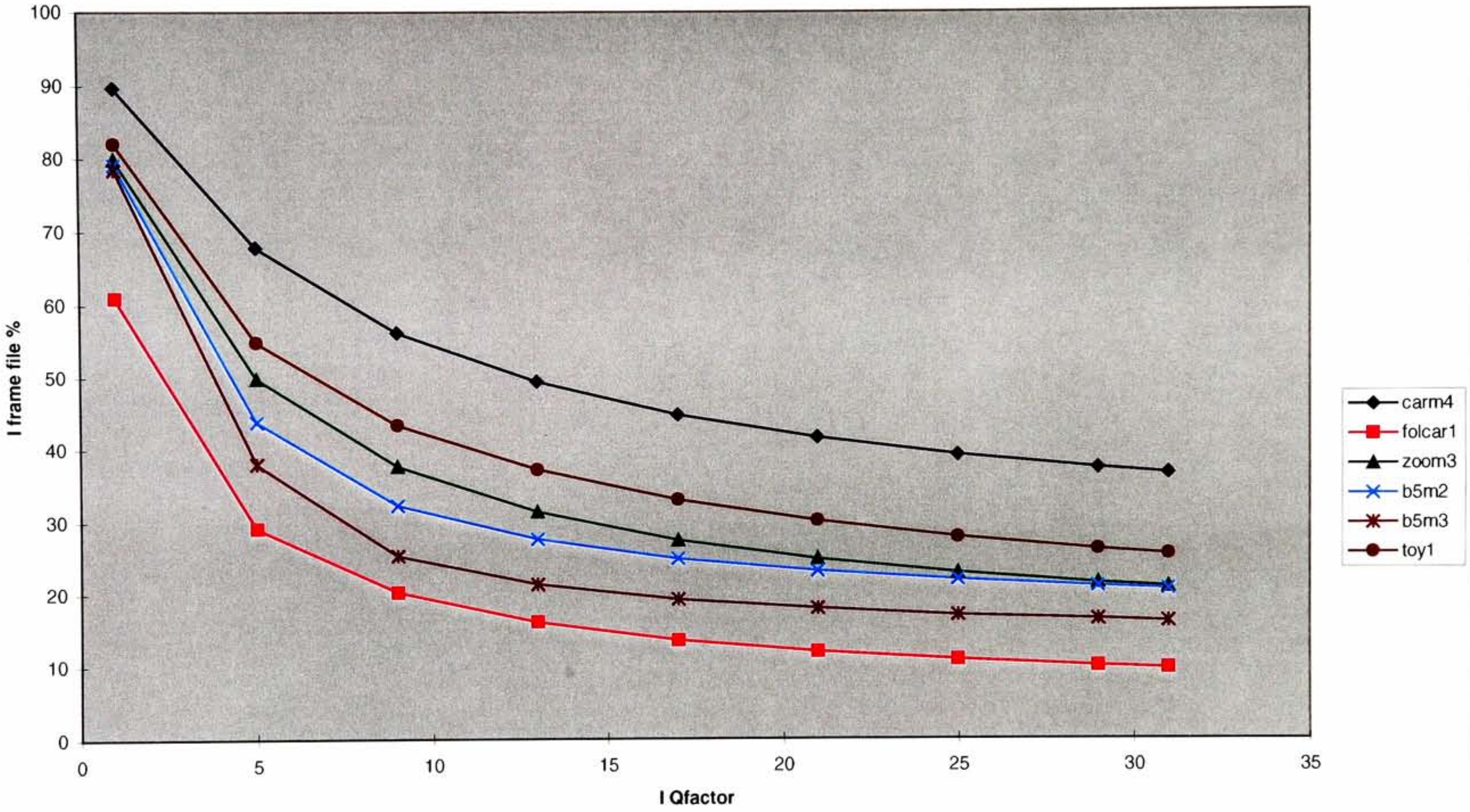
5.4.1 2-D Graph

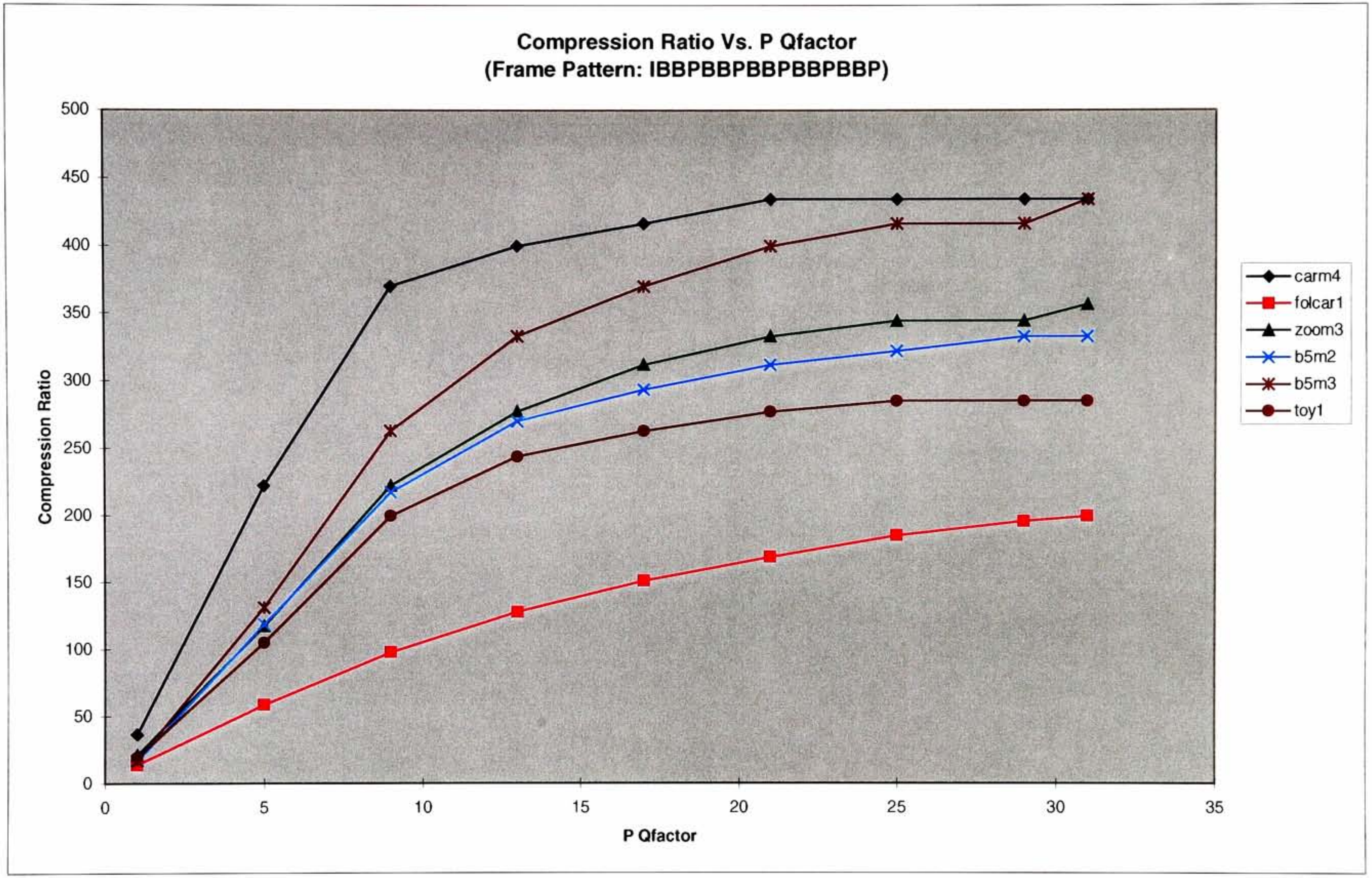

Compression Ratio Vs. I Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)
Compression Ratio
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
35
I Qfactor
carm4
folcar1
zoom3
b5m2
b5m3
toy1


Play Rate Vs. I Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)
Play Rate (frames/sec)
0
10
20
30
40
50
60
I Qfactor
0
5
10
15
20
25
30
35
carm4
folcar1
zoom3
b5m2
b5m3
toy1

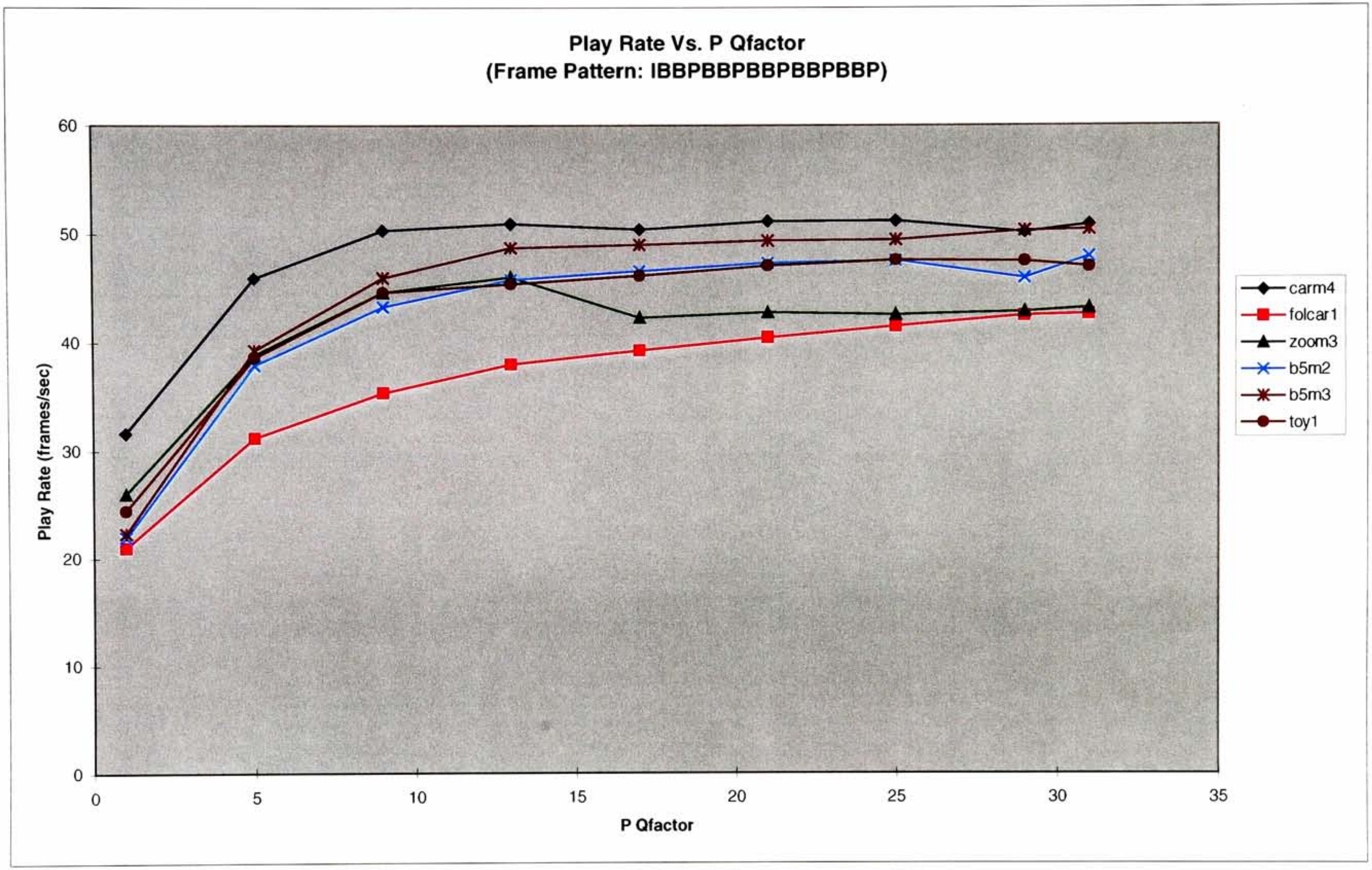

Iframe CR Vs. I Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)
Iframe CR
140
120
100
80
60
40
20
0
0
5
10
15
20
25
30
35
I Qfactor
carm4
folcar1
zoom3
b5m2
b5m3
toy1

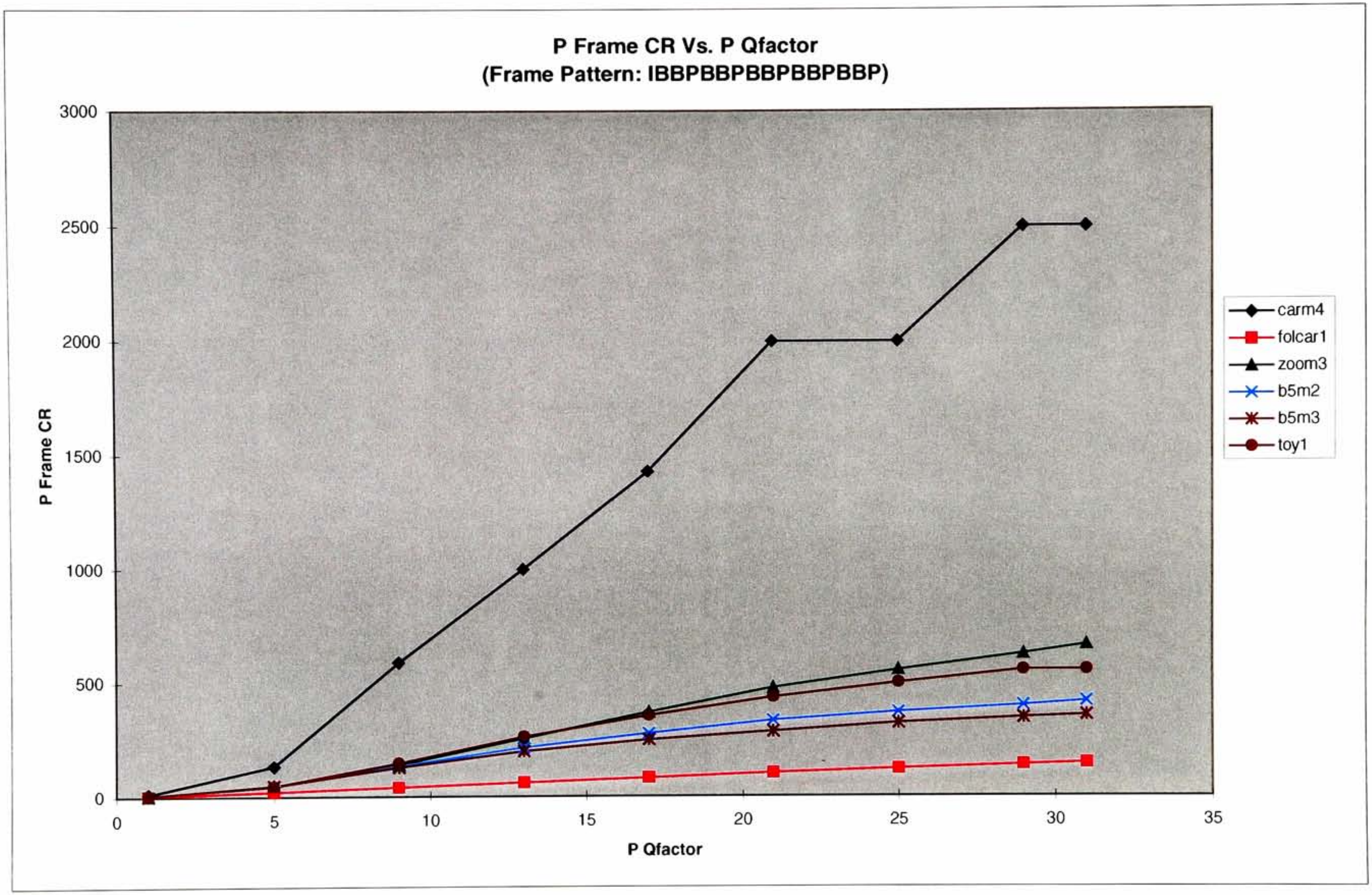
I frame file % Vs. I Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)



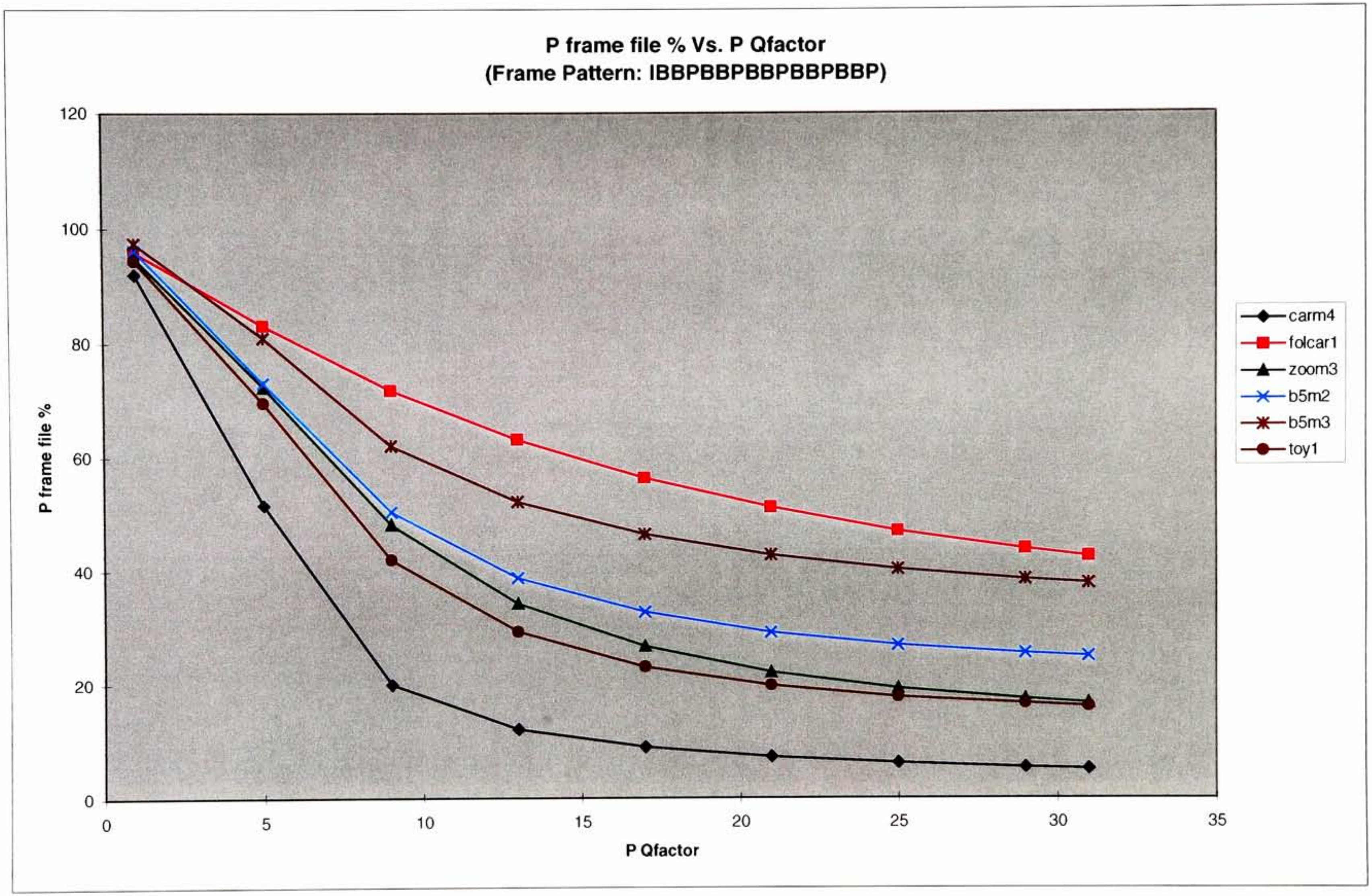


Compression Ratio Vs. P Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)

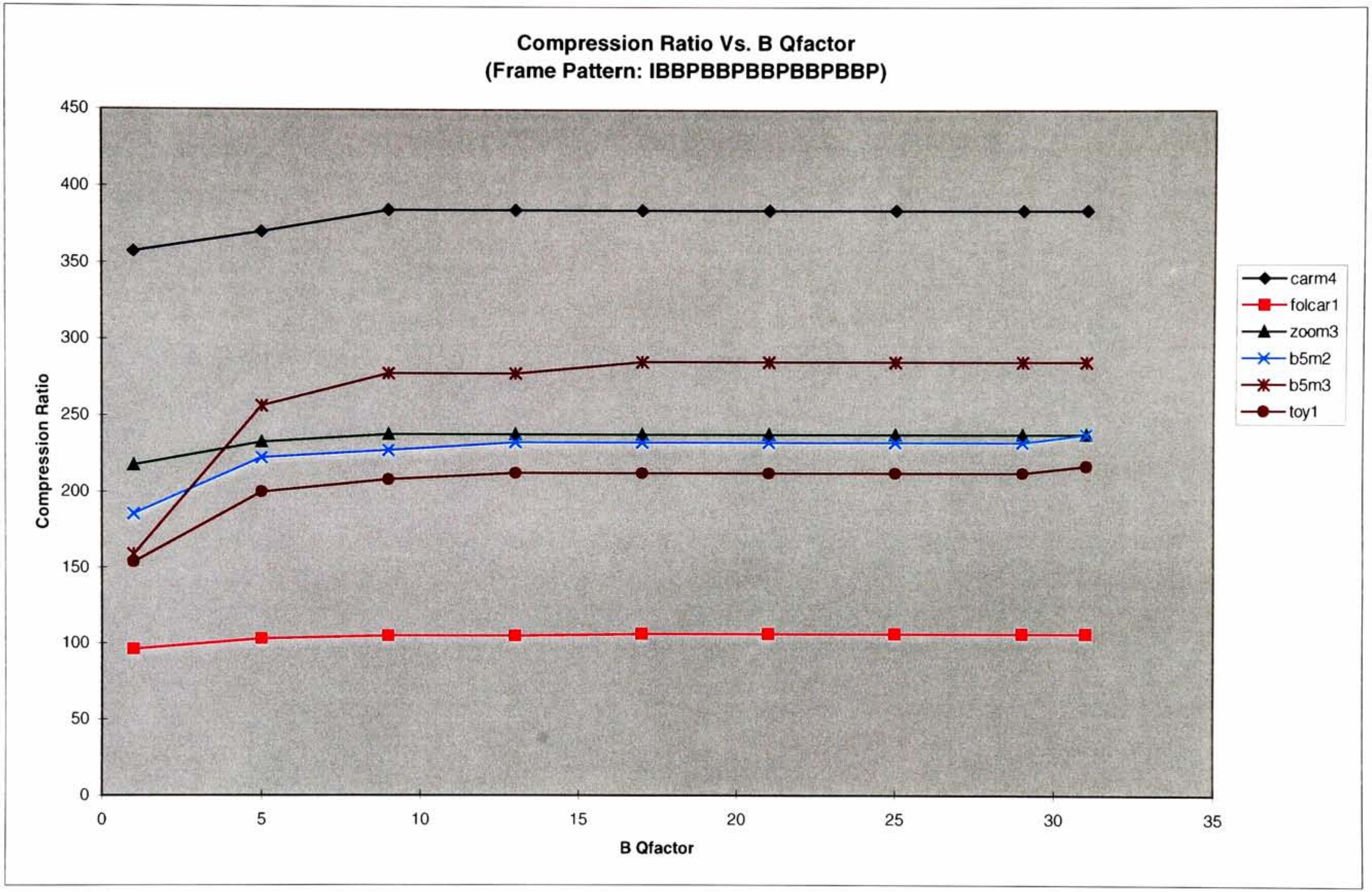

Play Rate Vs. P Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)



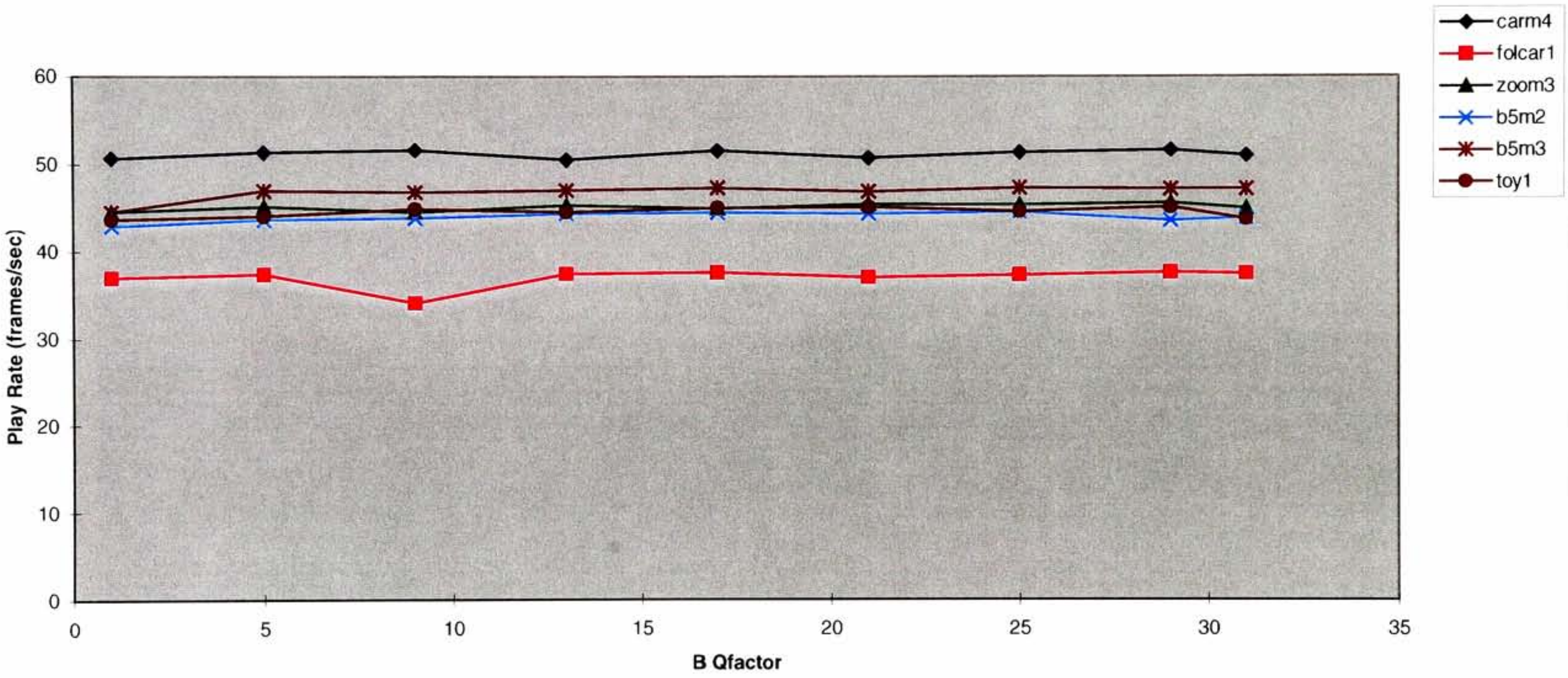
P Frame CR Vs. P Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)

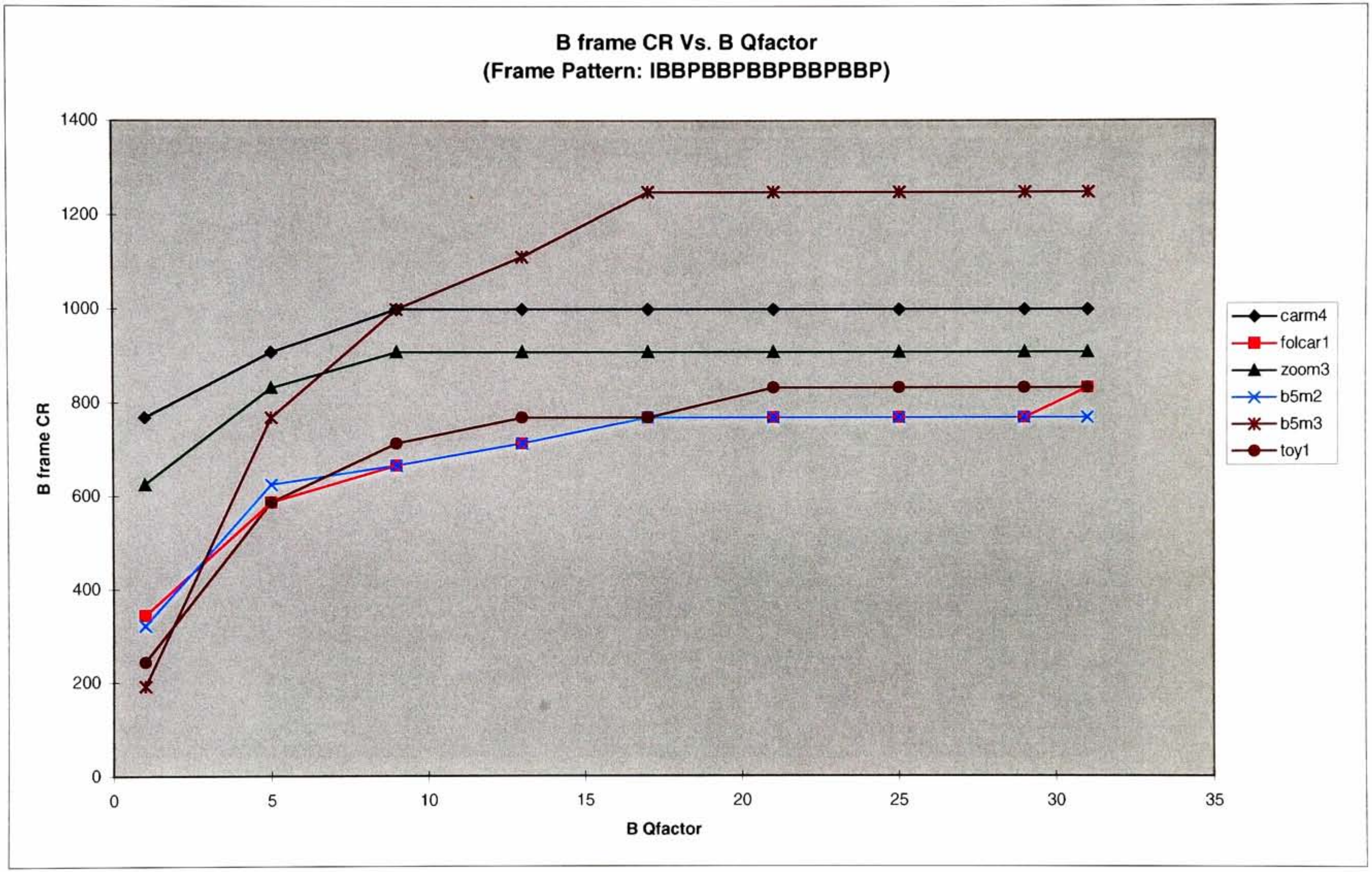


P frame file % Vs. P Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)

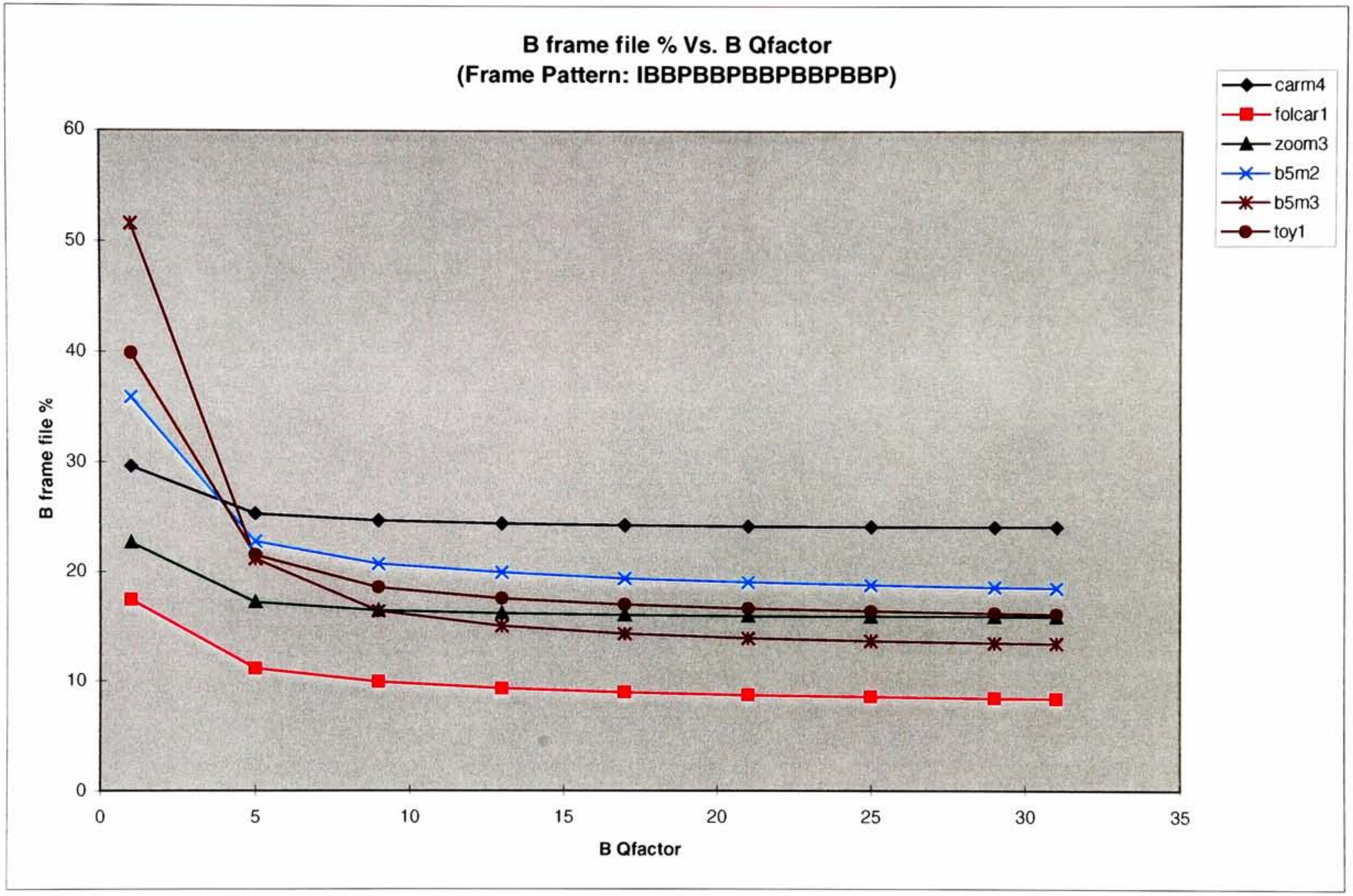

Compression Ratio Vs. B Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)
Compression Ratio
450
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
B Qfactor
carm4
folcar1
zoom3
b5m2
b5m3
toy1

Play Rate Vs. B Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)

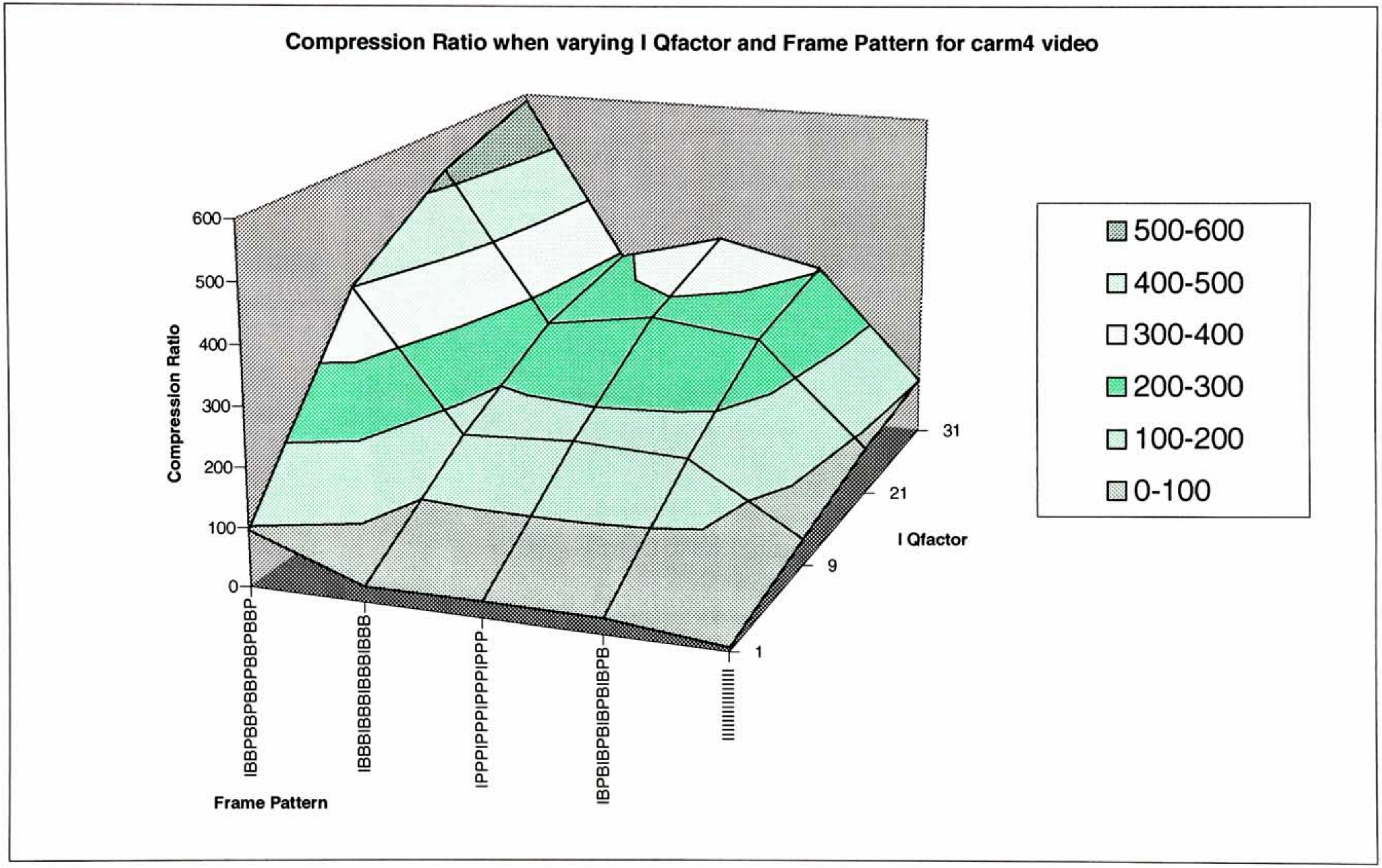




B frame CR Vs. B Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)

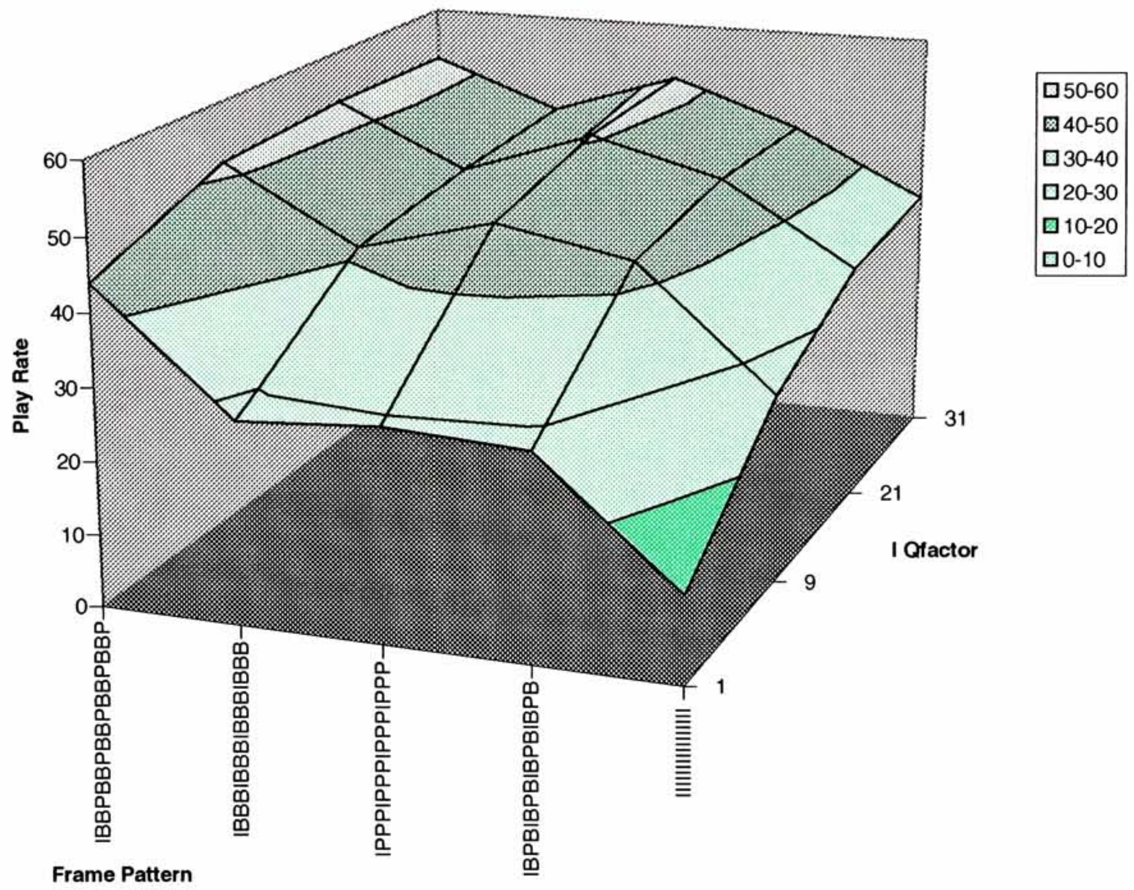

B frame file % Vs. B Qfactor
(Frame Pattern: IBBPBBPBBPBBPBBP)
B frame file %
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
B Qfactor
carm4
folcar1
zoom3
b5m2
b5m3
toy1

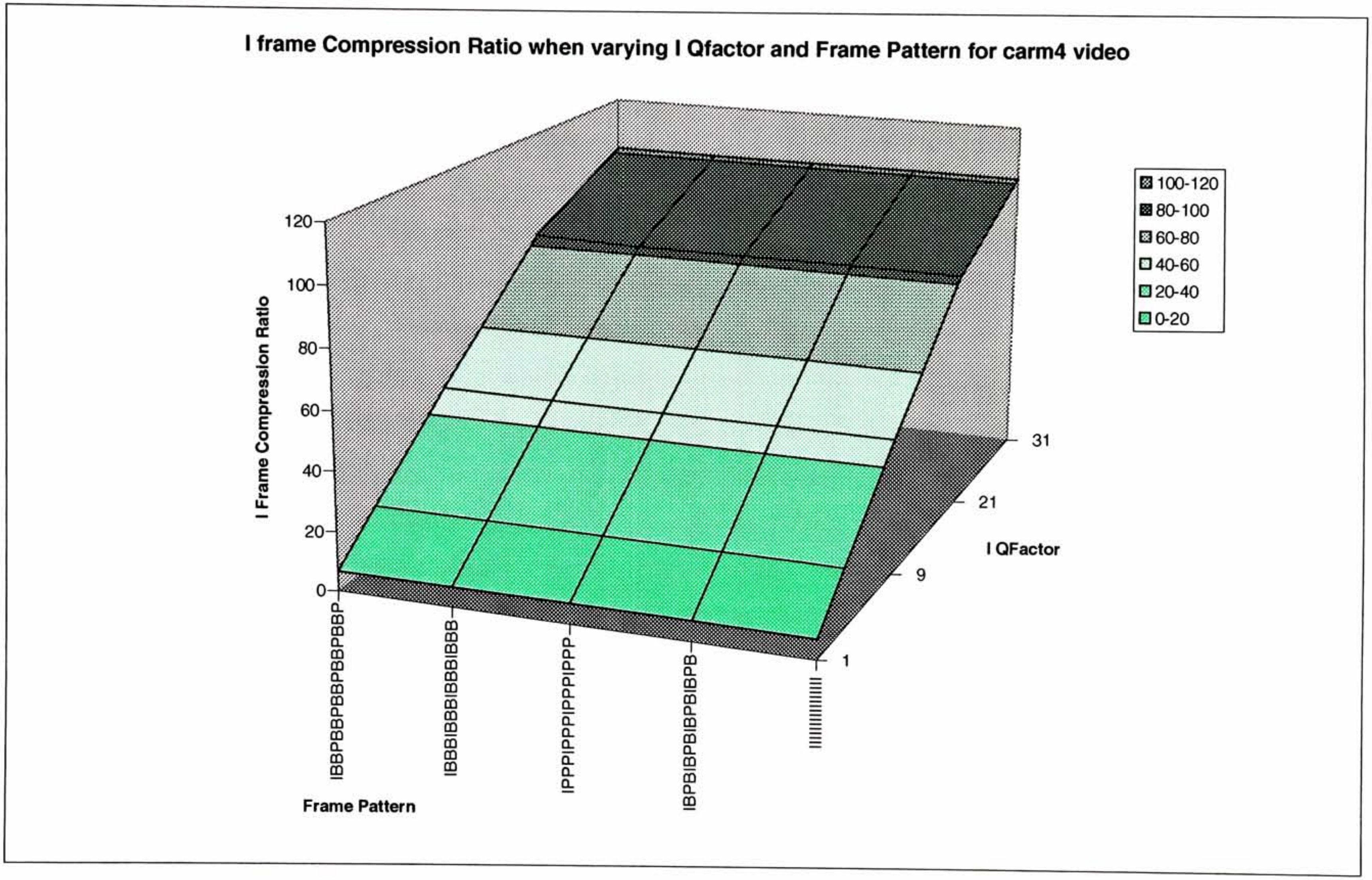
5.4.2 3-D Graphs



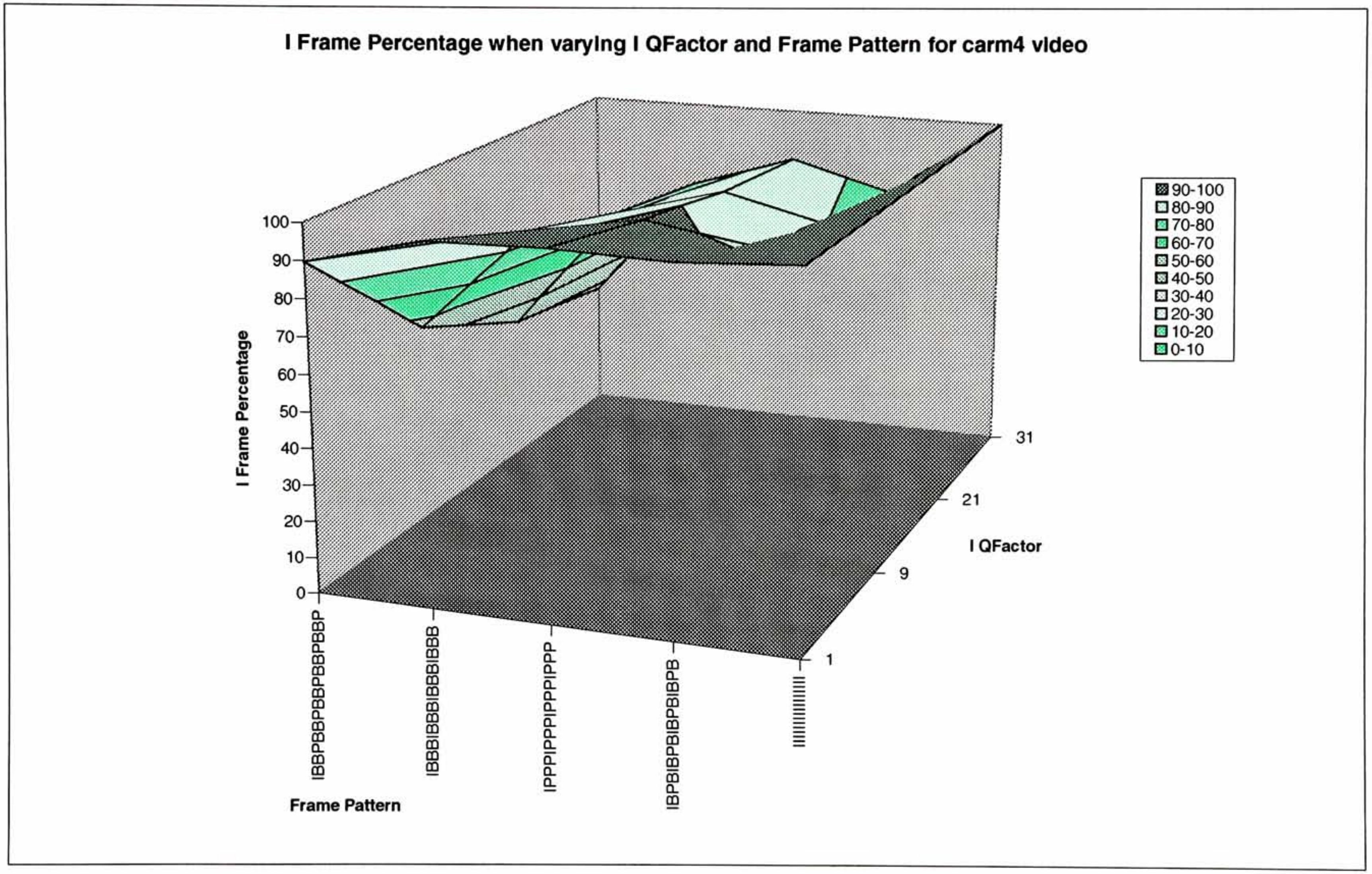
Compression Ratio when varying I Qfactor and Frame Pattern for carm4 video

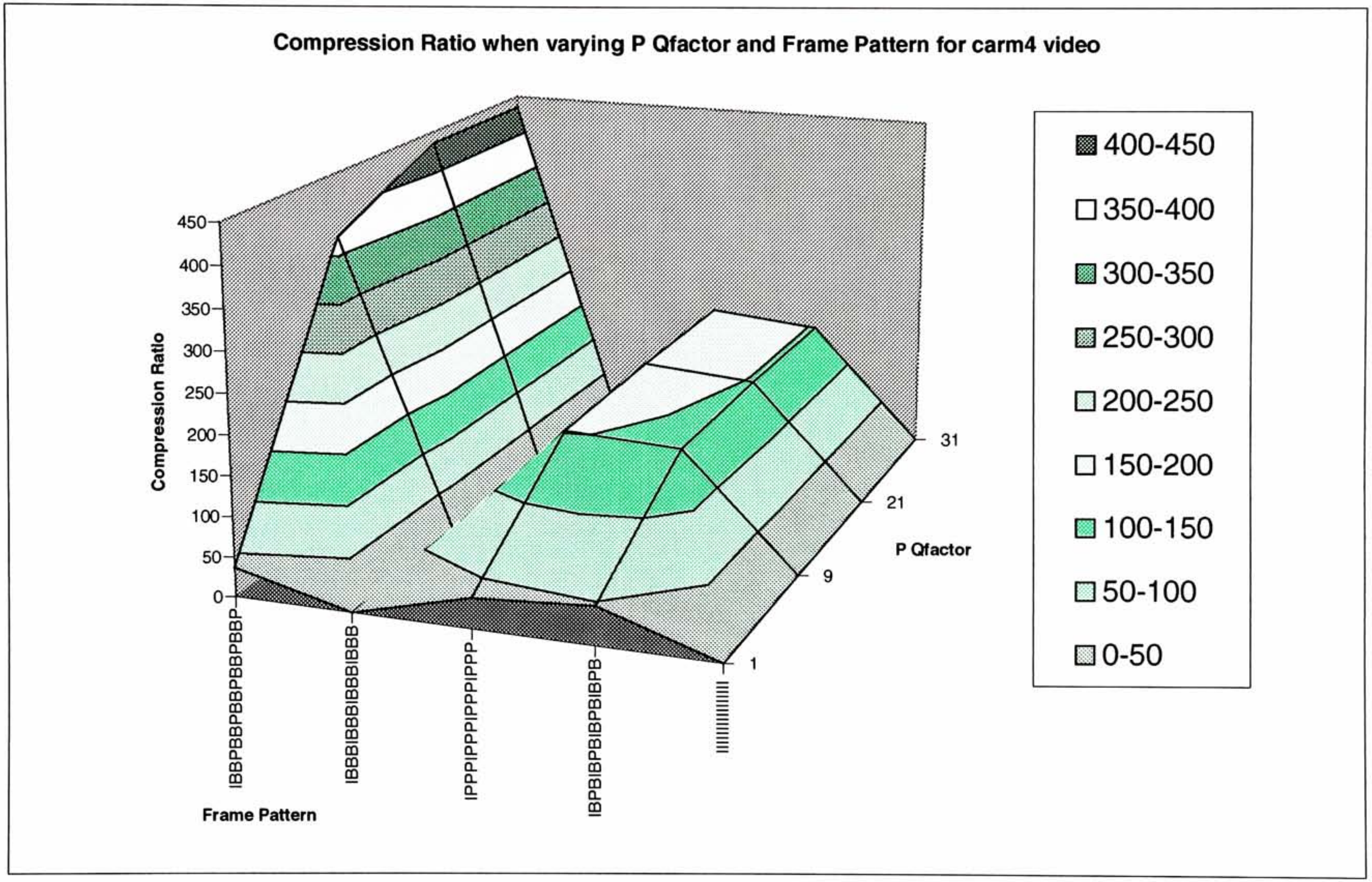
Play Rate when varying I Qfactor and Frame Pattern for carm4 video





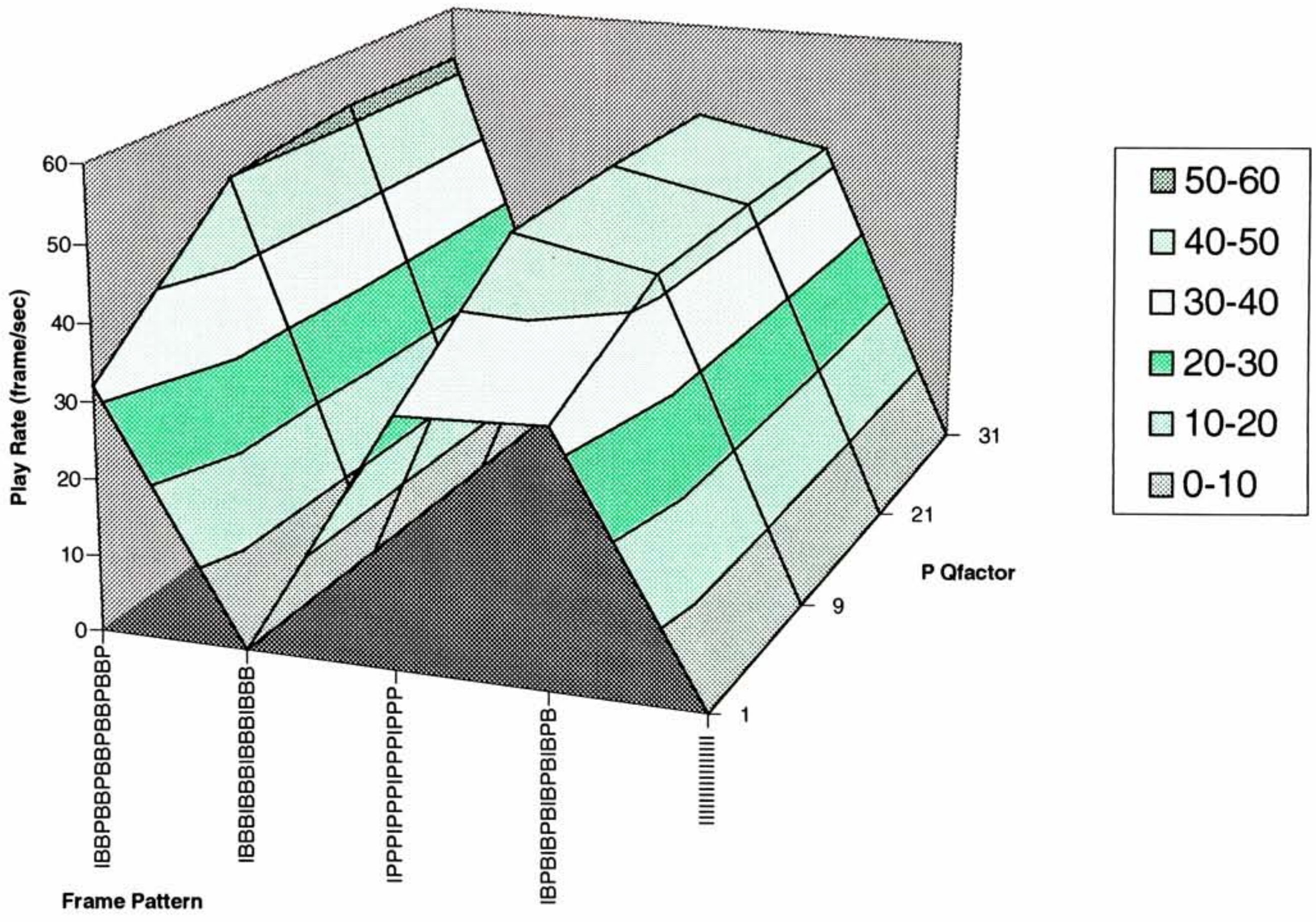
I frame Compression Ratio when varying I Qfactor and Frame Pattern for carm4 video


I Frame Percentage when varying I QFactor and Frame Pattern for carm4 video

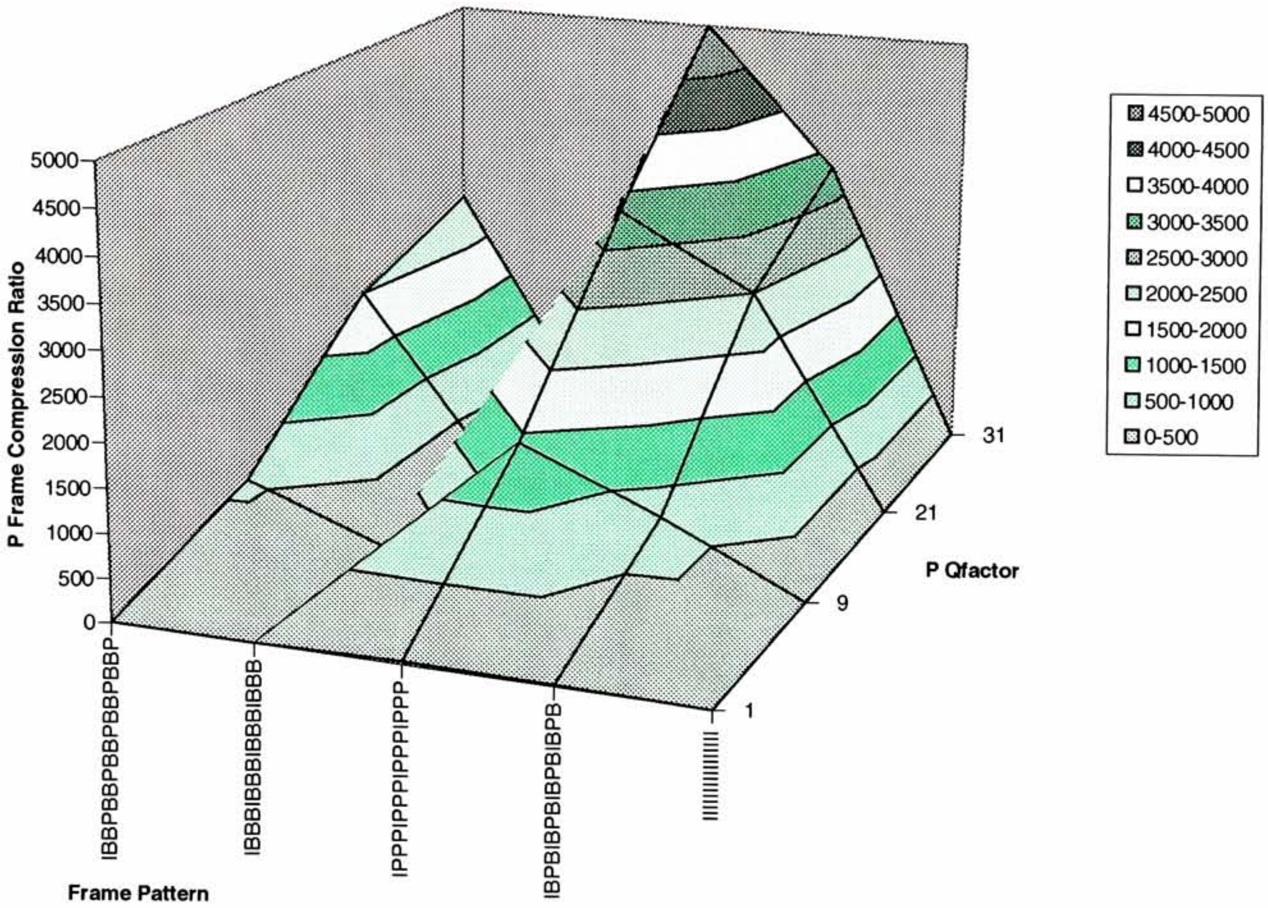


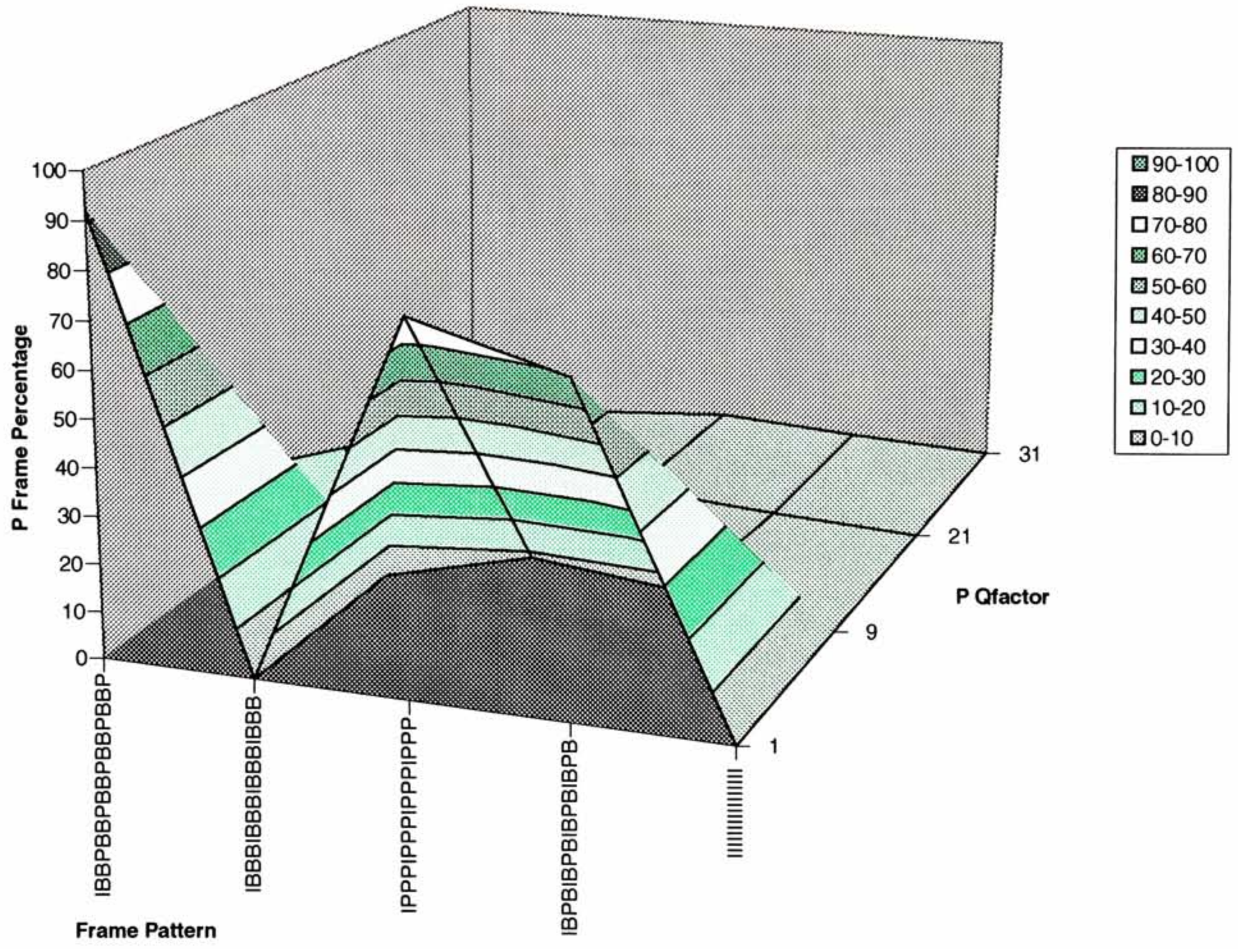
Compression Ratio when varying P Qfactor and Frame Pattern for carm4 video

Play Rate when varying P Qfactor and Frame Pattern for carm4 video



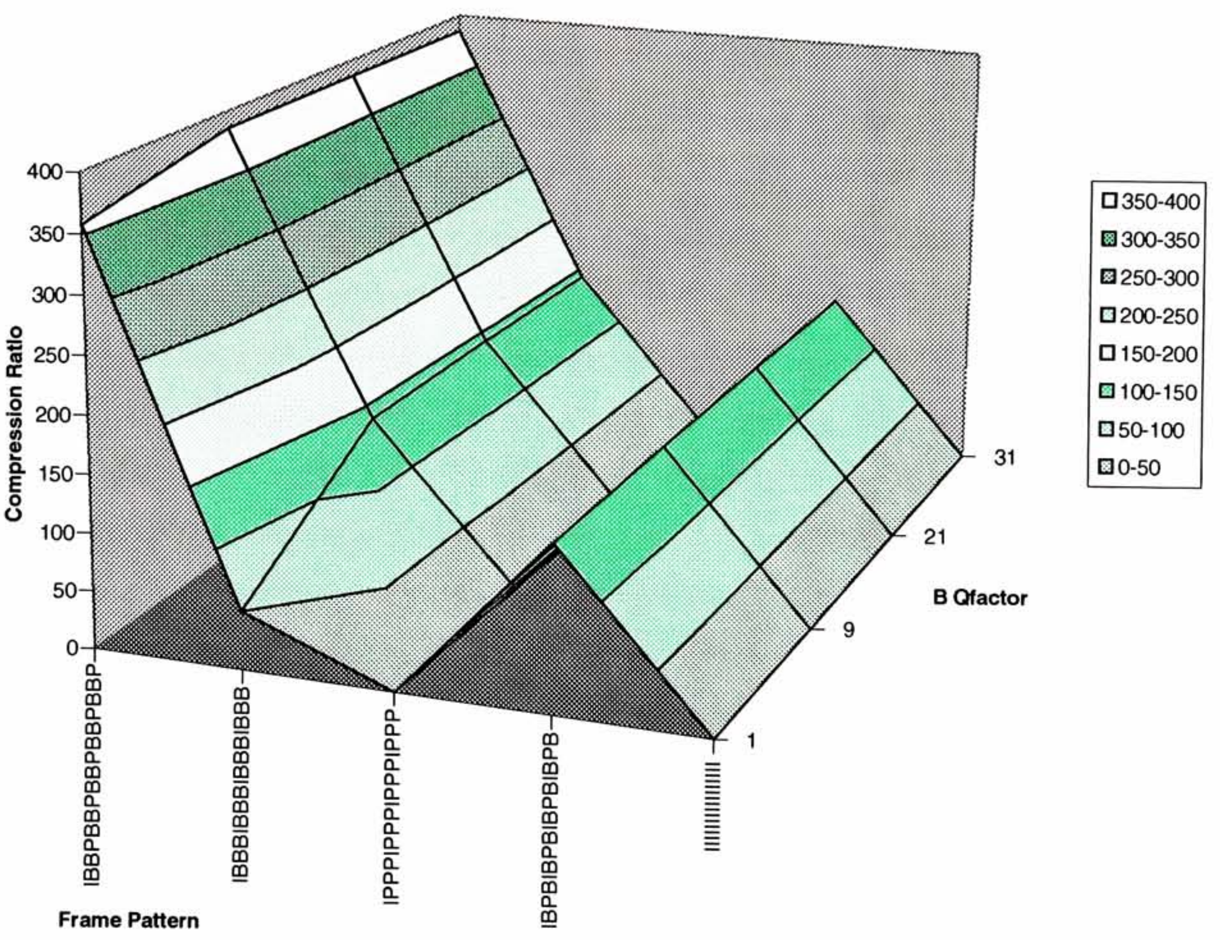
P Frame Compression Ratio when varying P Qfactor and Frame Pattern for carm4 video

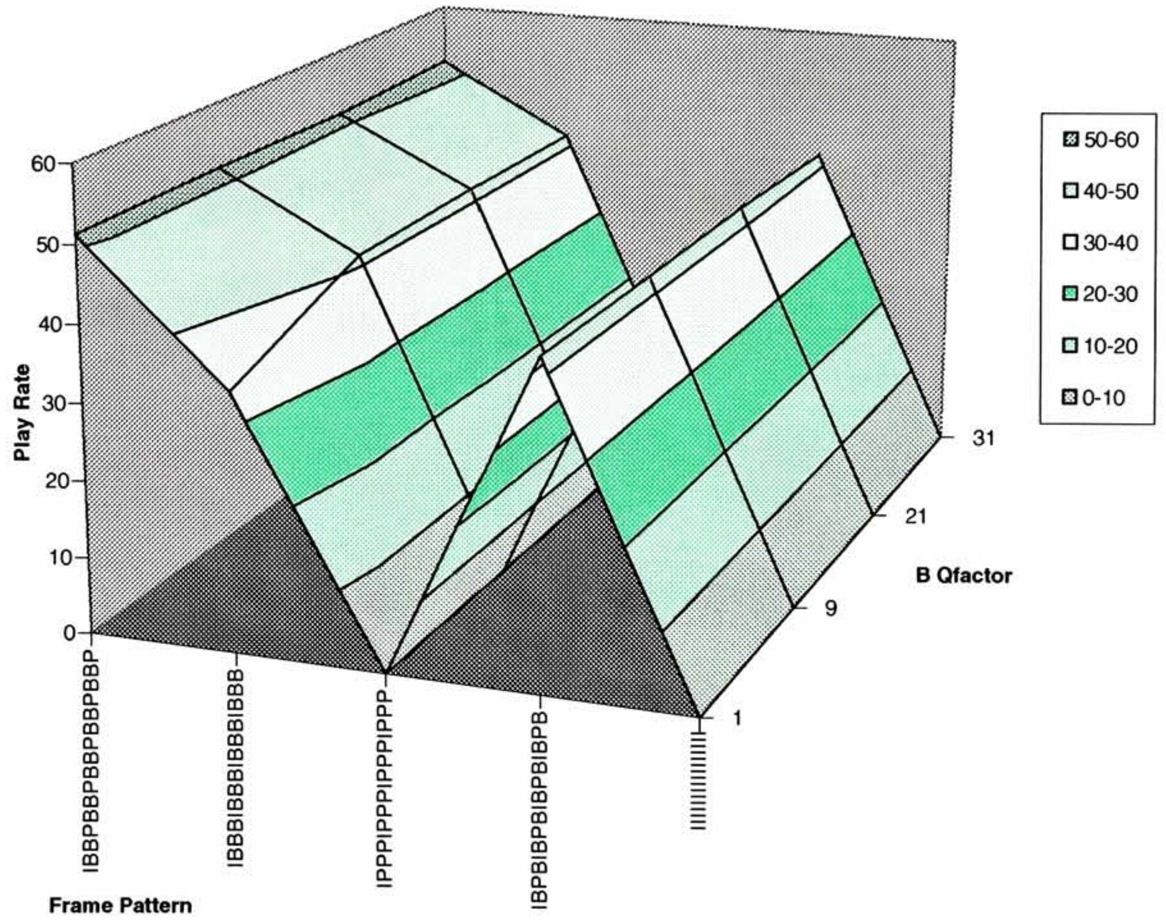




P Frame Percentage when varying P Qfactor and Frame Pattern for carm4 video

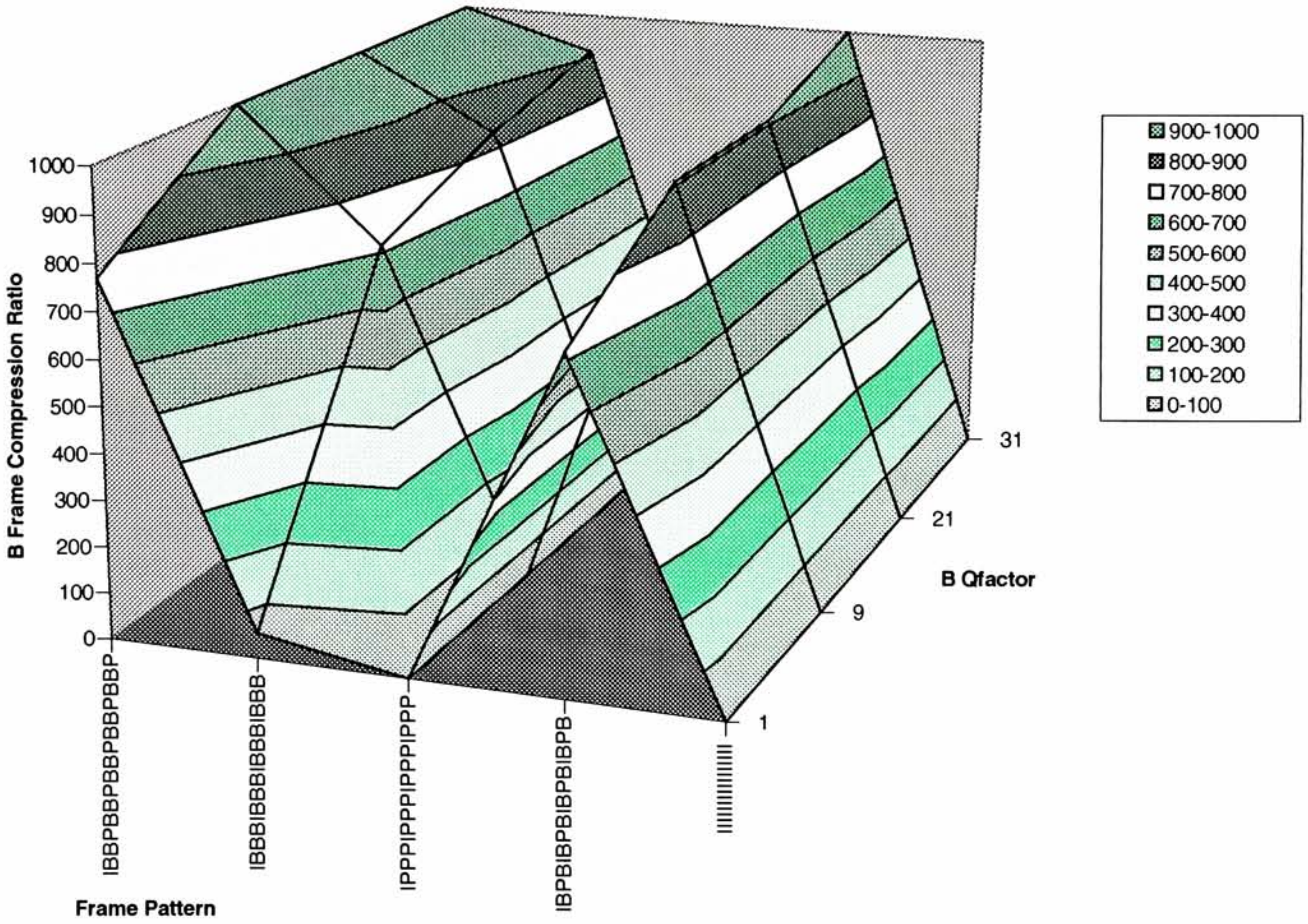
Compression Ratio when varying B Qfactor and Frame Pattern for carm4 video



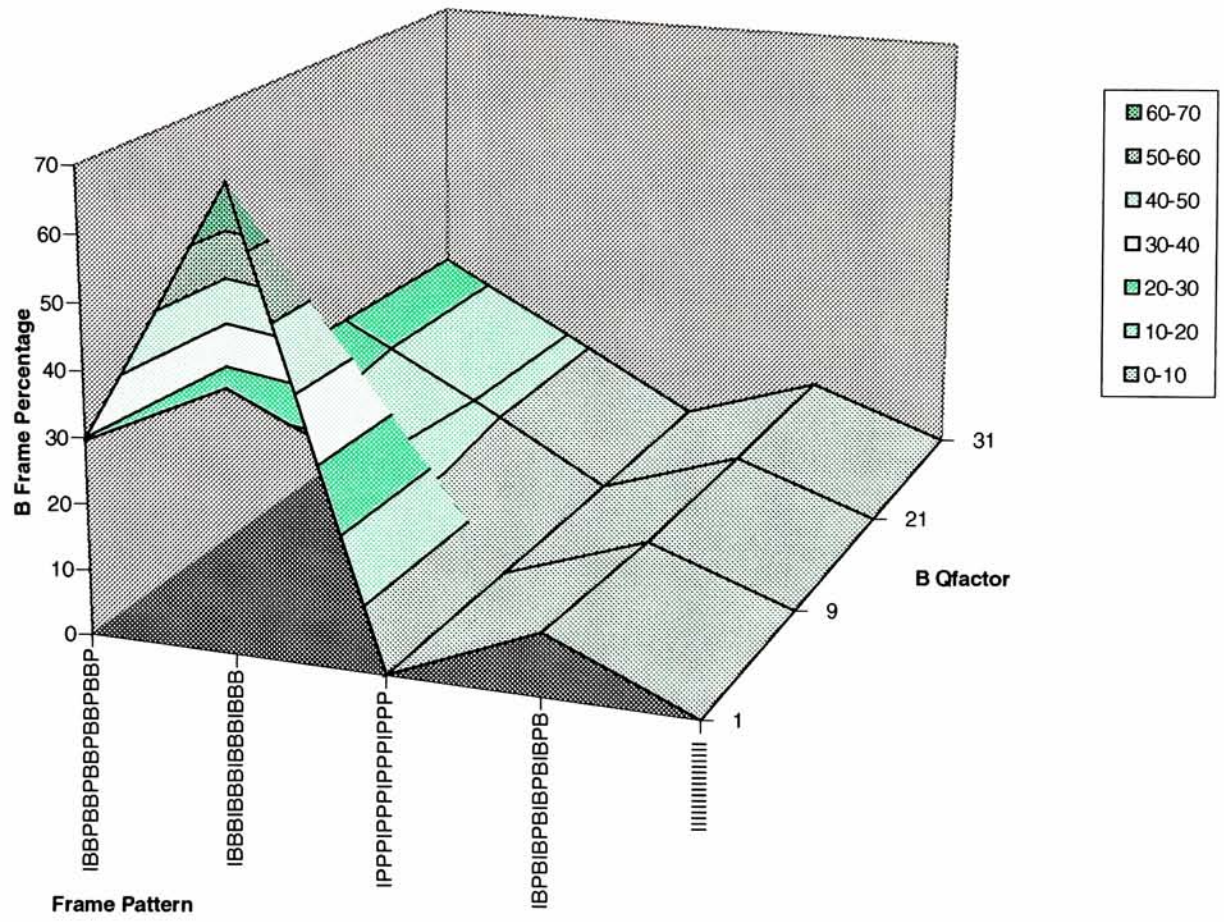


Play Rate when varying B Qfactor and Frame Pattern for carm4 video

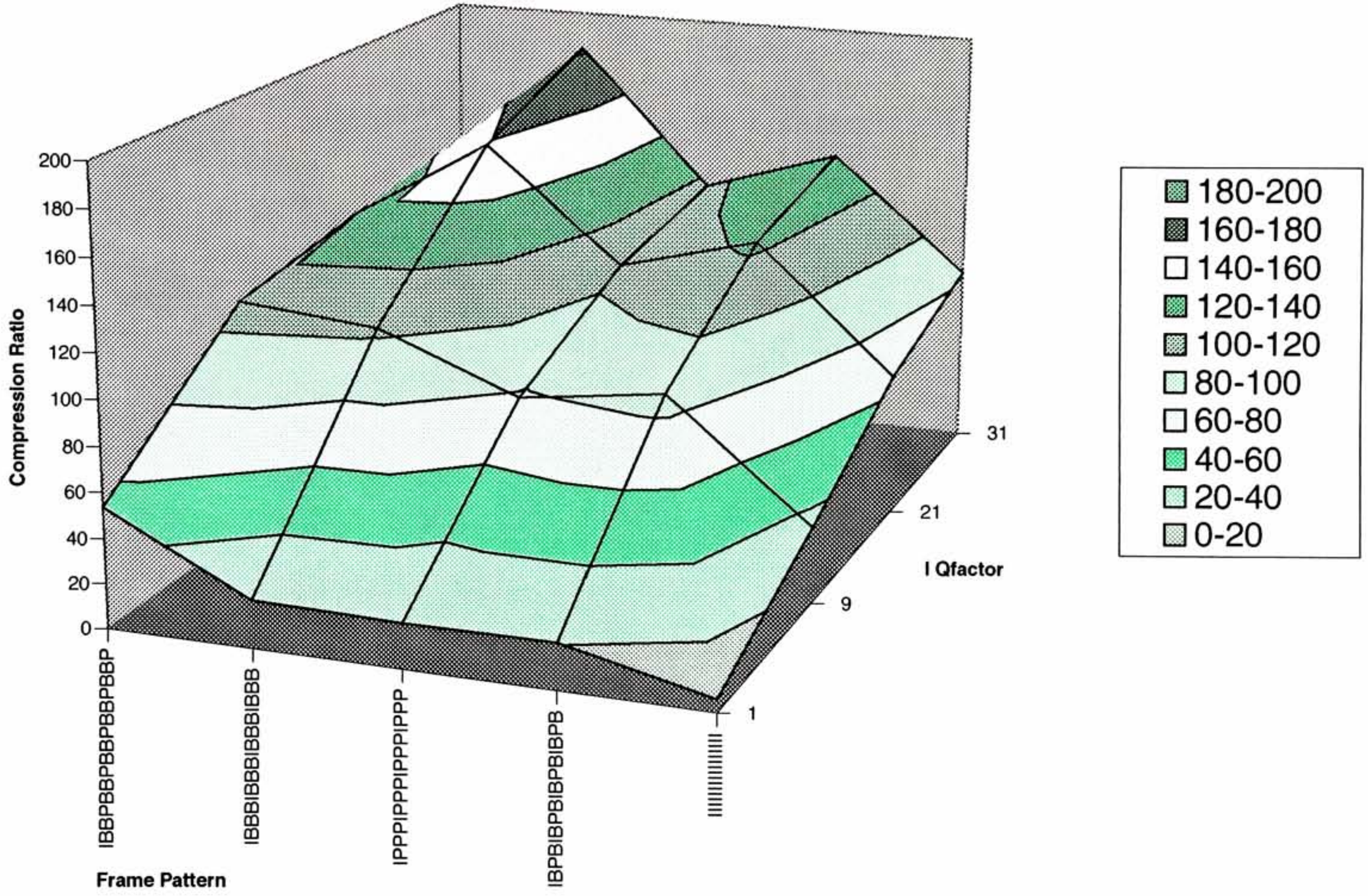
B Frame Compression Ratio when varying B Qfactor and Frame Pattern for carm4 video

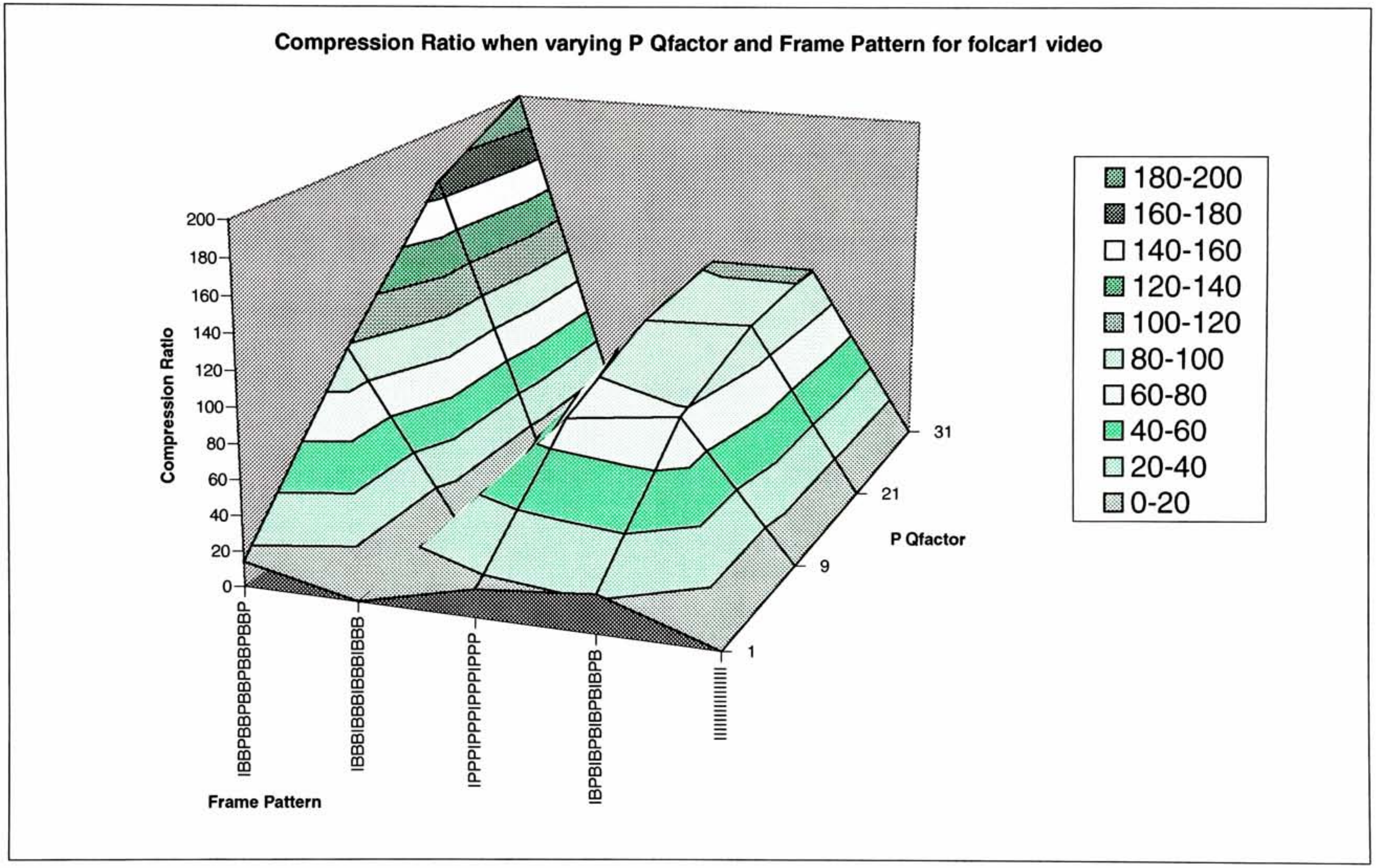


B Frame Percentage when varying B Qfactor and Frame Pattern for carm4 video



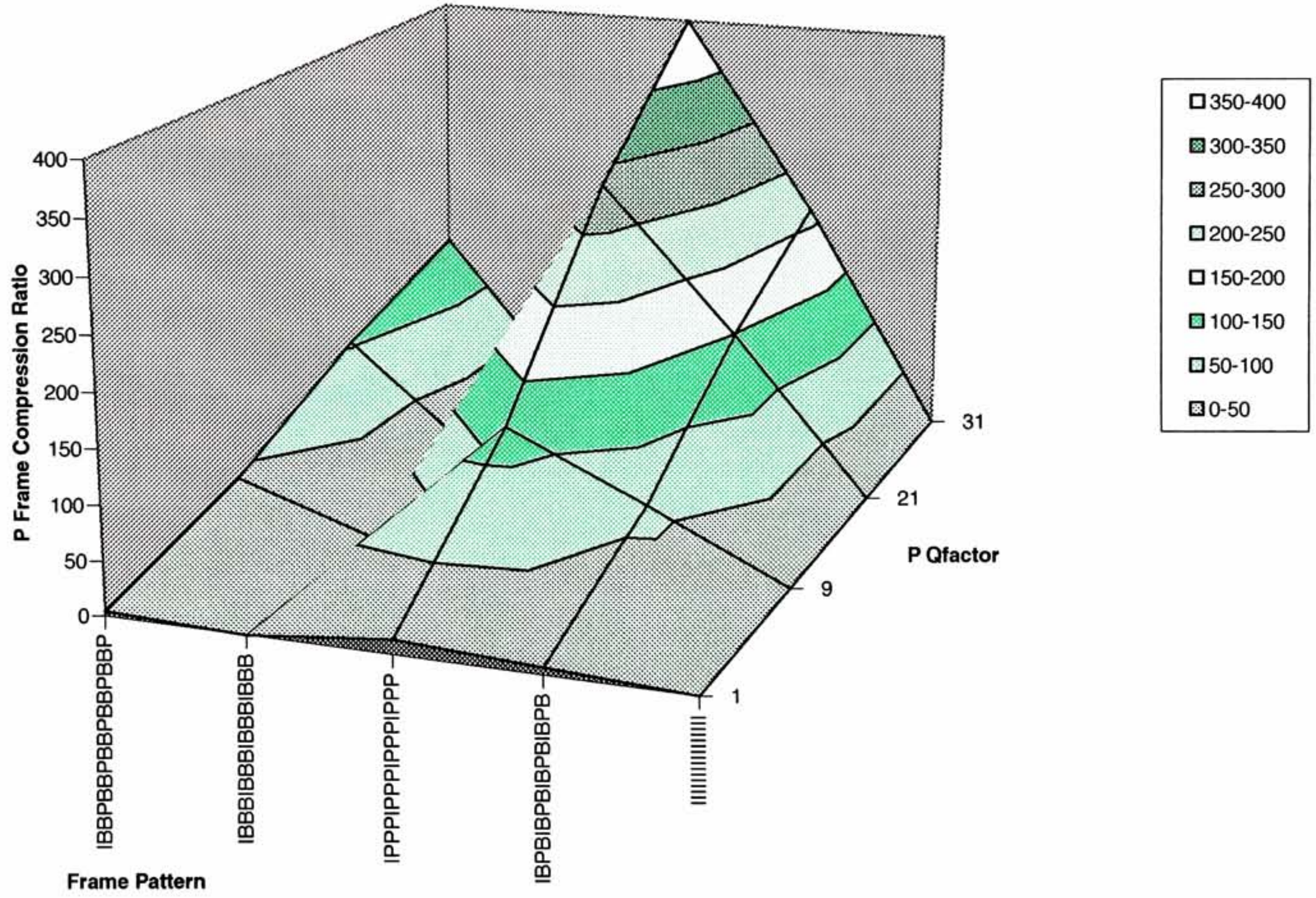
Compression Ratio when varying I Qfactor and Frame Pattern for folcar1 video



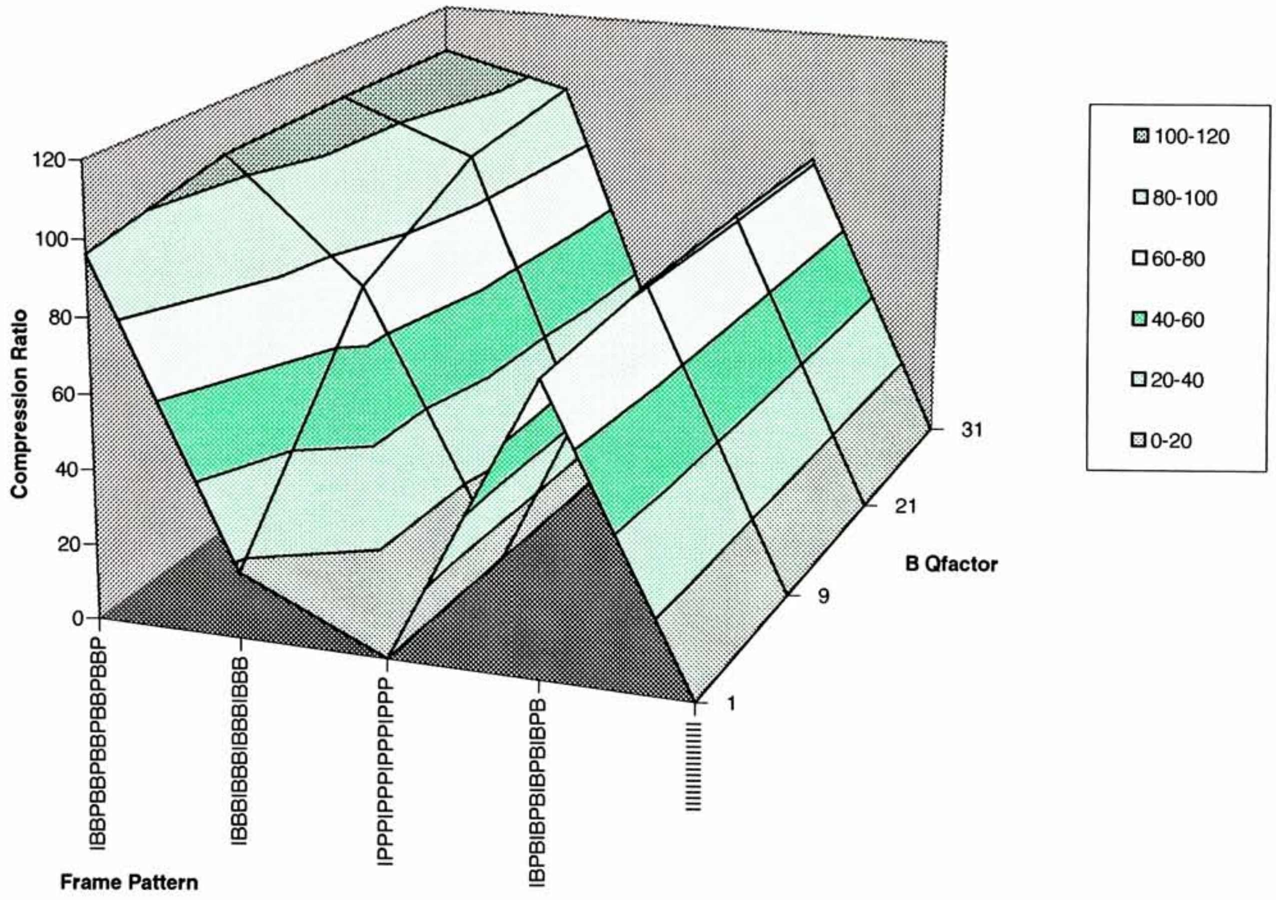


Compression Ratio when varying P Qfactor and Frame Pattern for folcar1 video

P Frame Compression Ratio when varying P Qfactor and Frame Pattern for folcar1 video



Compression Ratio when varying B Qfactor and Frame Pattern for folcar1 video



5.5 Appendix E: Processing Scripts

5.5.1 Survey Form Creation Script

```
#!/import/perl/bin/perl

# generates an MPEG survey form by using mpeg_stat and an MPEG file

sub findline {
   local ($searchstr) = @_;
   while (<INFILE>) {
      $line = $_;
      if ($line =~ /$searchstr/) {
         last;
      }
      if ($line =~ /Custom IQ matrix/) {
         $customIQ = 1;
         $IQline1 = $line;
         &findline (" ");
         $IQline2 = $line;
         &findline (" ");
         $IQline3 = $line;
         &findline (" ");
         $IQline4 = $line;
         &findline (" ");
         $IQline5 = $line;
         &findline (" ");
         $IQline6 = $line;
         &findline (" ");
         $IQline7 = $line;
         &findline (" ");
         $IQline8 = $line;
         &findline (" ");
         $IQline9 = $line;
      }
   }

   if (!($line =~ /$searchstr/)) {
      $line = "";
   }

}
```

```
$customIQ = 0;
open(INFILE, "mpeg_stat <$ARGV[0] |");

#while (<INFILE>) {
#    $line = $_;
#    #print $line;
#}

$ARGV[0] =~ /(\S+)$/;
$mpegname = $1;
#print $mpegname."\n";

&findline ("/");
&findline ("/");

$line =~ /(\w+)\W+(\w+)/;
$bitstreamorder = $1;
$displayorder = $2;
##print $line;
#print $bitstreamorder."\n";
#print $displayorder."\n";

&findline ("Total Bytes read");
$line =~ /read: (\d+)\D+(\d+)\D+(\d+)/;
$totalbyte = $1;
$numframes = $2;
$time = $3;

##print $line;
#print $totalbyte."\n";
#print $numframes."\n";
#print $time."\n";

&findline ("Width");
$line =~ /Width: (\d+)\D+(\d+)/;
$width = $1;
$height = $2;
#print $width."\n";
#print $height."\n";

&findline ("Avg. Frame");
$line =~ /(\d+)\D+(\d+)/;
$avgframebytes = $1;
$avgframebits = $2;

&findline ("Total Compression Rate");
$line =~ /Rate:\s+(\S+)/;
```

```
$comprate = $1;
#print $comprate."\n";

&findline ("Number of Macroblocks");
$line =~ /(\d+) per frame/;
$nummacro = $1;
#print $nummacro."\n";

&findline ("Skipped Macroblocks");
$line =~ /(\d+)\D+([^%]+)/;
$skippednum = $1;
$skippedperc = $2;
#print $skippednum."\n";
#print $skippedperc."\n";

&findline ("Required display speed");
$line =~ /speed:\s+(\d+)/;
$framerate = $1;
#print $framerate."\n";

# Motion Vectors
if (($displayorder =~ /P/) || ($displayorder =~ /B/)) {
   &findline ("Length of vectors");
   $v1 = $line;
   &findline (" ");
   $v2 = $line;
   &findline (" ");
   $v3 = $line;
   &findline (" ");
   $v4 = $line;
   &findline (" ");
   $v5 = $line;
}

# I frame info
#
if ($displayorder =~ /I/) {
   &findline ("FRAMES");
   $line =~ /(\d+)/;
   $iframes = $1;
   &findline ("Size:");
   $line =~ /(\d+)\D+(\d+)\D+([^%]+)/;
   $ibytes = $1;
   $ibits = $2;
   $ipercent = $3;
   &findline ("Compression Rate:");
   $line =~ /\D+([^%]+)/;
```

```
    $icomprate = $1;
    &findline ("Q Factor");
    $line =~ /\D+(\S+)/;
    $iqfactor = $1;

    #print $iframes."\n";
    #print $ibytes."\n";
    #print $ibits."\n";
    #print $ipercent."\n";
    #print $icomprate."\n";
    #print $iqfactor."\n";
}
# P frame info
#
if ($displayorder =~ /P/) {
    &findline ("FRAMES");
    $line =~ /(\d+)/;
    $pframes = $1;
    &findline ("Size:");
    $line =~ /(\d+)\D+(\d+)\D+([^%]+)/;
    $pbytes = $1;
    $pbits = $2;
    $ppercent = $3;
    &findline ("Compression Rate:");
    $line =~ /\D+([^%]+)/;
    $pcomprate = $1;
    &findline ("Q Factor");
    $line =~ /\D+(\S+)/;
    $pqfactor = $1;

    #print $pframes."\n";
    #print $pbytes."\n";
    #print $pbits."\n";
    #print $ppercent."\n";
    #print $pcomprate."\n";
    #print $pqfactor."\n";
}

# B frame info
#
if ($displayorder =~ /B/) {
    &findline ("FRAMES");
    $line =~ /(\d+)/;
    $bframes = $1;
    &findline ("Size:");
    $line =~ /(\d+)\D+(\d+)\D+([^%]+)/;
    $bbytes = $1;
```

```
    $bbits = $2;
    $bpercent = $3;
    &findline ("Compression Rate:");
    $line =~ /\D+([^%]+)/;
    $bcomprate = $1;
    &findline ("Q Factor");
    $line =~ /\D+(\S+)/;
    $bqfactor = $1;
    &findline ("interpolated");
    $line =~ /\D+([^%]+)/;
    $binterp = $1;

    #print $bframes."\n";
    #print $bbytes."\n";
    #print $bbits."\n";
    #print $bpercent."\n";
    #print $bcomprate."\n";
    #print $bqfactor."\n";
    #print $binterp."\n";
}

# read rest of file
while (<INFILE>) {
    $line = $_;
}
close (INFILE);

if (0) {
# Get playing frame rate info
$playrate = 0;
open(INFILE, "/tilde/dhoward/mpeg/play/mpeg_play/mpeg_play -dither color -no_display -
framerate 0 $ARGV[0] |");
&findline ("Frames/Sec");
$line =~ /:\s+(\S+)/;
$playrate1 = $1;
close (INFILE);

open(INFILE, "/tilde/dhoward/mpeg/play/mpeg_play/mpeg_play -dither color -no_display -
framerate 0 $ARGV[0] |");
&findline ("Frames/Sec");
$line =~ /:\s+(\S+)/;
$playrate2 = $1;
close (INFILE);

open(INFILE, "/tilde/dhoward/mpeg/play/mpeg_play/mpeg_play -dither color -no_display -
framerate 0 $ARGV[0] |");
&findline ("Frames/Sec");
```

```
$line =~ /:\s+(\S+)/;
$playrate3 = $1;
close (INFILE);

$playrate = ($playrate1 + $playrate2 + $playrate3) / 3.0;
}

# better play rate
$playrate = 0;
open (INFILE, "/tilde/dhoward/mpeg/play/mpeg_play/mpeg_play2 -dither color -display ruby:0.0 -
framerate 0 $ARGV[0] |");
&findline ("Frames/Sec");
$line =~ /:\s+(\S+)/;
$playrate1 = $1;
close (INFILE);

open (INFILE, "/tilde/dhoward/mpeg/play/mpeg_play/mpeg_play2 -dither color -display ruby:0.0 -
framerate 0 $ARGV[0] |");
&findline ("Frames/Sec");
$line =~ /:\s+(\S+)/;
$playrate2 = $1;
close (INFILE);

open (INFILE, "/tilde/dhoward/mpeg/play/mpeg_play/mpeg_play2 -dither color -display ruby:0.0 -
framerate 0 $ARGV[0] |");
&findline ("Frames/Sec");
$line =~ /:\s+(\S+)/;
$playrate3 = $1;
close (INFILE);

$playrate = ($playrate1 + $playrate2 + $playrate3) / 3.0;

print "\n\n";

# Print out form

print "File Statistics:\n";
print "\n";
$mpegname =~ /([^\/]+)$/;
$mpegnamenew = $1;
print "MPEG Stream Title: ".$mpegnamenew."\n";
print "MPEG Test Name: ".$ARGV[1]."\n";
print "Stream options: ".$ARGV[2]."\n";
print "Compression time: ".$ARGV[3]."\n";
printf ("Avg. Playing Frame Rate : %.4f\n",$playrate);
print "Frames: ".$numframes."\t Width: ".$width."\t Height: ".$height."\n";
```

```
print "Total bytes read: ".$totalbyte."\t Length: ".$time." sec\t Number of Frames:
".$numframes."\n";
print "Total compression rate: ".$comprate."%\t Speed:  ".$framerate." frames/sec\n";
print "Avg. Frame Size: ".$avgframebytes."+".$avgframebits." bytes\n";
print "Bitstream Order: ".$bitstreamorder."\tDisplay Order: ".$displayorder."\n";
print "Number of Macroblocks: ".$nummacro." per frame\tSkipped Macroblocks: ".$skippednum."
(".$skippedperc."%)\n";
print "\n";

print "Frame Info:\n";
print "\n";
print "\t# of frames\tSize\t% of file\tCR\tQfactor\tInterp. MB\n";
if ($displayorder =~ /I/) {
   print
"I\t".$iframes."\t\t".$ibytes."+".$ibits."\t".$ipercent."%\t\t".$icomprate."%\t".$iqfactor."\n";
}
if ($displayorder =~ /P/) {
   print
"P\t".$pframes."\t\t".$pbytes."+".$pbits."\t".$ppercent."%\t\t".$pcomprate."%\t".$pqfactor."\n";
}
if ($displayorder =~ /B/) {
   print
"B\t".$bframes."\t\t".$bbytes."+".$bbits."\t".$bpercent."%\t\t".$bcomprate."%\t".$bqfactor."\t".$bi
nterp."%\n";
}
print "\n";

if (($displayorder =~ /P/) ||($displayorder =~ /B/)) {
   print $v1;
   print $v2;
   print $v3;
   print "\n";
   print $v4;
   print $v5;
   print "\n";
}

if ($customIQ) {
   print $IQline1;
   print $IQline2;
   print $IQline3;
   print $IQline4;
   print $IQline5;
   print $IQline6;
   print $IQline7;
   print $IQline8;
   print $IQline9;
```

```
    print "\n";
  }

  print "Subjective Ratings:\n\n";
  print "\t\t\t\t\tWorst             Best\n";
  print "\t\t\t\t\tResult            Result\n";
  print "\t\t\t\t\t               (No change)\n";
  print "\t\t\t\t\t_________________________\n";

  print "Visibility of blocking artifacts\t1   2   3   4   5\n";
  print "Visibility of contouring\t\t1   2   3   4   5\n";
  print "Loss of sharpness of edges\t\t1   2   3   4   5\n";
  print "Ability to see fine detail\t\t1   2   3   4   5\n";
  print "Quality of motion (smoothness)\t\t1   2   3   4   5\n";
  print "Visibility of frame flickering\t\t1   2   3   4   5\n";
  print "Color shift from original\t\t1   2   3   4   5\n";
  print "Overall rating of video sequence\t1   2   3   4   5\n";
  print "\n\n";

  print "Additional comments:\n\n\n";
```

5.5.1.1 Survey Form Example

```
File Statistics:

MPEG Stream Title: carm4-iq2.mpg
MPEG Test Name: carm4 Iqscale Test
Stream options: IQSCALE = 5
Compression time: 2 minutes and 25 seconds
Avg. Playing Frame Rate : 49.9728
Frames: 298      Width: 320      Height: 240
Total bytes read: 231367         Length: 9 sec    Number of Frames: 298
Total compression rate: 0.34%    Speed:  30 frames/sec
Avg. Frame Size: 773+0 bytes
Bitstream Order: IPBBPBBPBBPBBPBB        Display Order: IBBPBBPBBPBBPBBP
Number of Macroblocks: 300 per frame  Skipped Macroblocks: 32731 (38.04%)

Frame Info:

      # of frames    Size    % of file       CR     Qfactor Interp. MB
I     19             8219+4 67.79%           3.57%  5.00
P     93             331+3  13.38%           0.14%  10.00
B     186            233+2  18.83%           0.10%  25.00    3.27%
```

Length of vectors in half pixels:

Horizontal forward vectors, maximum : 21 average: 0
Vertical forward vectors, maximum : 21 average: 0

Horizontal backward vectors, maximum: 19 average: 0
Vertical backward vectors, maximum : 18 average: 0

Subjective Ratings:

	Worst Result				Best Result (No change)
Visibility of blocking artifacts	1	2	3	4	5
Visibility of contouring	1	2	3	4	5
Loss of sharpness of edges	1	2	3	4	5
Ability to see fine detail	1	2	3	4	5
Quality of motion (smoothness)	1	2	3	4	5
Visibility of frame flickering	1	2	3	4	5
Color shift from original	1	2	3	4	5
Overall rating of video sequence	1	2	3	4	5

Additional comments:

5.5.2 Test Sequence Creation Script

```
#!/import/perl/bin/perl

# generates an MPEG survey test by using formcreate script, mpeg_encode, and
# and test input file

sub findline {
  local ($searchstr) = @_;
  while (<INFILE>) {
    $line = $_;
      if (($line =~ /Gamma/)||($line =~ /GAMMA/)) {
      $hasgamma = 1;
      $line = /:\D+(\S+)/;
      $gamma = $1;
      }
    if ($printon) {
```

```
            print $line;
        }
        if ($line =~ /$searchstr/) {
            last;
        }

    }


    if (!($line =~ /$searchstr/)) {
        $line = "";
    }

}

# Read in test file
$printon = 0;
$hasgamma = 0;
open(INFILE, "$ARGV[0]");
&findline ("Test Name");
$line =~ /:\s+(.+)/;
$testname = $1;

&findline ("Test Base");
$line =~ /:\s+(\S+)/;
$testbase = $1;

&findline ("Number of Tests");
$line =~ /\D+(\d+)/;
$numtests = $1;

&findline ("Output Dir");
$line =~ /:\s+(\S+)/;
$outputdir = $1;

&findline ("Input Dir");
$line =~ /:\s+(\S+)/;
$inputdir = $1;

&findline ("Input String");
$line =~ /:\s+([^\]]+])/;
$inputstring = $1;

#print $testname."\n";
#print $numtests."\n";
#print $outputdir."\n";
#print $inputdir."\n";
```

```
#print $inputstring."\n";

system ("mkdir ".$outputdir);
# test entries
for ($i = 0;$i < $numtests;$i++) {
    &findline ("Test");
    &findline ("Option String");
    $line =~ /:\s+(.+)/;
    $options[$i] = $1;

    &findline ("PATTERN");
    $line =~ /:\s+(\S+)/;
    $pattern[$i] = $1;

    &findline ("IQSCALE");
    $line =~ /:\s+(\d+)/;
    $iqscale[$i] = $1;

    &findline ("PQSCALE");
    $line =~ /:\s+(\d+)/;
    $pqscale[$i] = $1;

    &findline ("BQSCALE");
    $line =~ /:\s+(\d+)/;
    $bqscale[$i] = $1;

    &findline ("PSEARCH_ALG");
    $line =~ /:\s+(\S+)/;
    $psearch[$i] = $1;

    &findline ("BSEARCH_ALG");
    $line =~ /:\s+(\S+)/;
    $bsearch[$i] = $1;

}

#for ($i = 0;$i < $numtests;$i++) {
#    print $options[$i]."\n";
#    print $pattern[$i]."\n";
#    print $iqscale[$i]."\n";
#    print $pqscale[$i]."\n";
#    print $bqscale[$i]."\n";
#    print $psearch[$i]."\n";
#    print $bsearch[$i]."\n";
#
#    print "\n";
#}
```

```
# read rest of file
while (<INFILE>) {
   $line = $_;
}
close (INFILE);


# Main program loop
for ($i = 0;$i < $numtests;$i++) {
open(OUTFILE, ">/tmp/dantemp.param");
print "Processing MPEG #".$i."\n";


# Create param file
print OUTFILE "PATTERN ".$pattern[$i]."\n";
print OUTFILE "OUTPUT\t".$outputdir."/".$testbase.($i+1).".mpg\n";

print OUTFILE "BASE_FILE_FORMAT\tPNM\n";
print OUTFILE "INPUT_CONVERT\t*\n";
print OUTFILE "GOP_SIZE\t16\n";
print OUTFILE "SLICES_PER_FRAME\t1\n";
print OUTFILE "INPUT_DIR\t".$inputdir."\n";
print OUTFILE "INPUT\n";
print OUTFILE $inputstring."\n";
print OUTFILE "END_INPUT\n";
print OUTFILE "PIXEL\tHALF\n";
print OUTFILE "RANGE\t10\n";
print OUTFILE "PSEARCH_ALG\t".$psearch[$i]."\n";
print OUTFILE "BSEARCH_ALG\t".$bsearch[$i]."\n";
print OUTFILE "IQSCALE\t".$iqscale[$i]."\n";
print OUTFILE "PQSCALE\t".$pqscale[$i]."\n";
print OUTFILE "BQSCALE\t".$bqscale[$i]."\n";
print OUTFILE "REFERENCE_FRAME\tORIGINAL\n";
print OUTFILE "BUFFER_SIZE 327680\n";
print OUTFILE "FRAME_RATE 30\n";
if ($hasgamma) {
   print OUTFILE "GAMMA ".$gamma."\n";
}

print OUTFILE "\n\n\n";
close(OUTFILE);


# Create MPEG file
open (INFILE, "/tilde/dhoward/mpeg/encode/mpeg_encode/mpeg_encode /tmp/dantemp.param |");
```

```
$printon = 1;
&findline ("Total time");
$line =~ /:\s+(.+)/;
$totaltime = $1;

# read rest of file
while (<INFILE>) {
   $line = $_;
   print $line;
}
close (INFILE);
$printon = 0;


# Create survey form
system ("/tilde/dhoward/mpeg/scripts/formcreate.scr ".$outputdir."/".$testbase.($i+1).".mpg
\"".$testname."\" \"".$options[$i]."\" \"".$totaltime."\" >".$outputdir."/".$testbase.($i+1).".form");
}
```

5.5.2.1 Test Sequence Definition File Examples

5.5.2.1.1 Example varying only Iqscale

```
Test Name:  carm4 Iqscale Test
Test Base: carm4-iq
Number of Tests: 9
Output Dir: /tilde/dhoward/mpeg/tests/carm4-iq
Input Dir: /net/ruby/local/dhoward/mpeg/carm4
Input String: carm400*.pnm [001-300]
Gamma: 0.5

Test 1
Option String:  IQSCALE = 1
PATTERN:        IBBPBBPBBPBBPBBP
IQSCALE:        1
PQSCALE:        10
BQSCALE:        25
PSEARCH_ALG:          LOGARITHMIC
BSEARCH_ALG:          CROSS2

Test 2
Option String:  IQSCALE = 5
PATTERN:        IBBPBBPBBPBBPBBP
IQSCALE:        5
```

PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 3
Option String: IQSCALE = 9
PATTERN: IBBPBBPBBPBBPBBP
IQSCALE: 9
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 4
Option String: IQSCALE = 13
PATTERN: IBBPBBPBBPBBPBBP
IQSCALE: 13
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 5
Option String: IQSCALE = 17
PATTERN: IBBPBBPBBPBBPBBP
IQSCALE: 17
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 6
Option String: IQSCALE = 21
PATTERN: IBBPBBPBBPBBPBBP
IQSCALE: 21
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 7
Option String: IQSCALE = 25
PATTERN: IBBPBBPBBPBBPBBP
IQSCALE: 25
PQSCALE: 10
BQSCALE: 25

PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 8
Option String: IQSCALE = 29
PATTERN: IBBPBBPBBPBBPBBP
IQSCALE: 29
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 9
Option String: IQSCALE = 31
PATTERN: IBBPBBPBBPBBPBBP
IQSCALE: 31
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

5.5.2.1.2 Example varying Iqscale and Frame Pattern

Test Name: carm4 Pattern Iqscale Test
Test Base: carm4-pat-i
Number of Tests: 20
Output Dir: /tilde/dhoward/mpeg/tests/carm4-pat-i
Input Dir: /net/ruby/local/dhoward/mpeg/carm4
Input String: carm400*.pnm [001-300]
Gamma: 0.5

Test 1
Option String: IQSCALE = 1
PATTERN: IBBPBBPBBPBBPBBP
IQSCALE: 1
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 2
Option String: IQSCALE = 9
PATTERN: IBBPBBPBBPBBPBBP
IQSCALE: 9
PQSCALE: 10
BQSCALE: 25

PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 3
Option String: IQSCALE = 21
PATTERN: IBBPBBPBBPBBPBBP
IQSCALE: 21
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 4
Option String: IQSCALE = 31
PATTERN: IBBPBBPBBPBBPBBP
IQSCALE: 31
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 5
Option String: IQSCALE = 1
PATTERN: IBBBIBBBIBBBIBBB
IQSCALE: 1
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 6
Option String: IQSCALE = 9
PATTERN: IBBBIBBBIBBBIBBB
IQSCALE: 9
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 7
Option String: IQSCALE = 21
PATTERN: IBBBIBBBIBBBIBBB
IQSCALE: 21
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 8
Option String: IQSCALE = 31
PATTERN: IBBBIBBBIBBBIBBB
IQSCALE: 31
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 9
Option String: IQSCALE = 1
PATTERN: IPPPIPPPIPPPIPPP
IQSCALE: 1
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 10
Option String: IQSCALE = 9
PATTERN: IPPPIPPPIPPPIPPP
IQSCALE: 9
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 11
Option String: IQSCALE = 21
PATTERN: IPPPIPPPIPPPIPPP
IQSCALE: 21
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 12
Option String: IQSCALE = 31
PATTERN: IPPPIPPPIPPPIPPP
IQSCALE: 31
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 13

Option String: IQSCALE = 1
PATTERN: IBPBIBPBIBPBIBPB
IQSCALE: 1
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 14
Option String: IQSCALE = 9
PATTERN: IBPBIBPBIBPBIBPB
IQSCALE: 9
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 15
Option String: IQSCALE = 21
PATTERN: IBPBIBPBIBPBIBPB
IQSCALE: 21
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 16
Option String: IQSCALE = 31
PATTERN: IBPBIBPBIBPBIBPB
IQSCALE: 31
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 17
Option String: IQSCALE = 1
PATTERN: IIIIIIIIIIIIIIII
IQSCALE: 1
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 18
Option String: IQSCALE = 9
PATTERN: IIIIIIIIIIIIIIII

IQSCALE: 9
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 19
Option String: IQSCALE = 21
PATTERN: IIIIIIIIIIIIIII
IQSCALE: 21
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

Test 20
Option String: IQSCALE = 31
PATTERN: IIIIIIIIIIIIIII
IQSCALE: 31
PQSCALE: 10
BQSCALE: 25
PSEARCH_ALG: LOGARITHMIC
BSEARCH_ALG: CROSS2

5.5.3 Graph Creation Script

```
#!/import/perl/bin/perl

# generates an graph data file to be loaded into EXCEL

sub findline {
   local ($searchstr) = @_;
   while (<INFILE>) {
      $line = $_;
      if ($line =~ /$searchstr/) {
         last;
      }
   }

   if (!($line =~ /$searchstr/)) {
      $line = "";
   }

}

# Read graph def file
```

```
open(INFILE, $ARGV[0]);

&findline ("Title");
$line =~ /:\s+(\S+)/;
$title = $1;
#print $title."\n";

&findline ("Type");
$line =~ /:\s+(\S+)/;
$type = $1;
#print $type."\n";

&findline ("Video Name");
$line =~ /:\s+(\S+)/;
$vidname = $1;
#print $vidname."\n";

&findline ("Test Param");
$line =~ /:\s+(\S+)/;
$testparam = $1;
#print $testparam."\n";

&findline ("XNum");
$line =~ /:\s+(\S+)/;
$xnum = $1;
#print $xnum."\n";

&findline ("XField");
$line =~ /:\s+(\S+)/;
$xfield = $1;
#print $xfield."\n";

for ($i = 0; $i < $xnum; $i++) {
   $line = <INFILE>;
   $line =~ /(\S+)/;
   $xvalue[$i] = $1;
}
for ($i = 0; $i < $xnum; $i++) {
   #print $xvalue[$i]."\n";
}

if (($type =~ /3-D/) || ($type =~ /3-d/)) {
   &findline ("YNum");
   $line =~ /:\s+(\S+)/;
   $ynum = $1;
   #print $ynum."\n";
```

```
    &findline ("YField");
    $line =~ /:\s+(\S+)/;
    $yfield = $1;
    #print $yfield."\n";

    for ($i = 0; $i < $ynum; $i++) {
        $line = <INFILE>;
        $line =~ /(\S+)/;
        $yvalue[$i] = $1;
    }
    for ($i = 0; $i < $ynum; $i++) {
        #print $yvalue[$i]."\n";
    }
}
# read rest of file
while (<INFILE>) {
    $line = $_;
}
close (INFILE);

# Read in values from form files

@formlist = grep (/form/, @ARGV);
#print @formlist."\n\n\n";

foreach $file (@formlist) {
    open(INFILE, $file);
#   print $file."\n";

    &findline ("Title");
    $line =~ /Title:\s+(\S+)/;
    $streamtitle = $1;
    #print $streamtitle."\n";

    &findline ("Avg. Playing Frame Rate");
    $line =~ /Frame Rate :\s+(\S+)/;
    $playrate = $1;
    #print $playrate."\n";

    &findline ("Total compression rate");
    $line =~ /Total compression rate:\s+([^%]+)%/;
    $comprate = 1 / ($1 / 100);
    #print $comprate."\n";

    &findline ("Display Order");
    $line =~ /Display Order:\s+(\S+)/;
    $displayorder = $1;
```

```
#print $displayorder."\n";

&findline ("Qfactor");

# I frame info
&findline ("I");
$line =~ /(\S+)%\s+(\S+)%\s+(\d+)/;
$ifilepercent = $1;
$icomprate = 1 / ($2/100);
$iqfactor = $3;
#print $ifilepercent."\n";
#print $icomprate."\n";
#print $iqfactor."\n";

$pfilepercent = 0;
$pcomprate = 0;
$pqfactor = 0;
if ($displayorder =~ /P/) {
        # P frame info
        &findline ("P");
        $line =~ /(\S+)%\s+(\S+)%\s+(\d+)/;
        $pfilepercent = $1;
        $pcomprate = 1 / ($2/100);
        $pqfactor = $3;
        #print $pfilepercent."\n";
        #print $pcomprate."\n";
        #print $pqfactor."\n";



}

$bfilepercent = 0;
$bcomprate = 0;
$bqfactor = 0;
if ($displayorder =~ /B/) {
        # B frame info
        &findline ("B");
        $line =~ /(\S+)%\s+(\S+)%\s+(\d+)/;
        $bfilepercent = $1;
        $bcomprate = 1 / ($2/100);
        $bqfactor = $3;
        #print $bfilepercent."\n";
        #print $bcomprate."\n";
        #print $bqfactor."\n";

}
```

```
#print "\n\n\n";
# read rest of file
while (<INFILE>) {
      $line = $_;
}
close (INFILE);

# Check for required param and fill in if present
if (($type =~ /3-D/) || ($type =~ /3-d/)) {
   # 3-D
   $found = 0;
   $xpos = 0;
   if ($xfield =~ /IQSCALE/) {
      for ($i=0;$i<$xnum;$i++) {
      #print $i."\n";
         if ($iqfactor == $xvalue[$i]) {
            $found = 1;
            $xpos = $i;
            #print $pos."\n";
         }
      }
   }
   elsif ($xfield =~ /PQSCALE/) {
      for ($i=0;$i<$xnum;$i++) {
         if ($pqfactor == $xvalue[$i]) {
            $found = 1;
            $xpos = $i;
         }
      }
   }
   elsif ($xfield =~ /BQSCALE/) {
      for ($i=0;$i<$xnum;$i++) {
         if ($bqfactor == $xvalue[$i]) {
            $found = 1;
            $xpos = $i;
         }
      }
   }
   elsif ($xfield =~ /PATTERN/) {
      for ($i=0;$i<$xnum;$i++) {
         if ($displayorder =~ $xvalue[$i]) {
            $found = 1;
            $xpos = $i;
            #print $displayorder."\n";
            #print $xvalue[$i]."\n";
         }
```

```
    }
}

if ($found) {
    #if ($xpos == 0) {
    #     print $streamtitle."\n";
    #}
    $found = 0;
    $ypos = 0;
    if ($yfield =~ /IQSCALE/) {
     for ($i=0;$i<$ynum;$i++) {
     #print $i."\n";
            if ($iqfactor == $yvalue[$i]) {
                $found = 1;
                $ypos = $i;
                #print $pos."\n";
            }
     }
    }
    elsif ($yfield =~ /PQSCALE/) {
     for ($i=0;$i<$ynum;$i++) {
            if ($pqfactor == $yvalue[$i]) {
                $found = 1;
                $ypos = $i;
            }
     }
    }
    elsif ($yfield =~ /BQSCALE/) {
     for ($i=0;$i<$ynum;$i++) {
            if ($bqfactor == $yvalue[$i]) {
                $found = 1;
                $ypos = $i;
            }
     }
    }
    elsif ($yfield =~ /PATTERN/) {
     for ($i=0;$i<$ynum;$i++) {
            if ($displayorder =~ $yvalue[$i]) {
                $found = 1;
                $ypos = $i;
            }
     }
    }
    elsif ($yfield =~ /VIDNAME/) {
     for ($i=0;$i<$ynum;$i++) {
            if ($streamtitle =~ /$yvalue[$i]/) {
                $found = 1;
```

```
                    $ypos = $i;
                }
            }
            }

        }

        if ($found) {
            $pos = $xpos*$ynum+$ypos;
            if ($testparam =~ /CompRate/) {
                $result3d[$pos] = $comprate;
            }
            elsif ($testparam =~ /PlayRate/) {
                $result3d[$pos] = $playrate;
            }


            elsif ($testparam =~ /Ipercent/) {
                $result3d[$pos] = $ifilepercent;
            }
            elsif ($testparam =~ /ICompRatio/) {
                $result3d[$pos] = $icomprate;
                #print $icomprate."\n";
                #print $xpos,$xpos."\n";
                #print $streamtitle."\n";
            }
            elsif ($testparam =~ /Ppercent/) {
                $result3d[$pos] = $pfilepercent;
            }
            elsif ($testparam =~ /PCompRatio/) {
                $result3d[$pos] = $pcomprate;
            }
            elsif ($testparam =~ /Bpercent/) {
                $result3d[$pos] = $bfilepercent;
            }
            elsif ($testparam =~ /BCompRatio/) {
                $result3d[$pos] = $bcomprate;
            }



        }

    }
    else {
        # 2-D
        #print $streamtitle."\n";
```

```
    #print $vidname."\n";
    if (!($streamtitle =~ /$vidname/)) {
#        print "break\n";
       next;
    }

    $found = 0;
    $pos = 0;
    if ($xfield =~ /IQSCALE/) {
       for ($i=0;$i<$xnum;$i++) {
       #print $i."\n";
          if ($iqfactor == $xvalue[$i]) {
             $found = 1;
             $pos = $i;
             #print $pos."\n";
          }
       }
    }
    elsif ($xfield =~ /PQSCALE/) {
       for ($i=0;$i<$xnum;$i++) {
          if ($pqfactor == $xvalue[$i]) {
             $found = 1;
             $pos = $i;
          }
       }
    }
    elsif ($xfield =~ /BQSCALE/) {
       for ($i=0;$i<$xnum;$i++) {
          if ($bqfactor == $xvalue[$i]) {
             $found = 1;
             $pos = $i;
          }
       }
    }
    elsif ($xfield =~ /PATTERN/) {
       for ($i=0;$i<$xnum;$i++) {
          if ($displayorder =~ $xvalue[$i]) {
             $found = 1;
             $pos = $i;
          }
       }
    }



    if ($found) {
```

```
         if ($testparam =~ /CompRate/) {
            $result2d[$pos] = $comprate;
         }
         elsif ($testparam =~ /PlayRate/) {
            $result2d[$pos] = $playrate;
         }


         elsif ($testparam =~ /Ipercent/) {
            $result2d[$pos] = $ifilepercent;
         }
         elsif ($testparam =~ /ICompRatio/) {
            $result2d[$pos] = $icomprate;
         }
         elsif ($testparam =~ /Ppercent/) {
            $result2d[$pos] = $pfilepercent;
         }
         elsif ($testparam =~ /PCompRatio/) {
            $result2d[$pos] = $pcomprate;
         }
         elsif ($testparam =~ /Bpercent/) {
            $result2d[$pos] = $bfilepercent;
         }
         elsif ($testparam =~ /BCompRatio/) {
            $result2d[$pos] = $bcomprate;
         }



      }

   }

}


# Create graph data output

if (($type =~ /3-D/) || ($type =~ /3-d/)) {
   # 3-D
   print "\n\n";
   print "Title: ".$title."\n";
   print "\n";
   print "\t\t".$yfield."\n\n";
   print $xfield."\t";
   for ($i=0;$i<$ynum;$i++) {
      print $yvalue[$i]."\t";
```

```
    }
    print "\n";
    for ($i=0;$i<$xnum;$i++) {
       print $xvalue[$i];
       for ($j=0;$j<$ynum;$j++) {
          printf ("\t%.2f", $result3d[$i*$ynum+$j]);
          #print "\t".$result3d[$i*$ynum+$j];
       }
       print "\n";
    }



 }
 else {
    # 2-D
    print "\n\n";
    print "Title: ".$title."\n";
    print "\n";
    print $xfield."\t".$testparam."\n";
    for ($i=0;$i<$xnum;$i++) {
       print $xvalue[$i];
       printf ("\t%.2f\n", $result2d[$i]);
       #print $xvalue[$i]."\t".$result2d[$i]."\n";

    }


}


print "\n\n\n";
```

5.5.3.1 Graph Definition File Examples

5.5.3.1.1 Example of varying lqscale and Video Sequence

Title: comprate-i
Type: 3-D
Video Name: carm4
Test Param: CompRate

XNum: 9
XField: IQSCALE
1
5
9
13
17
21
25
29
31
YNum: 6
YField: VIDNAME
carm4
folcar1
zoom3
b5m2
b5m3
toy1

5.5.3.1.2 Example of varying Iqscale and Frame Pattern for carm4 Video

Title: comprate-i-pat-carm4
Type: 3-D
Video Name: carm4
Test Param: CompRate
XNum: 5
XField: PATTERN
IBBPBBPBBPBBPBBP
IBBBIBBBIBBBIBBB
IPPPIPPPIPPPIPPP
IBPBIBPBIBPBIBPB
IIIIIIIIIIIIIIII
YNum: 4
YField: IQSCALE
1
9
21
31