

Confidential

Video Streaming Quality Curves

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1 Experimental Design

Nine video segments with various content were collected for use in the experiment. Each segment was 30 seconds long. The nine segments were compressed at seven different bitrates (28 kilobits per second (kbps), 56kbps, 100kbps, 256kbps, 512kbps, 1000kbps, and 3000kbps), three different frame sizes (720×480 , 360×240 , and 180×120), and two frame rates (30 frames per second (fps) and 15fps). The sound on all of the video segments was eliminated since it was not of interest in this study. The video segments were generated using two codecs (DivX ;-) MPEG4 Fast-Motion (version 4.1.00.3917) and DivX ;-) MPEG4 low-motion (version 4.1.00.3920)).

This procedure produced 756, 30 second video segments. The video segments were previewed informally, and the codec which produced the high quality results was used for the experiment. All but two (Fish, Private2) video segments used the Fast-Motion version of the DivX ;-) MPEG4 codec. The quality of all the video segments captured at 30fps was evaluated at five viewing resolutions (360×240 , 720×480 , 900×600 , 1152×768 , and 1600×1067). In addition, the quality of all the video segments captured at 15fps was evaluated at two viewing resolutions (720×480 and 1600×1067). In total, over 14 hours of video were viewed and evaluated.

The codecs are available at <http://divx.ctw.cc>.

2 Conclusions

With few exceptions, the video segments captured at a frame size of 360×240 produced the highest quality video for bitrates ranging from 56kbps to 1000kbps. At bitrates of 3000kbps the video segments captured at a frame size of 720×480 provided a slightly better viewing experience for viewing sizes above 360×240 . At bitrates of 28kbps the video segments captured at a frame size of 180×120 provided a slightly better viewing experience when viewed at 360×240 .

The experiment demonstrates that for all but a very few scenarios, an encoding frame size of 360×240 is superior.

3 Graphs

The following graphs show the results of the experiments. The y axis represents the quality of the video segment. Here is the quality scale that was used:

1. Intolerable
2. Poor
3. Acceptable
4. Good
5. Excellent
6. Indistinguishable from original

Further refinement of the scale was achieved by using a \pm system. For example, if the segment was given a rating of 2^+ or 3^- it was given a quality value of 2.3 or 2.7 respectively. The x axis is $\log_2\left(\frac{1}{kbps}\right) + 12$ where $kbps$ is the number of kilobits per second required to transmit the video segment. Using this scale provided for an approximately even distribution of the seven bitrates tested (28kbps, 56kbps, 100kbps, 256kbps, 512kbps, 1000kbps, and 3000kbps). Note that the left most data points represent the 3000kbps bitrate and the right most data points represent the 28kbps bitrate.

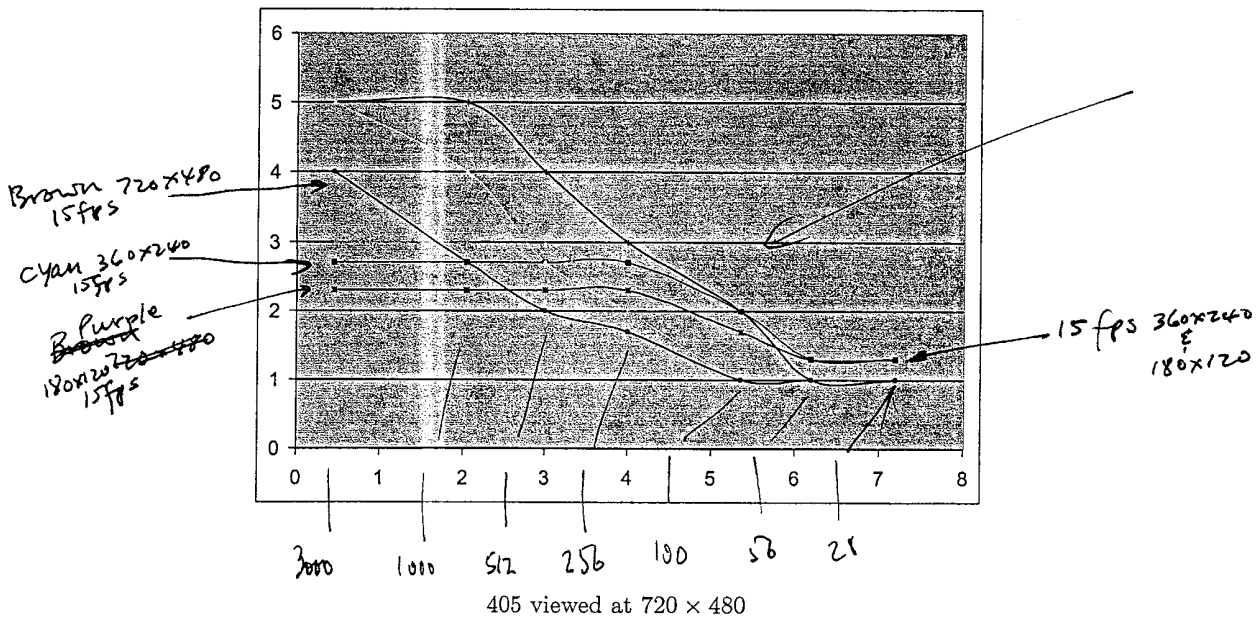
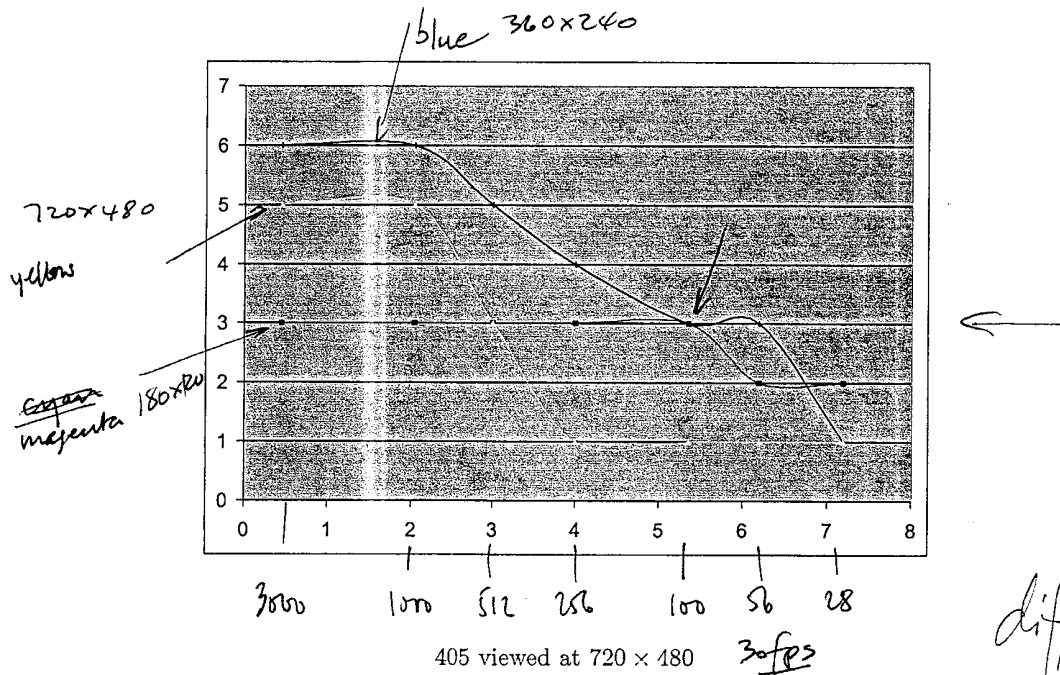
Nine different video segments were used in the experiment. The results for each video segment are given in a separate subsection. Six graphs are included in each subsection. The first two graphs in each subsection display the results for a viewing resolution of 720×480 . The remaining graphs display the results for viewing resolutions of 900×600 , 350×240 , 1152×768 , and 1600×1067 .

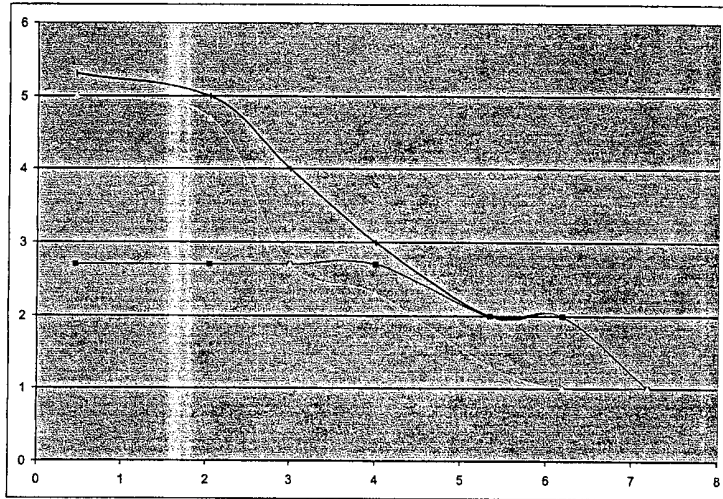
Most of the graphs contain three curves. The blue curve represents the video segment quality as a function of bitrate for video captured at 30 frames per second with a frame size of 360×240 . The magenta curve represents the video segment quality as a function of bitrate for video captured at 30 frames per second with a frame size of 180×120 . The yellow curve represents the video segment quality as a function of bitrate for video captured at 30 frames per second with a frame size of 720×480 . The graphs with six curves add three additional curves for video segments that were captured at 15 frames per second (instead of 30 frames per second). The cyan

curve corresponds to a capture frame size of 360×240 . The purple curve corresponds to a capture frame size of 180×120 . The brown curve corresponds to a capture frame size of 720×480 .

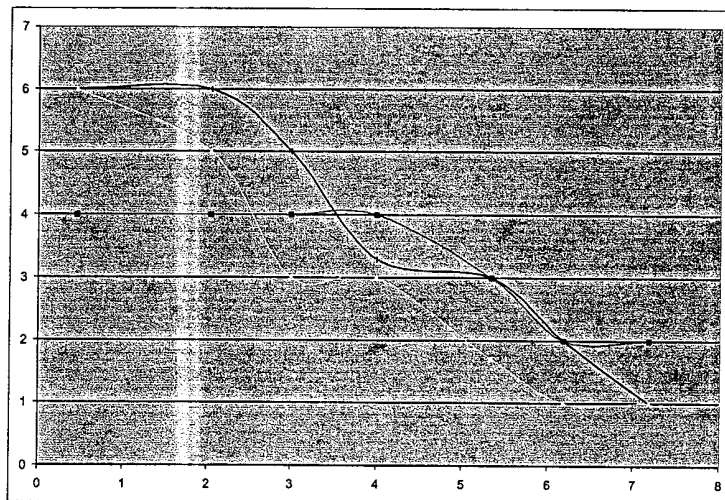
3.1 405

It was taken from a high quality source at <http://www.405themovie.com/> (although the higher quality source is no longer available). This video segment is motion intensive.

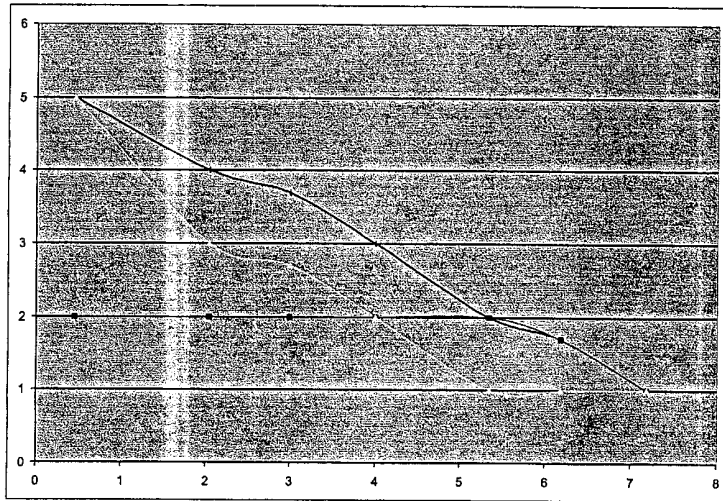




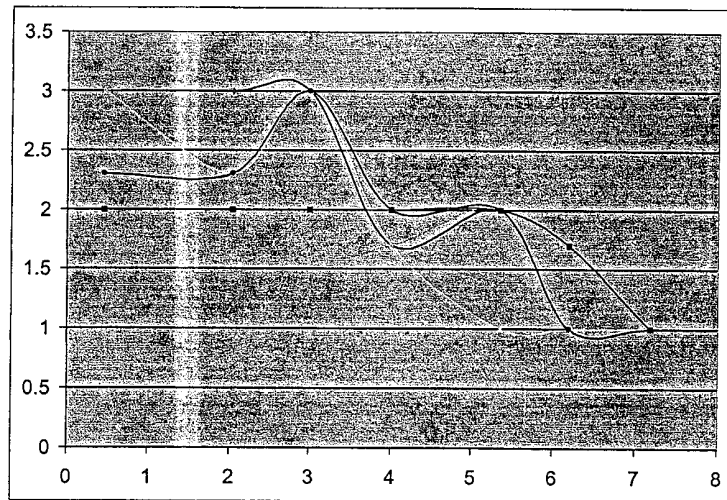
405 viewed at 900 × 600



405 viewed at 360 × 240



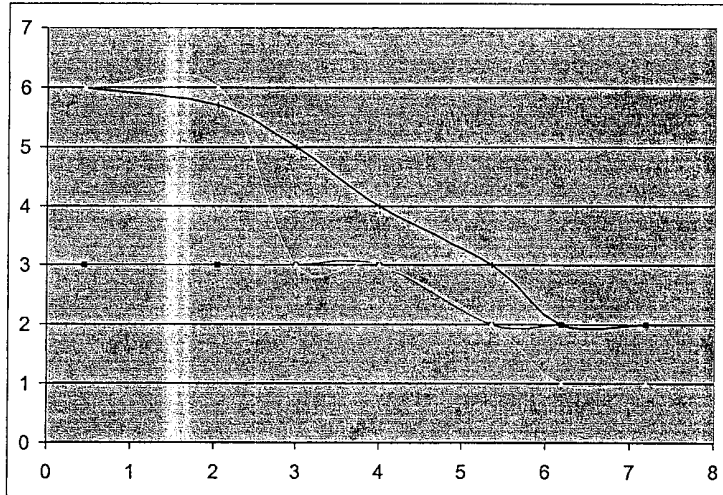
405 viewed at 1152 x 768



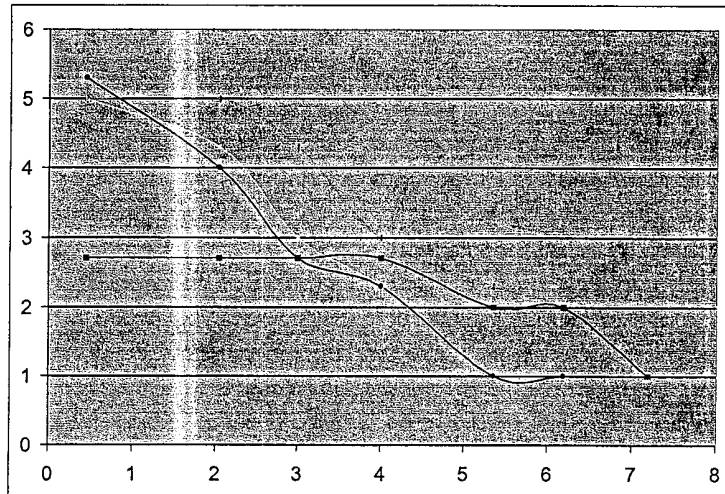
405 viewed at 1600 x 1067

3.2 Bullitt

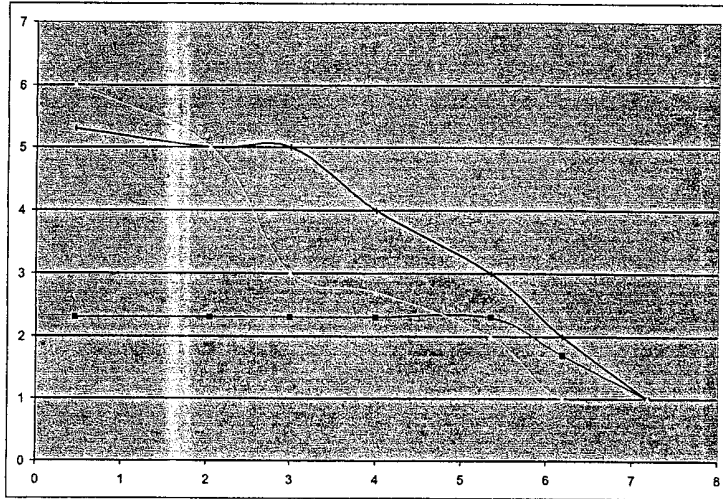
Bullitt is a video capture from a high quality movie trailer for the movie "Bullitt" found at <http://divx.ctw.cc>. This video segment is somewhat motion intensive.



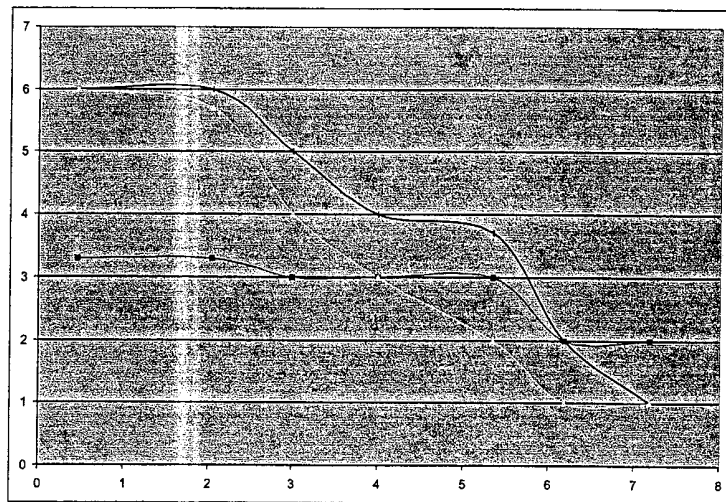
Bullitt viewed at 720 × 480



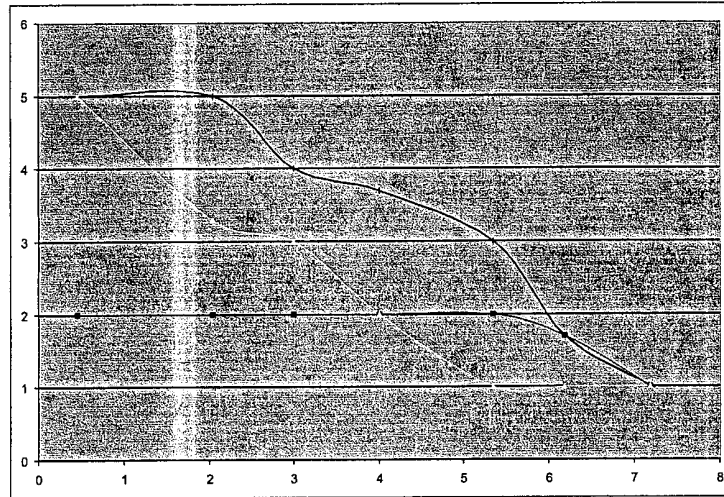
Bullitt viewed at 720 × 480



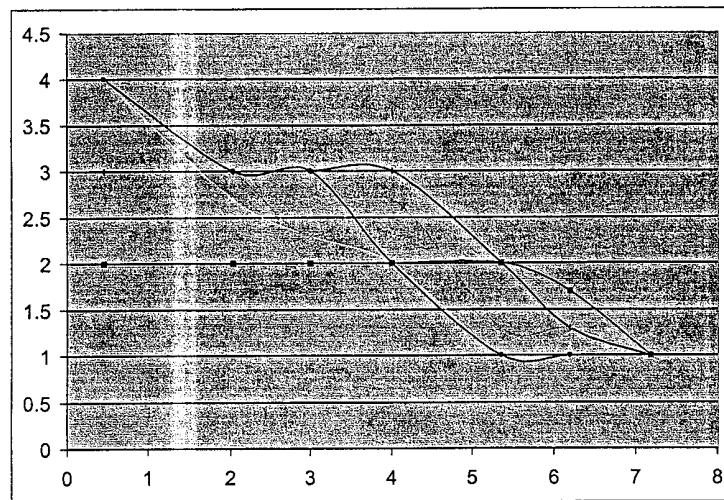
Bullitt viewed at 900 × 600



Bullitt viewed at 360 × 240



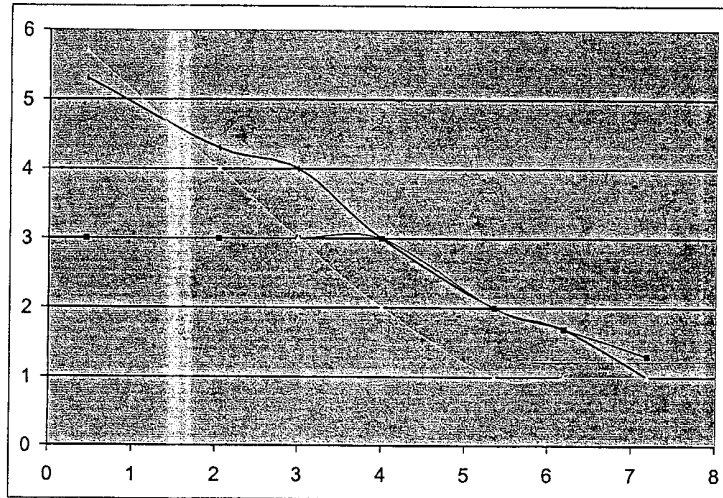
Bullitt viewed at 1152 x 768



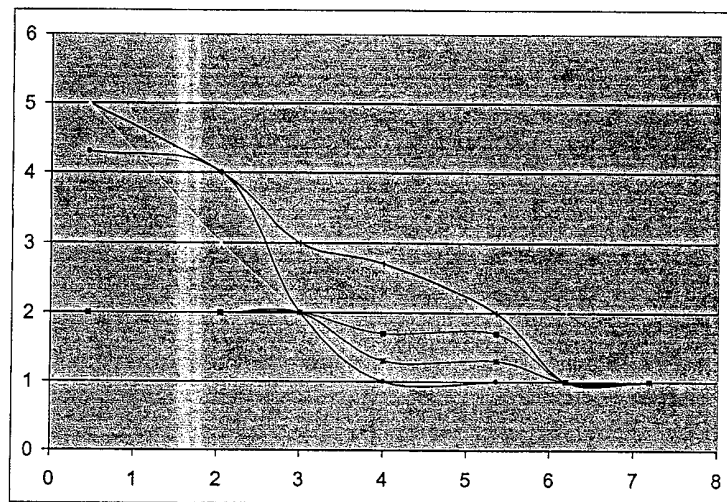
Bullitt viewed at 1600 x 1067

3.3 Fish

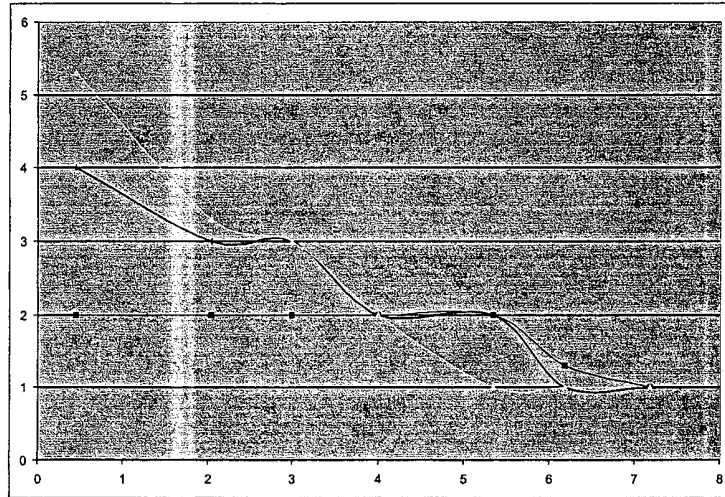
The name of this segment is a bit deceptive in that only the second half of the segment is of fish. The first half is a shot of a giraffe. This video segment has little motion on the whole, but there is one zooming out portion which gave the codec a some trouble. The video segment was recorded with a Canon Elura digital video camera.



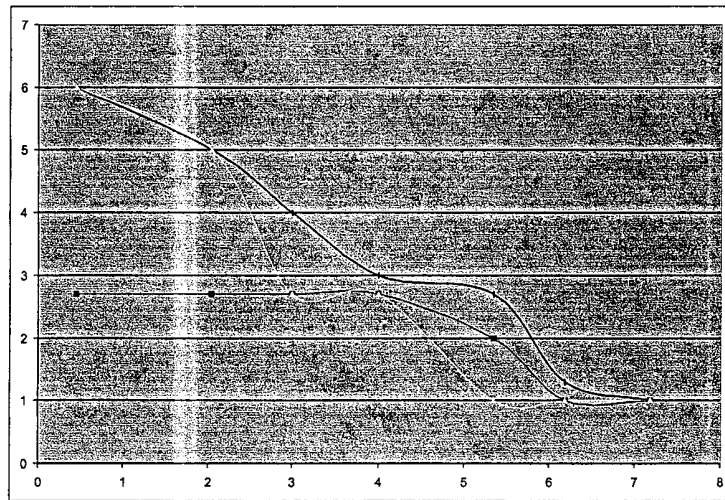
Fish viewed at 720×480



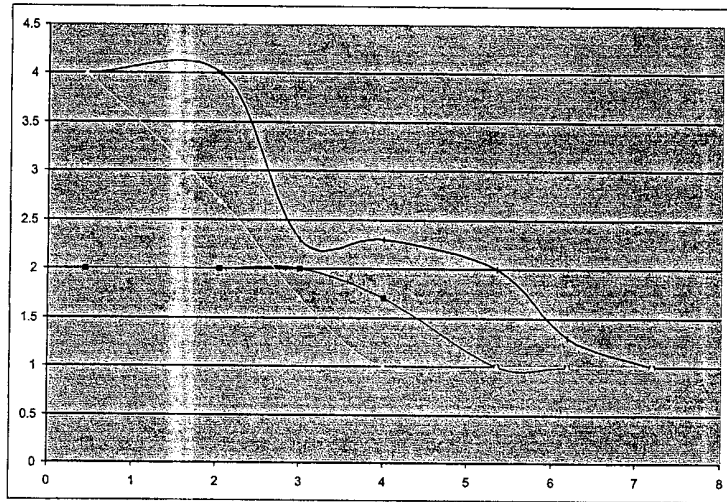
Fish viewed at 720×480



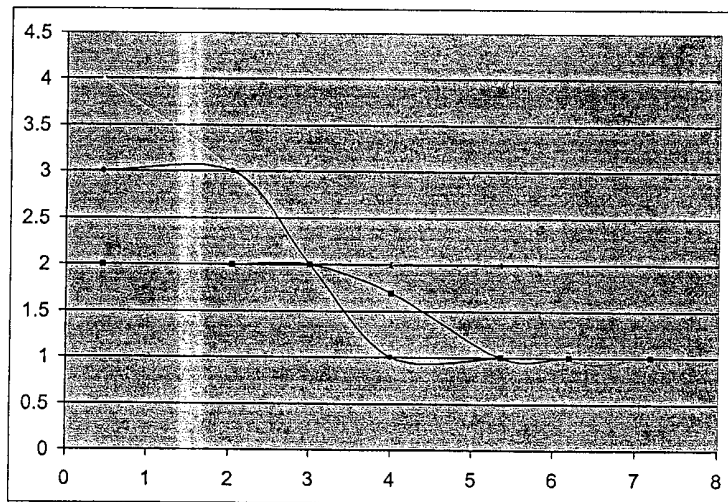
Fish viewed at 900 × 600



Fish viewed at 360 × 240



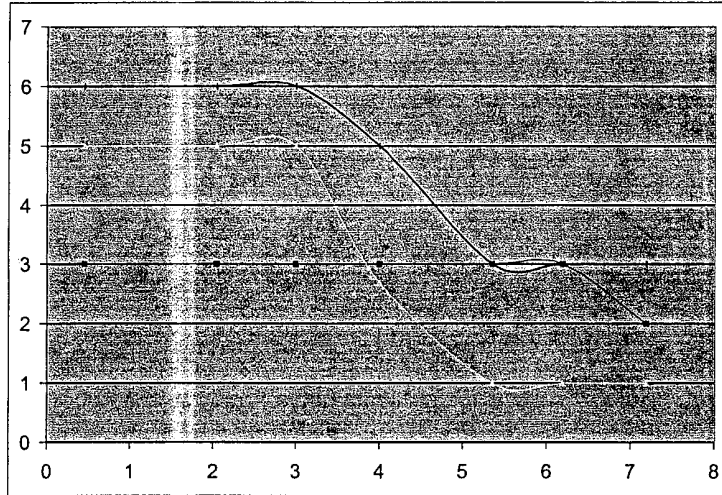
Fish viewed at 1152 x 768



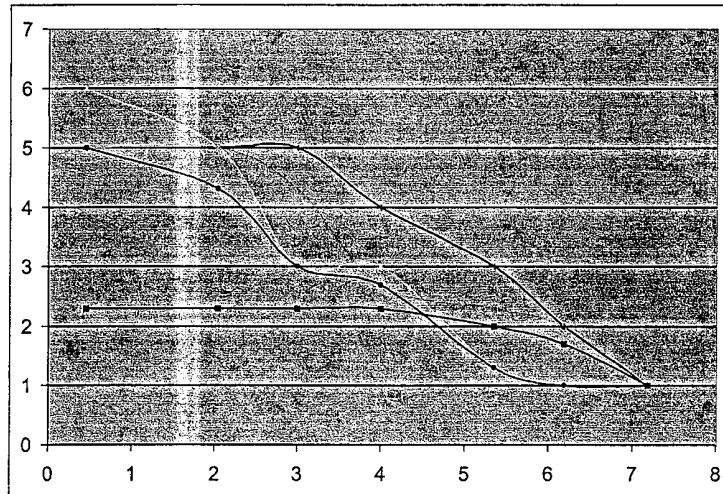
Fish viewed at 1600 x 1067

3.4 Gilda

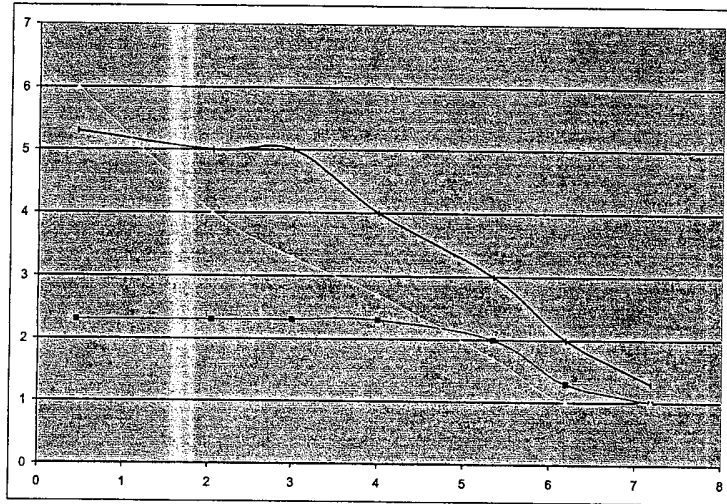
Gilda is a video capture from a high quality movie trailer for the movie "Gilda" found at <http://divx.ctw.cc>. This video segment is somewhat motion intensive.



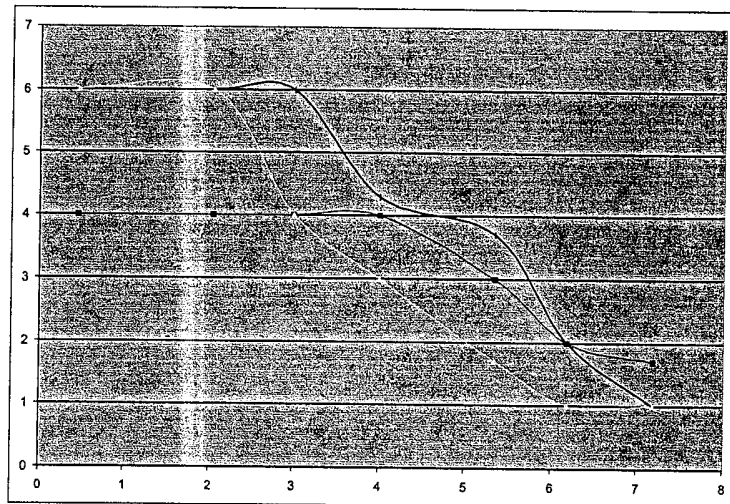
Gilda viewed at 720 × 480



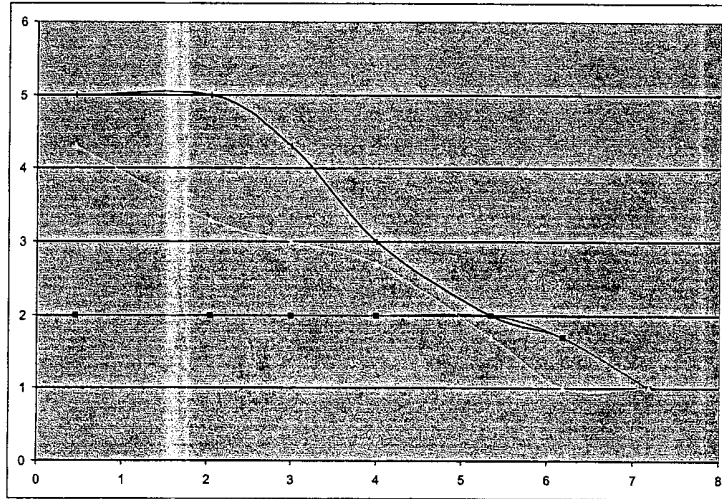
Gilda viewed at 720 × 480



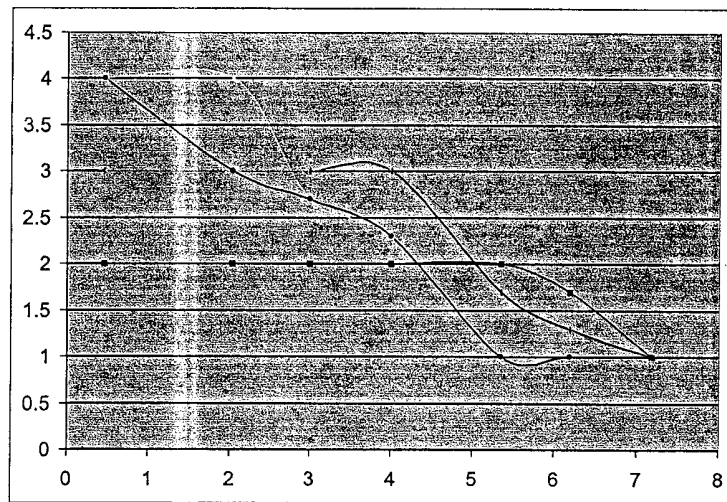
Gilda viewed at 900 × 600



Gilda viewed at 360 × 240



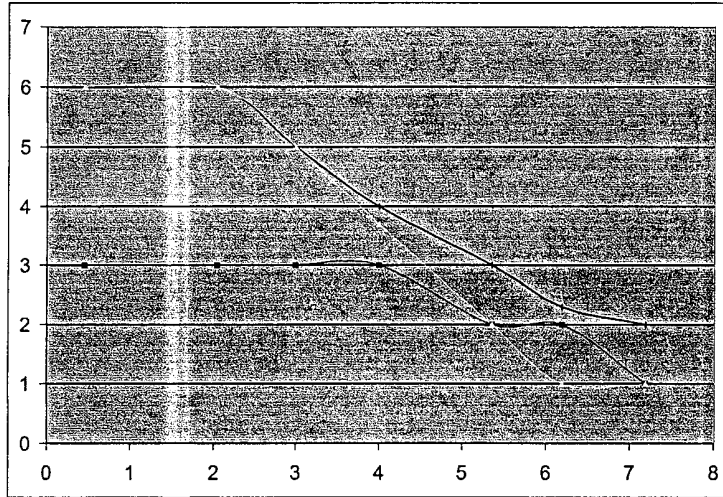
Gilda viewed at 1152 x 768



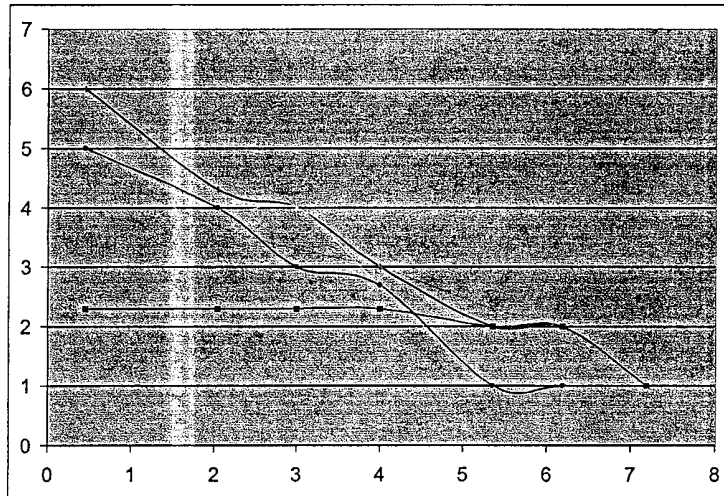
Gilda viewed at 1600 x 1067

3.5 Mars

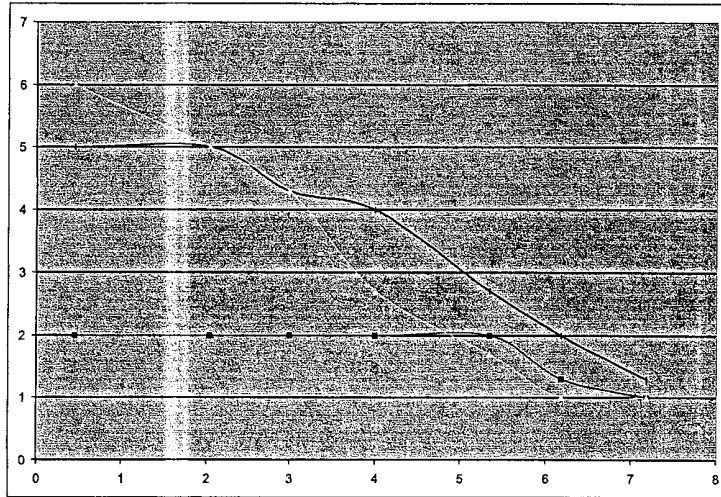
Mars is a video capture from a high quality movie trailer for the movie "Mars" found at <http://divx.ctw.cc>. This video segment is somewhat motion intensive.



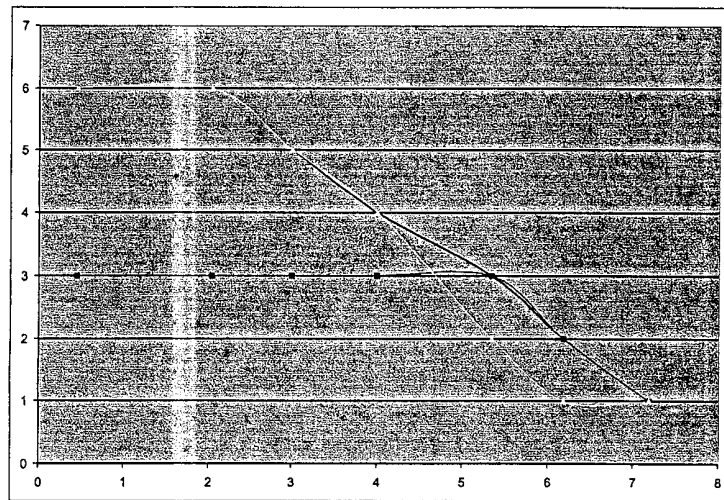
Mars viewed at 720 × 480



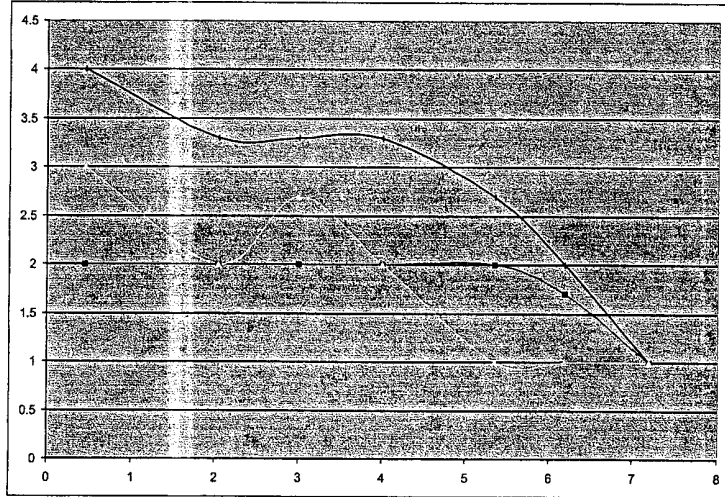
Mars viewed at 720 × 480



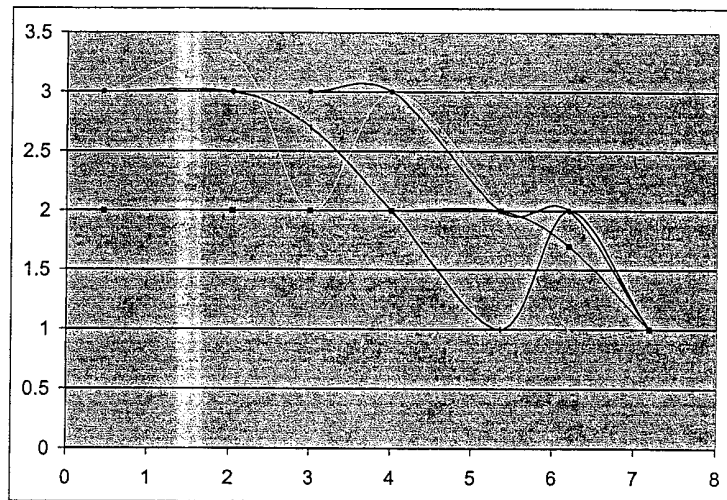
Mars viewed at 900 × 600



Mars viewed at 360 × 240



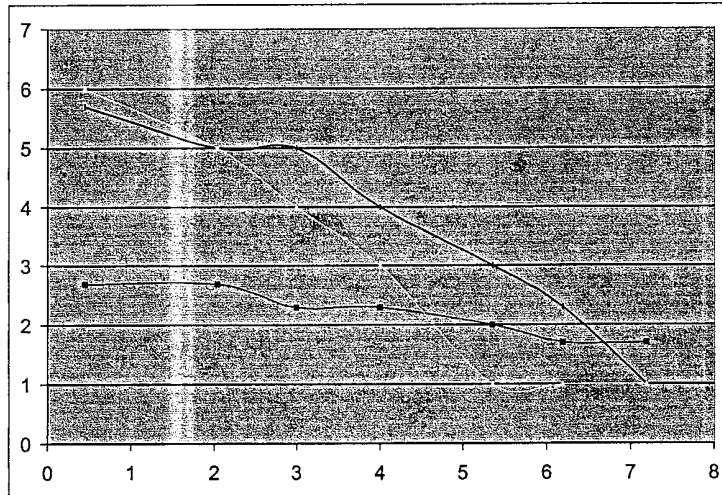
Mars viewed at 1152 x 768



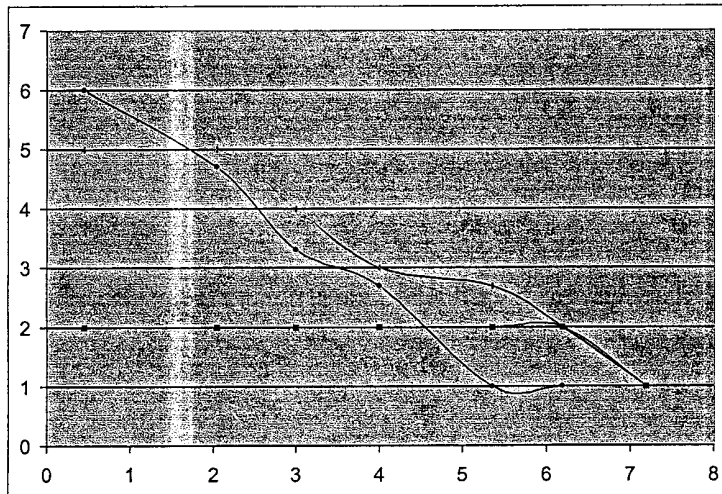
Mars viewed at 1600 x 1067

3.6 Matrix

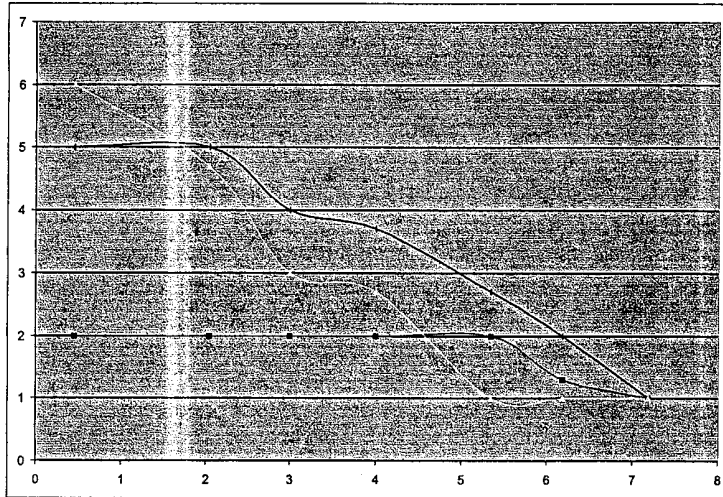
Matrix is a video capture from a high quality movie trailer for the movie "Matrix" found at <http://divx.ctw.cc>. This video segment is very motion intensive.



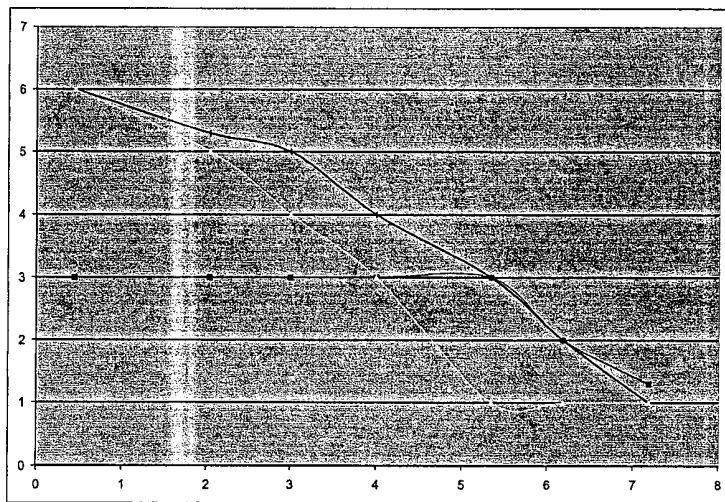
Matrix viewed at 720 × 480



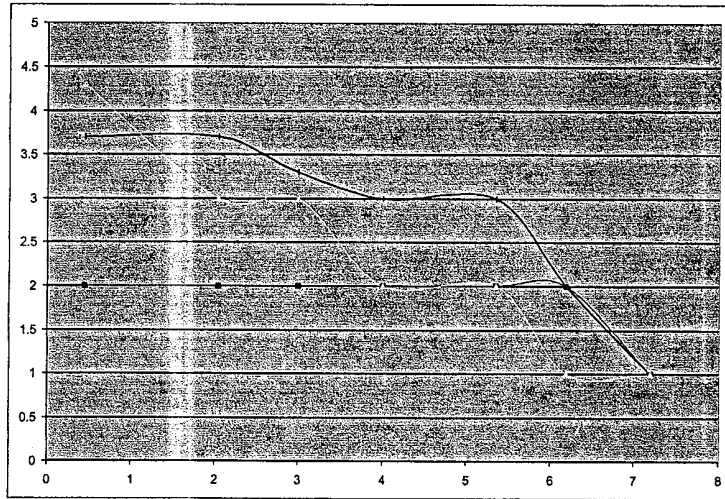
Matrix viewed at 720 × 480



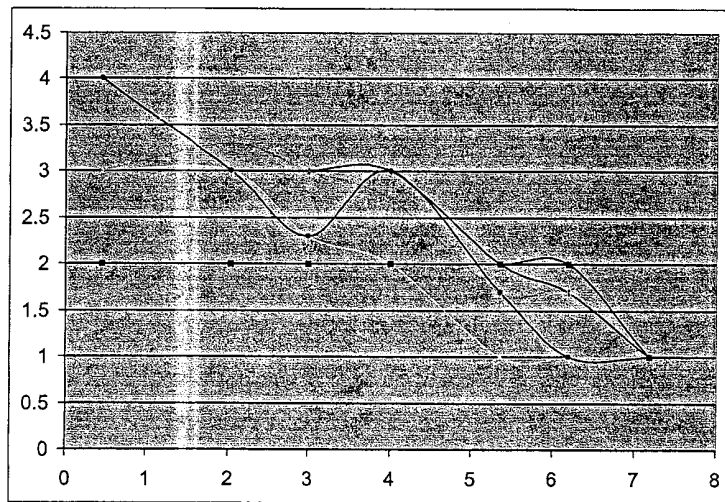
Matrix viewed at 900 × 600



Matrix viewed at 360 × 240



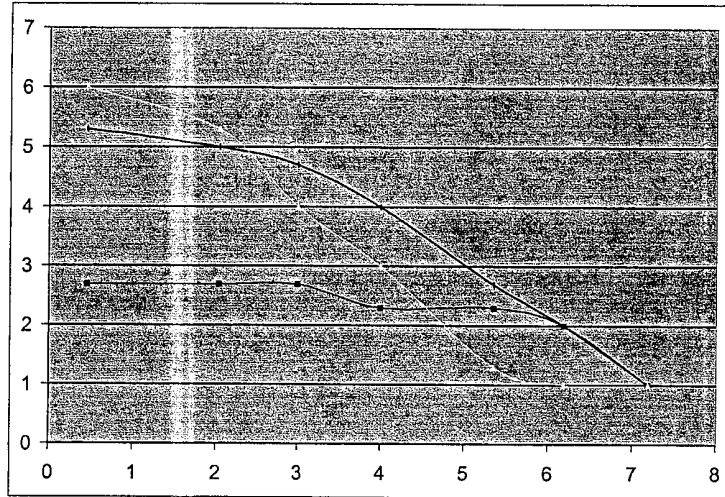
Matrix viewed at 1152 x 768



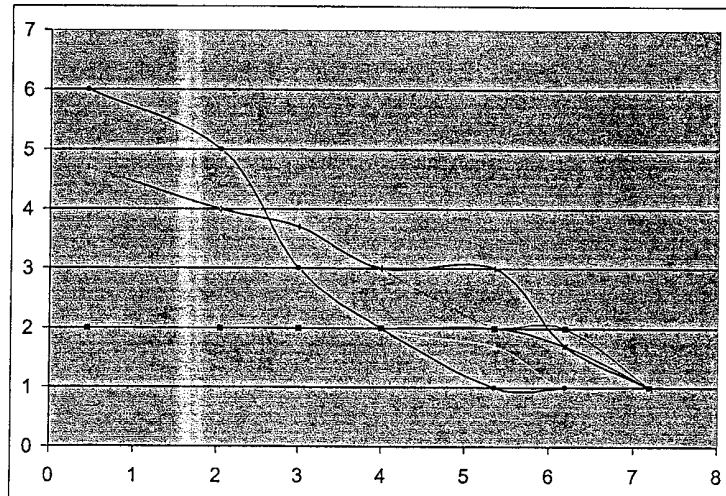
Matrix viewed at 1600 x 1067

3.7 Private

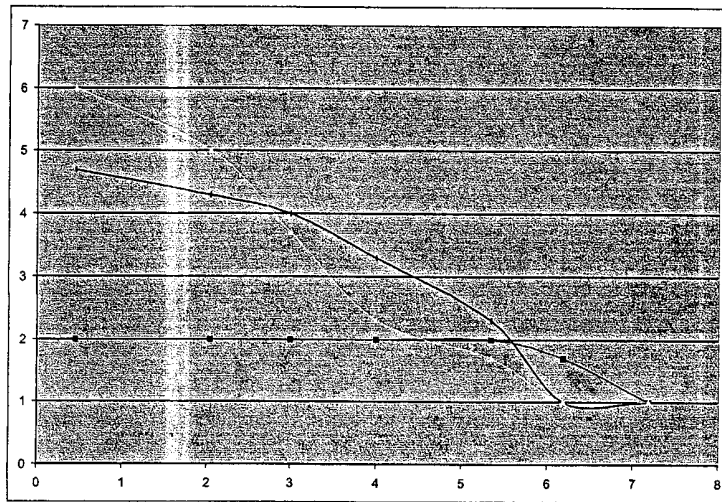
Private is a video capture from a high quality movie trailer for the movie "Saving Private Ryan" found at <http://divx.ctw.cc>. This video segment is very motion intensive.



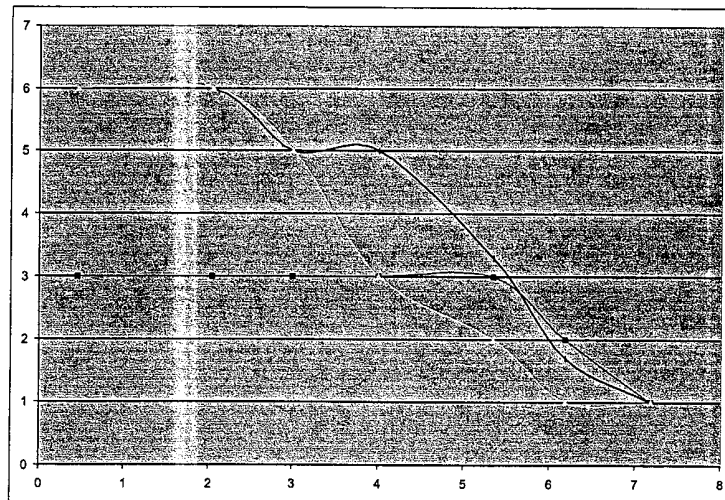
Private viewed at 720 × 480



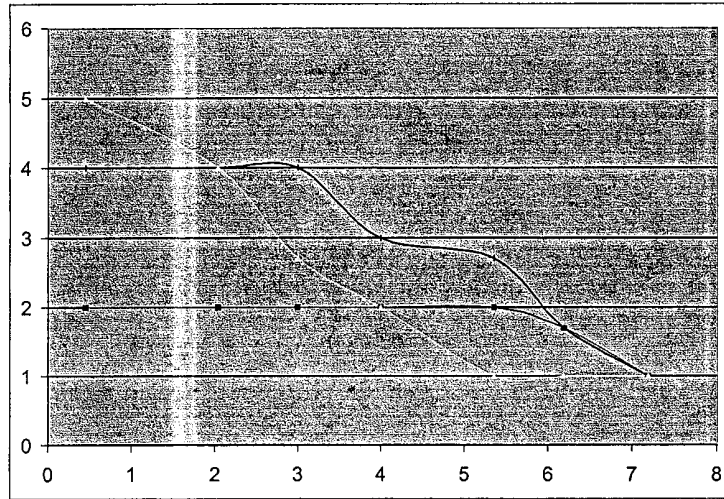
Private viewed at 720 × 480



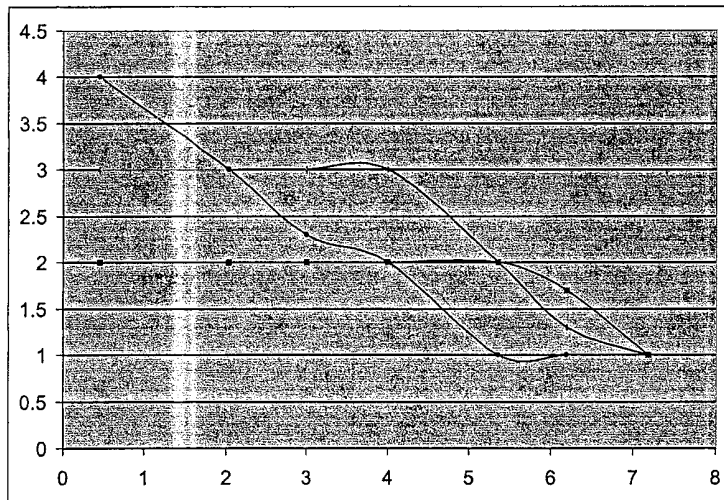
Private viewed at 900 × 600



Private viewed at 360 × 240



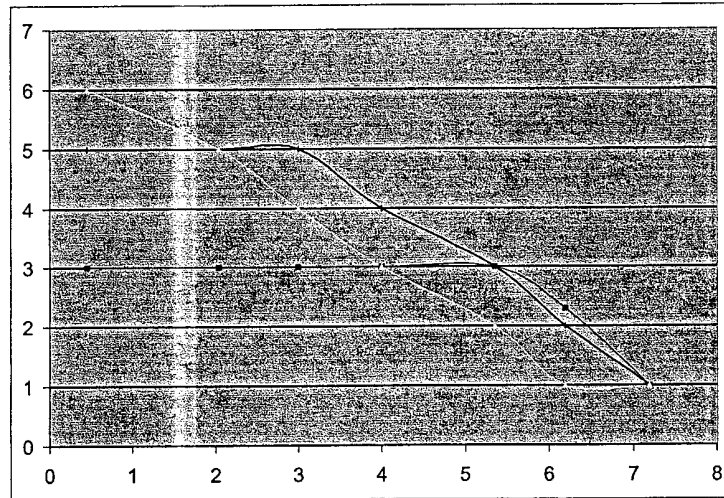
Private viewed at 1152 x 768



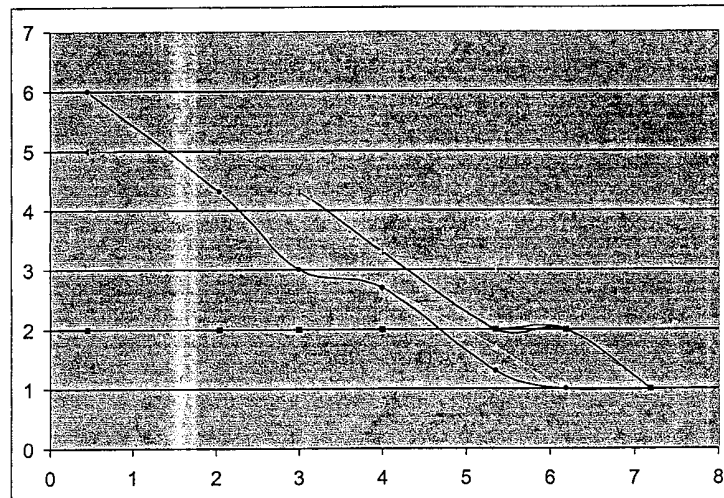
Private viewed at 1600 x 1067

3.8 Private2

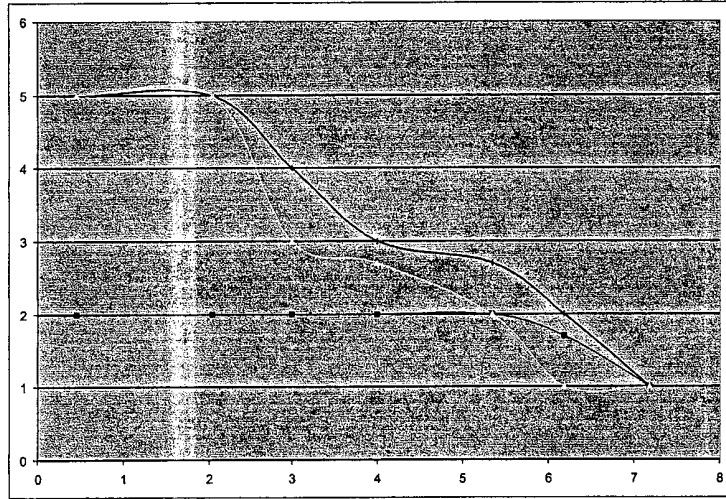
Private2 is another video capture from a high quality movie trailer for the movie "Saving Private Ryan" found at <http://divx.ctw.cc>. This video segment contains little motion.



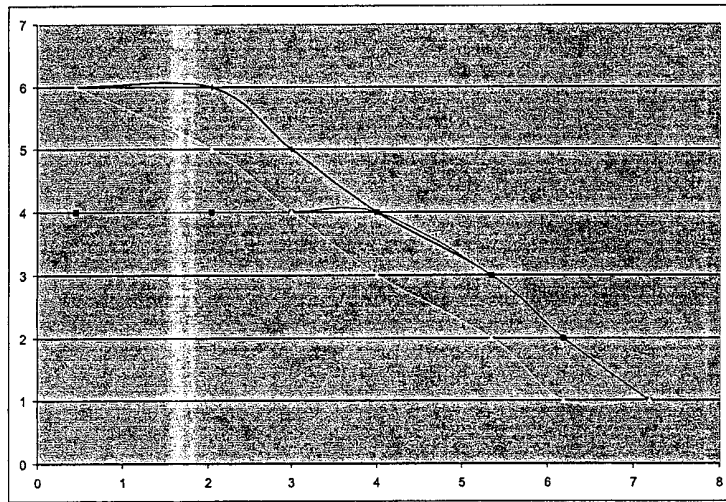
Private2 viewed at 720 × 480



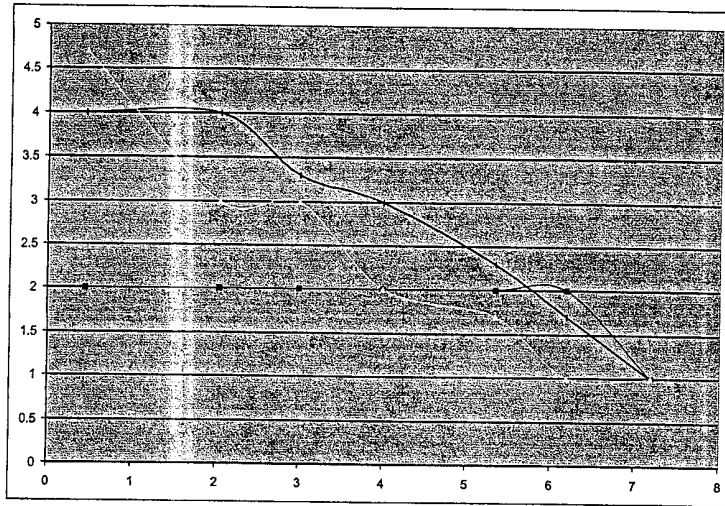
Private2 viewed at 720 × 480



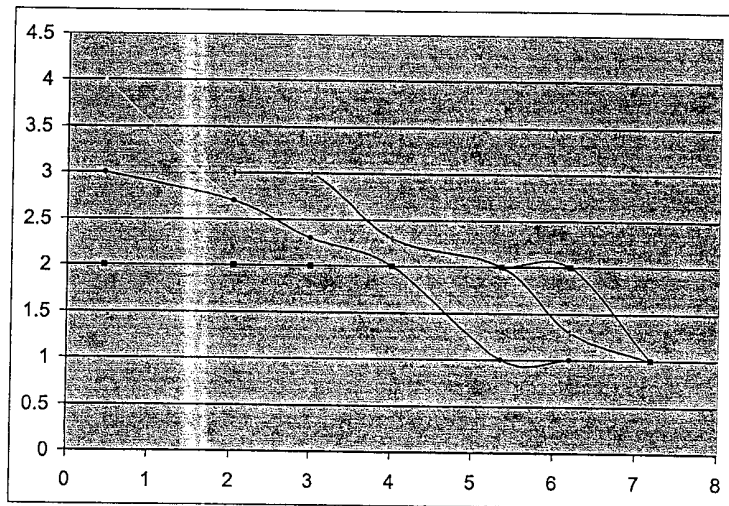
Private2 viewed at 900 × 600



Private2 viewed at 360 × 240



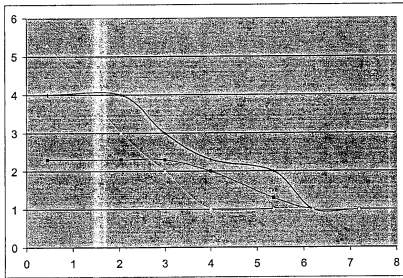
Private2 viewed at 1152 x 768



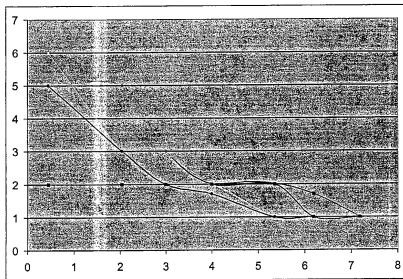
Private2 viewed at 1600 x 1067

3.9 SeaLion

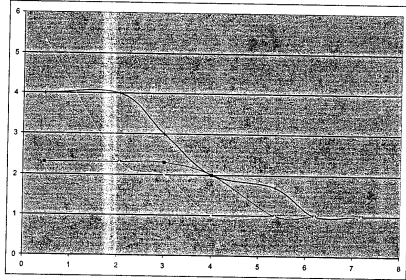
This segment was very difficult. It was taken by a Canon Elura digital video camera through a glass pane. The segment captures a few sea lions swimming in a large tank. The murky water, light reflections, and rippling surface water created a challenging video to compress.



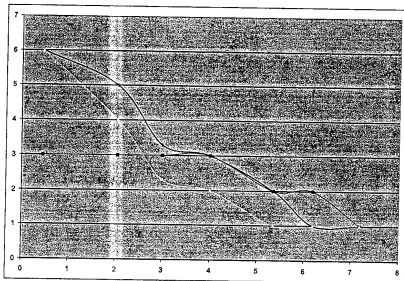
SeaLion viewed at 720 x 480



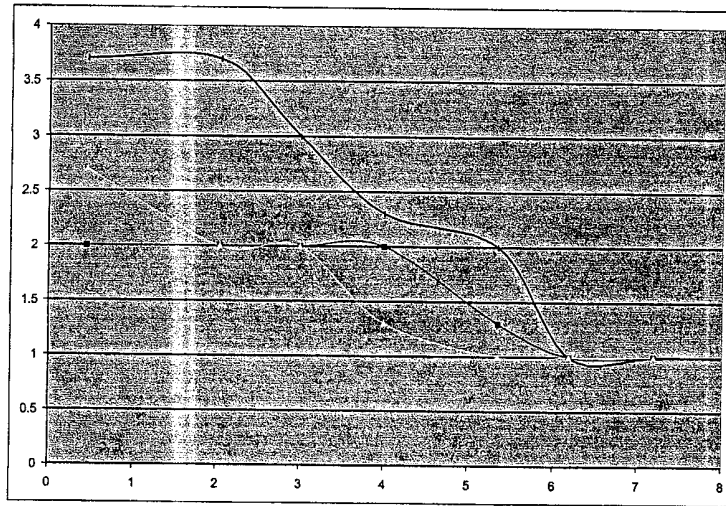
SeaLion viewed at 720 x 480



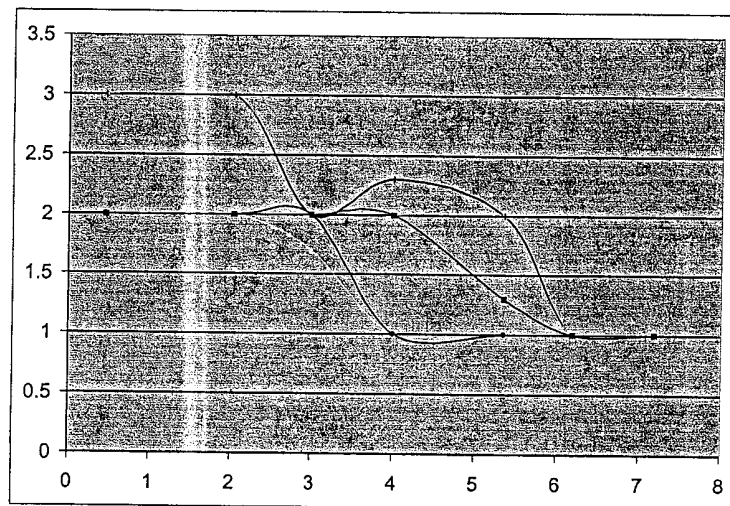
SeaLion viewed at 900 x 600



SeaLion viewed at 360 x 240



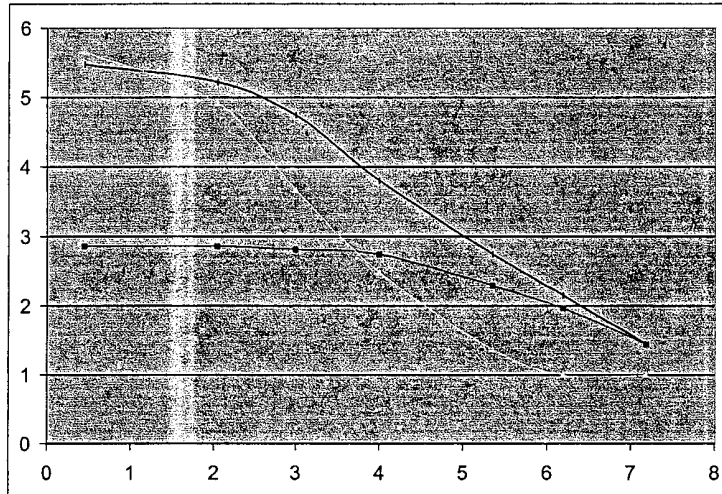
SeaLion viewed at 1152 x 768



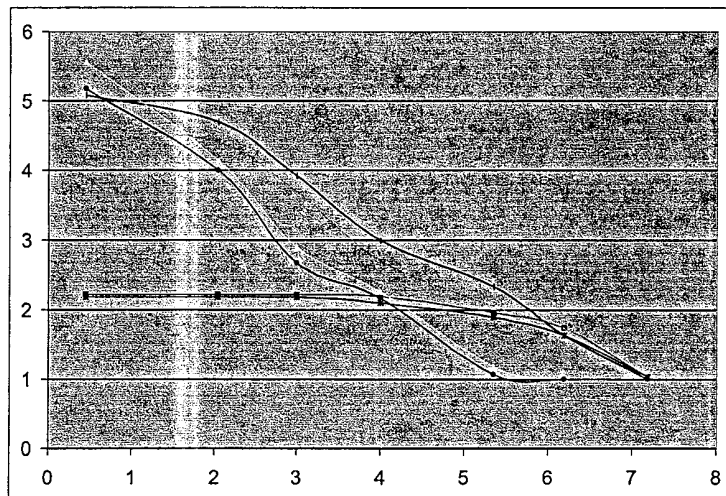
SeaLion viewed at 1600 x 1067

3.10 Average

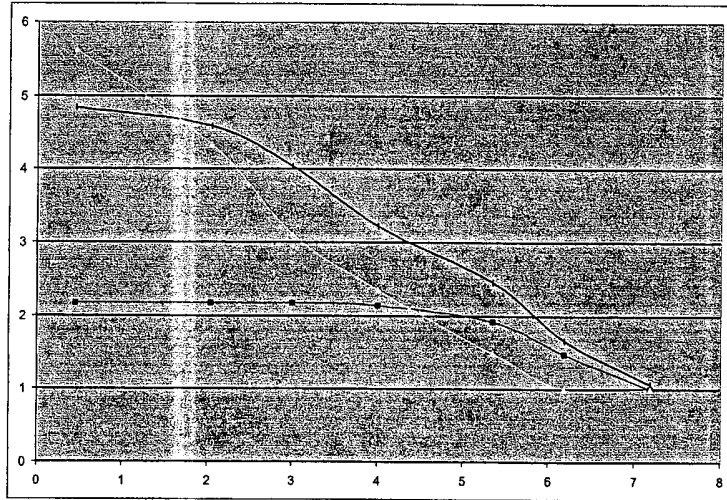
These graphs are a summary of the curves shown above. Each curve is an average of the nine curves for the different video segments.



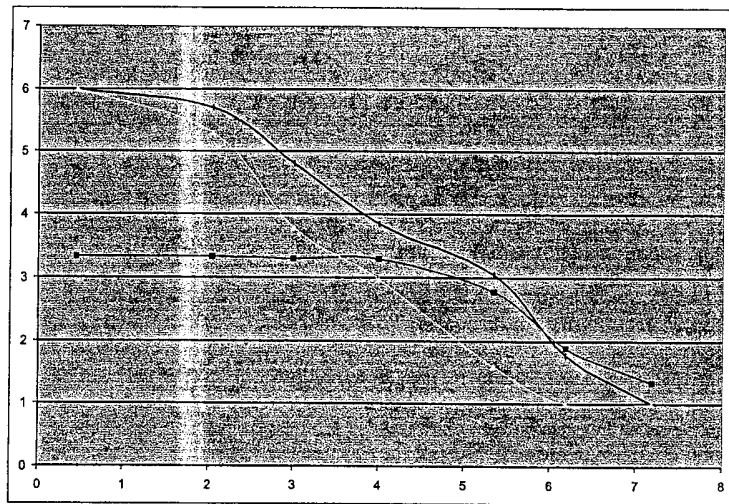
Average of all viewed at 720 × 480



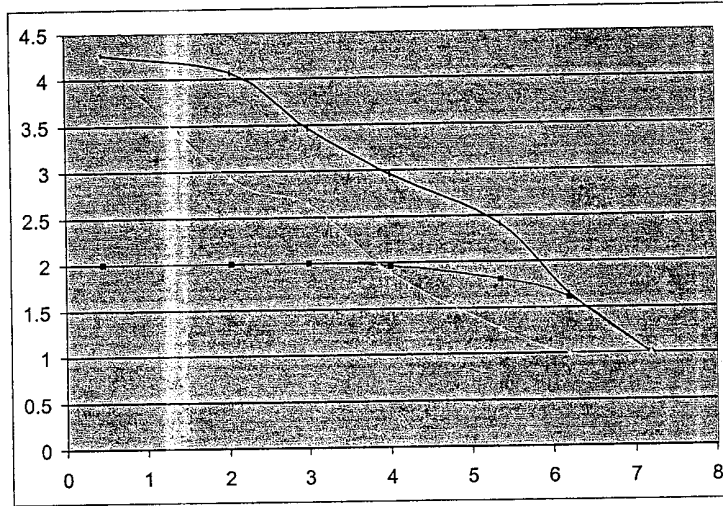
Average of all viewed at 720 × 480



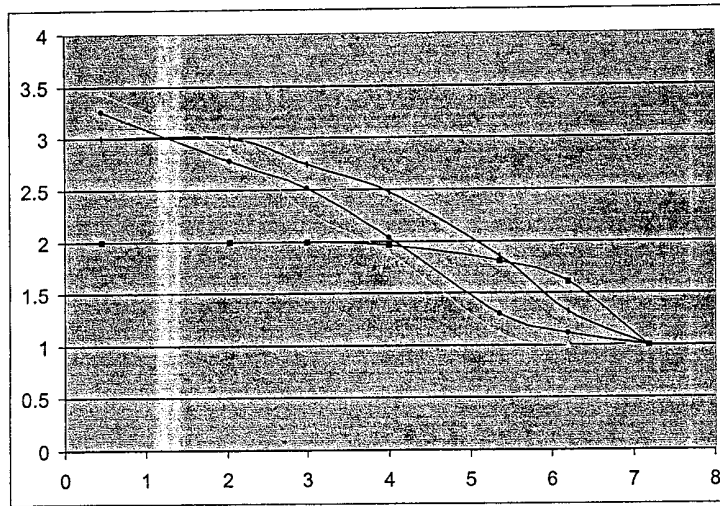
Average of all viewed at 900 × 600



Average of all viewed at 360 × 240



Average of all viewed at 1152 x 768



Average of all viewed at 1600 x 1067