
INTERNET FILM
AN EVOLUTIONARY MEDIUM
SURF 2001
JORDAN BOYD-GRABER
MENTOR: ROBERT ROSENSTONE

Table of Contents

Introduction

DEFINITIONS

In 1999, American commerce seemed to be moving to the Internet. A misanthrope could buy groceries, books, furniture, and pay his utilities online – all without the trouble of interpersonal interaction. Companies were jumping on the bandwagon, affixing the letter "e" to every service or product that could be sold over the Internet. Yet despite this craze, few of these new ventures were truly novel, and looking backward from the rubble of the painful dot-bomb of 2001, even fewer were good ideas.

The rare success stories of the e-explosion are those that merely extended services readily available in other forms to the online arena. Amazon.com is catalogue shopping, Priceline.com is an automated travel agency, and AOL only remains profitable because it used its massive capitalization to move into more mainstream media by through acquisitions. One of the few exceptions is the area of Internet film – a genre that is delivering original content that would not (at least in America) otherwise have an audience or a creative force driving it.

What is Internet Film? The most difficult task in understanding Internet film is defining it by its scope and content. Any experienced web user is probably familiar with animation incorporated into pages such as the infamous "Punch the Monkey and Win" promotion, yet would hardly consider such navigational tools and advertisements a film. Surprisingly, however, the same tools designed to make buttons light up when a user moves his mouse over them have been reimagined to create animations on par with traditional pen-and-ink endeavors.

Figure 1: Internet Ads as Movies?

It would then be reasonable to classify an Internet film as a piece that can be (but not necessarily) appreciated outside of the context of an individual webpage. This does open the door for some advertisements to be considered Internet films, but given the blurred line between self promotion and artistic expression on the Internet, this ambiguity is a necessary evil.

In order to understand how content fits into the definition of an Internet film, consider the example of books. Both Kate Chopin's *The Awakening* and Steven King's *Ride the Bullet* are readily available online, the former from Project Gutenberg and the latter from Amazon.com. Whereas the former is available in print form and has probably been read more often using traditional means, the latter is solely (as of this writing) available on the Internet. It would then be reasonable to assume that *Ride the Bullet* is an "Internet book" because its primary mode of distribution is over the web.

Internet films offer some nuances of transmission, however, that are absent in the printed word. Where a book is a series of characters, easily encoded via digital methods, a movie is more difficult to classify. Is a bootlegged film available only on the Internet still an online film? While it has the same scenes, script, and actors as the original, the audience as well as the technology involved in displaying it are forever changed: gradients are more abrupt,

motion is less smooth, and it is now watched on computer monitors. A new film converted from traditional sources – bootlegged from a theater, ripped from a DVD whose encryption has been broken, or a cartoon captured from TV – is easily recognizable in its new form.

With the exception of theater bootlegging, the critical difference from the original lies in the technology used to send them over the limited bandwidth of the Internet. The codec, or algorithm that compresses a multimedia file, is the primary arbiter of whether a film is an unwatchable digital transcription or a true Internet film. The logical conclusion, then, is that the evolution of Internet film is dependent upon codec development – progress and development in one is contingent on the growth in the other and vice versa.

Buzzwords like "adaptive" and "evolutionary" have invaded everyday parlance, and litter busted dotcom mission statements - fallout from a world attempting to seem innovative and fresh without actually being either. Such misuse behooves us then rigorously to construct meanings for these terms. I would argue that an evolutionary medium is one whose modes of distribution are in flux, a sensible definition given the inherent change involved in "evolution."

Yet none of our media outlets are static - new movie houses with better sound systems and more screens are popping up everywhere *(1)*, and cable and satellite systems deluge the viewer with more choices than ever before. Yet the world of television and cinema is, at least at most levels, still the same as it was forty years ago. Hour-long movies hyped and produced by gigantic film studios play at local theaters with popcorn in the foyer, TV is still dominated by major networks who depend on news and situation comedies for the bulk of their revenue, and if a show is successful, it will reemerge in syndication.

Codecs, however, have a more profound impact on the development of Internet film, however, making an argument for an evolutionary medium in both content and infrastructure more plausible. Codecs shape the message they transmit. Other than the obviously different visual appearance directly addressed in the quantitative aspect of this project, the proprietary nature of codecs also changes the distributed content.

Some things just look better in certain formats. No film maker in her right mind would attempt to create a live action film and then piece the individual movies together in Macromedia Flash, which is the domain of animation. Moreover, some formats work better for action-packed sequences than others. Panning shots, when implemented, are far less suited for web delivery than stable constant shots. These constraints force the adaptation of shooting style as well as difficult decisions when choosing codecs.

The proprietary nature of codecs comes into play because often codecs are only distributed by a single entity, and only one player (provided by an affiliated company) distributed software to play the media. When these players are affiliated with hardware or OS manufacturers, often a choice of a codec is an implicit choice of a preferred operating system. These programs (called players) are happy to suggest content that viewers can watch, thus altering the viewing habits of those who use the players, which then creates advertising revenue for the content providers. The exclusivity and technological limitations affect the users media experience: what he sees, how he sees it, and what other online programming he'll watch.

Content creators conscious of these differences will then choose a codec that their target audience will be able to use, and then keep the limitations of the codec in mind when creating their films. Thus,

the world of Internet film changes every time a new codec is introduced. If it is technically better, and more people will be able to use it, then it will be adopted by the industry. Unlike the world of television and theater, drastic changes in delivery can be accomplished overnight - consumers don't need a new television or theater, just a new player, and more often than not, the supplier of the codec and the player are often one in the same.

Figure 2: Media Players

BACKGROUND Introduction

Film is as much about the content as the presentation. Ornate cathedrals showcased the glamourous pictures of the roaring twenties while the flat-roofed stucco buildings of the thirties reflected the true to life social realism that emerged with nickel cinema matinees. The audience's perception is shaped by the way the film is delivered. In the spirit of Marshall McCluhan, the medium is the message.

Much like the development of video cassette and urban cine-plexes, the media industry is undergoing a paradigm shift *(2)*. The music industry has already seen its traditional distribution modes undercut by the development of web alternatives, but the essence of the media remains unchanged - people still use speakers to listen to music that is identical to conventional counterparts in quality and content.

Unlike music, the quality of Internet-distributed content is not on par with traditional sources. A greater emphasis is placed on media that is easily compressed - like animation and computer-generated images. Moreover, rather than feature length films, the primary content produced by web-focused producers is on relatively short films that appeal specifically to niche markets from Star Wars fans to gays and lesbians *(3)*. Such direct distribution methods are "orient[ed] towards the needs of the audience," unlike traditional media *(4)*. Henry Jenkins of the MIT Technology Review speculates that homebrew films will undermine traditional outlets and usher in a new digital renaissance unencumbered by market concerns.

Like music, film is facing the same threat of piracy and intellectual property dissolution from internet

communities where files are shared without regard to copyright laws. While films require a greater infrastructure than the much hyped mp3 revolution, the development of broadband Internet delivery via agents like Gnutella is as much a cause for alarm for the film industry as Napster was for the music community *(5)*. Current film analysis is still focusing on traditional film venues - when it does look at films designed for the web, such as the wildly popular Lucas in Love, the film is often removed from the context where it garnered its success *(2)*. The Internet film revolution is still seen as an oddity - a glitzy modern paracinema that is a conglomeration of art-house films and sleaze. While some industry insiders such as Dreamworks are embracing technology, most fear it. Once an Internet film breaks out, copies are sent to university departments and critics on traditional media, thus changing the way the movie was meant to be viewed. The Internet is seen as a tertiary medium - a bridge to more lucrative outlets *(6)*.

The technical aspects, however, play a vital role in what the final image looks like. At some point in the transmission of analog data over the Internet, a quantanization must be made to convert the continuous data of the source into discrete information. Even when the source data is discrete and compressed, such as with DVD quality MPEG-2 or digital video, the data rate is far too infrastructure-intensive for current networks to handle. We will ignore lossless compression strategies, as these are irrelevant for multimedia. Instead we will focus on compression strategies that have become the lingua franca of the online world: MPEG, AVI, RealVideo, QuickTime-affiliated codecs, and the new Microsoft codecs derived from MPEG (Motion Pictures Expert Group.

Chronologically, the first of the codecs to be examined was developed in the mid 1980s as a part of a hardware package, but quickly moved beyond its beginnings to become incorporated and almost synonymous with the AVI video format used in windows *(7a)*. The codec uses a technique called vector quantanization, which assigns the changes of each pixel (or group of pixels) to a vector. Clearly, some changes from frame to frame are going to be more common than others, and this technique assigns each of the vectors corresponding to the entire picture to simpler code words. More common vectors are rigorously defined while those that occur less frequently are given broader definitions, leading to acceptable loss of image information *(8)*.

Closely related to Intel's Indio codec is Radius's Cinepak codec, which also employs vector quantanization. Cinepak is less processor intensive, however, and is often used instead of Indeo because of user hardware limitations (or the perception thereof). Because of QuickTime's adoption of the Cinepak codec early on, the Cinepak codec has seemed to be associated with the Apple platform while Indeo has become more associated with the Windows platform.

The Sorenson codec, released in 1998, also uses vector quantanization, but also employs motion prediction to improve the quality of video at very low bandwidths (Brady). The motion prediction looks for blocks of frames that are similar to blocks in previous frames and then encodes the information based on the similarity to those previous blocks by conducting a brute force search of surrounding areas in subsequent frames (CodecCentral Sorenson).

While the previous three codecs can be viewed in a sort of continuum of development, a parallel development was occurring about the same time with the Motion Picture Expert Group which was developing an international and non-proprietary analog of Intel's Indeo. From 1989 to 1993, MPEG devel-

oped a standard for digital video compression based on the Discrete Cosine Transform with frame prediction which moves images from the spatial domain to the frequency domain, reducing redundancy and allowing for easier quantanization with lossy compression (Avila). Because it is not proprietary, MPEG has become a widespread standard because there are no licensing fees associated with creating hardware or software encoders or decoders.

The Microsoft Video codec is derived from a newer codec from MPEG called MPEG-4, which builds upon their proven success. MPEG-4 employs video object planes, deformable texture segmentation, and quad-tree coding *(9)*. Microsoft has adapted MPEG-4, although specific changes remain unclear. Microsoft's embrace of MPEG-4 in their new WV codec has made it a market leader despite the relatively late release and substantial software overheads (PressPass).

The Real Media codec also employs a derivative of the Fourier transformation, but first decomposes the signal into frequency bands. This takes advantage of the time-resolution properties of signals and gives priority to the crucial information for the image discrimination to be sent first, and scales well to settings where there is variable bandwidth *(10)*. Despite its early adoption across the Internet *(11)*, Real Media has fallen behind Microsoft in many areas where scalability is not as important as quality.

Procedure
MATERIALS

1. Hypercam 2.0
2. Java 2.1
3. MATLAB 6
4. RealPlayer 8
5. SCIELAB Matlab Module 1.0
6. SPARC Solaris Workstation
7. Sony DCR-VX1000
8. Terran Cleaner 5
9. QuickTime 5 Pro
10. WindowsMedia Encoder

Procedure
METHODS

Gamma Correction

1. The image was loaded into an array with RGB values in the range [0, 1]. This was stored in the program in an array of classes that had three internal elements consisting of a red, green and blue element. The image could be thought of as a matrix of 1 x 3 sub-matrices.

$$I \equiv \begin{bmatrix} [r_{11}, g_{11}, b_{11}] & \cdots & [r_{1c}, g_{1c}, b_{1c}] \\ \vdots & \ddots & \vdots \\ [r_{r1}, g_{r1}, b_{r1}] & \cdots & [r_{rc}, g_{rc}, b_{rc}] \end{bmatrix}$$

Equation 1

2. Since the only S-CIELAB implementation available is only the Stanford Matlab version, the same quantanization and gamma correction procedure was used so that results could be verified to ensure the accuracy of the algorithm. This requires a different organization of the matrix easily achieved through a function to change the location accessed by each index.

$$I' = \begin{bmatrix} r_{11} & g_{11} & b_{11} \\ \vdots & \vdots & \vdots \\ r_{1c} & g_{1c} & b_{1c} \\ \vdots & \vdots & \vdots \\ r_{rc} & g_{rc} & b_{rc} \end{bmatrix}$$

Equation 2

3. Please note that the method used by Zhang in the Stanford SCIELAB implementation, which called for a reindexing into an *m* x *3n* matrix, was not used.
4. The matrix was multiplied by a scalar, and the floor function was mapped to it. This allows the values to correspond with a gamma correction factor in the matrix.

$$I_g = \lfloor \varrho * I' \rfloor = \begin{bmatrix} \lfloor \varrho * r_{11} \rfloor & \lfloor \varrho * g_{11} \rfloor & \lfloor \varrho * b_{11} \rfloor \\ \vdots & \vdots & \vdots \\ \lfloor \varrho * r_{1\nu} \rfloor & \lfloor \varrho * g_{1\nu} \rfloor & \lfloor \varrho * b_{1\nu} \rfloor \\ \vdots & \vdots & \vdots \\ \lfloor \varrho * r_{\sigma\nu} \rfloor & \lfloor \varrho * g_{\sigma\nu} \rfloor & \lfloor \varrho * b_{\sigma\nu} \rfloor \end{bmatrix}$$

Equation 3

5. The corresponding gamma correction values are obtained by replacing the previous value with the lookup table value and putting the matrix back into the original image form, thus mapping linear display intensity to relative linear display intensity.

Edge Detection

1. Within the SCIELABImage class, a function to detect the edges within an image after it had been passed to the class via the constructor was implemented. A new image is created, where the edges of an image are high intensity regions and non-edge regions are black.
2. Because Java stores information in a BufferedImage as a raster, the edges - places where there are major color gradients - can be found by applying an appropriate convolution transformation. The following kernel from the Java documentation is applied:

$$k_e = \begin{bmatrix} 0 & -1 & 0 \\ 4 & -1 & 0 \\ 0 & -1 & 0 \end{bmatrix}$$

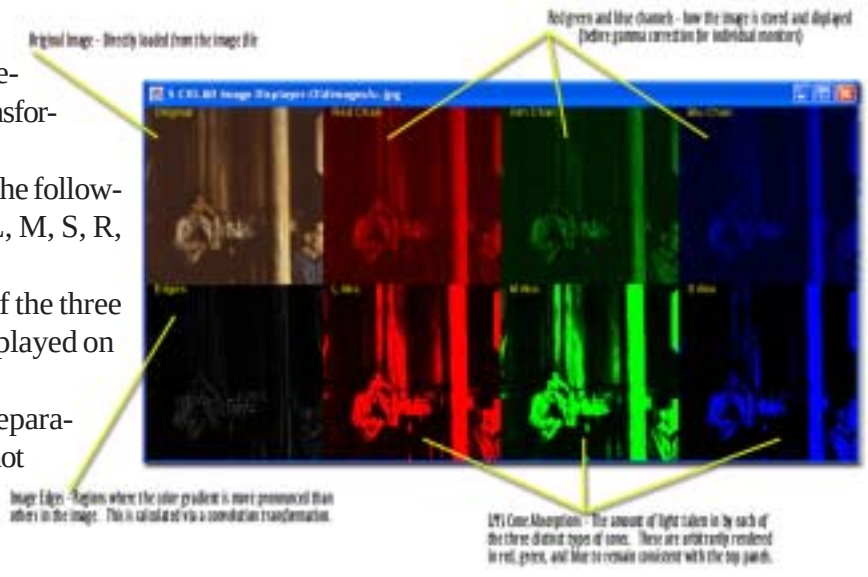
Equation 4

3. After the convolution is applied, it is stored in a new BufferedImage within the SCIELABImage class.

Converting RGB values into LMS

1. The desired matrix form was three-column, requiring following the transformation:
2. Once the transformation is made, the following result was obtained (where L, M, S, R, G, and B are column vectors):
3. The relative absorption of each of the three retinal cone types can now be displayed on screen.

The actual implementation of the color separation and image analysis is shown in screenshot 1, which is the ImageDisplayer class. The figure outlines the contents of the ImageDisplayer frame.



Running the SCIELAB algorithm

1. A new script was created that takes two input images, converts RGB image data to LMS, and then calculates the color error using the Matlab files obtained from the Imaging Group at Stanford.
2. The output of the algorithm was then directed to output files which could then be read by any application. Because Matlab is proprietary, a new standalone program was created that would perform the same task even on platforms without Matlab.
3. The output file was saved to ASCII text and then reformatted by an additional C++ program that read in the file and replaced all whitespace with carriage returns.

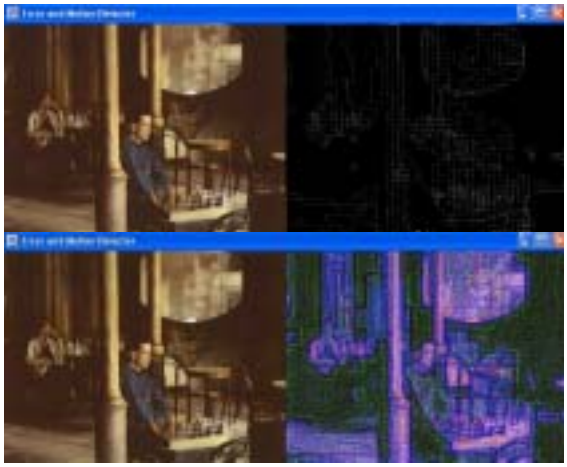


Figure 3: SCIELAB Error

Motion Determination

1. Because it was desired to correlate compression quality with motion of an image, a means of monitoring the motion of objects within a pair of images was created. The general outline of the of the figure is shown below. A constraint which is fed into the program is the maximum distance to search for a neighboring edge.
2. If the algorithm exceeds the distance in pixels another edge can be in the previous image, the search aborts and returns negative one. If the pixel in question was not an edge in the first place, it's value is -2.
3. This computation is carried out by the motion class, which returns an array of integers for each pixel in the image.
4. After some initial experimentation, "motion" detection was also deemed useful in looking at two images compressed with different codecs. Edges should be in the same position in a compressed image as they are in an uncompressed image. Thus, any "motion" can be considered additional error.

Displaying Motion and Errors

1. A method of displaying these images was needed, so a simple class without the massive overhead of ImageDisplayer was created for quick and dirty calculation and viewing of image errors and motion.
2. The image was turned into a half-intensity grayscale image. Using the other half of the available intensity range, the error values were displayed using the blue channel and motion with green.
3. Since the SCIELAB errors were saved as positive real numbers without an upper bound, an arbitrary upper bound for errors (17.5) was used as the maximum error. Because most errors are far less than this value, the amount of error is easily visualized throughout an image.

Figure 4: Error and Motion

4. Each of the edges was displayed with 1/4 green intensity, and the available quarter of the green intensity was used to display motion relative to the value of the "maximum distance" - the greatest number of pixels the algorithm would look to find another edge.
5. The screenshots below demonstrate this display. The first merely shows motion while the second shows both error and same image "motion." The top images display the edges detected in the image (compressed or previous).

Movie Processing Procedure

1. Film samples were collected using a Sony DV Professional grade camera. Care was taken to ensure that a wide range of lighting conditions and motion levels were observed. Approximately one minute of each situation was recorded - the scenes collected are below, with a small image of the first frame (these images are from the uncompressed source), a short description, and the name associated with the movie.
2. In addition two the four live action videos, two public domain cartoons were downloaded in the Macromedia Flash format and converted to 30 fps image sequences using QuickTime Pro 5 and then to a DV stream using Terran Cleaner 5.
3. The source tape was transferred to a standard 30 MB/sec DV video file and chopped into 30 second clips using Final Cut Pro editing software.
4. The sources were then moved into Terran Cleaner 5 and then converted new files with the following codecs set at 400 x 300 pixel dimensions at 500 kbs:

These codecs were selected because of the wide use, historic significance and clout within the industry. Notable omissions include MPEG - 2 and MPEG - 4 - the former is designed for high bandwidth settings outside the scope of the project and the latter was unavailable at the time of the encoding.

5. Individual frames of the movies were then extracted and saved as uncompressed TIFF images at 2 fps by QuickTime Pro 5 from both the uncompressed DV file as well as each file compressed by the individual codecs where possible.
6. If QuickTime was unable to read the files after they were encoded (Real and WindowsMedia), a freeware program called HyperCam was used capture the movies from the screen raster and save it to an uncompressed AVI file - QuickTime was then used to extract the images from these sources. Because of slight jittering in the first few frames, new reference frames from the DV files were encoded for the Real and Windows Media files.
7. The source files were scaled down to 400 pixels by 300 pixels using a B-Spline filter.
8. A Unix script was written to process each of the files that outputted the average error of each image comparison from the source and encoded file as well as the motion from the previous frame examined.
9. It was assumed that the average error for each frame is approximately normal since it is average of 120000 pixels (Central Limit Theorem). An ANOVA test was run for each of the clips to determine which codec (if any) created the least amount of error using, rejecting the null at 95% confidence.
10. Since motion seemed to be a general linear trend with variation about said linear trend, simple regression models were calculated for each codec using error as a response to the motion factor. The r-squared factor was considered the most important factor, as variation within the error was explained by variation within the motion.

Results
FILM SAMPLES

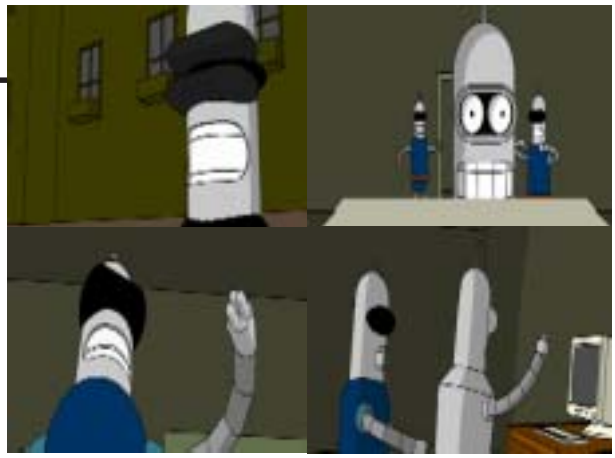
These are the films shot with the Sony DV camera. Each are thirtyseconds in length, and contrast in visual composition.

Identifier: *Action*
Source: *Filmed*

This video was shot at the intersection of Foothills Boulevard and Dartmouth in Claremont, CA - just north of the Claremont Colleges. Cars are passing through the intersection quickly in bright daylight. The background is relatively static.

Identifier: *Bender*
Source: *http://www.flashkit.com*

Created by Diego C. Zuberbuhler, this animation features intense action sequences as well as fairly vibrant color sequences. This film also has several stretches where very little changes from one frame to the next, which helps to demonstrate some compression qualities of animations. This was converted to DV from the SWF file by QuickTime.



Identifier: *Kids*
Source: *Filmed*

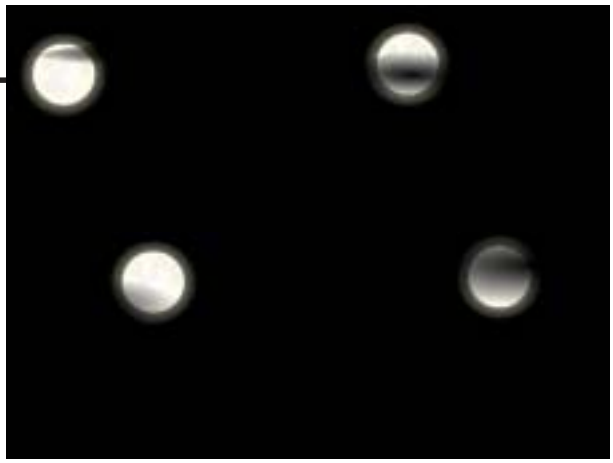
As the camera slowly pans across the garden, two small children run across the field of view of the camera. This features subdued color, some motion and moderate light.

Identifier: *Light Talk*
Source: *Filmed*

This film was shot using medium light and a stationary camera. The participates moved around slightly, but were primarily stationary. This video was designed to emulate newscasts.

Identifier: *Moon*
Source: *Gnutella*

This monochrome animation was downloaded from a file sharing community to emphasize the advantages of an animation created using a simple color scheme as well as very slight motion as the moon moves across the sky. This film, like "Bender" was converted to DV from Flash by QuickTime.



Identifier: *Out*
Source: *Filmed*

Also shot on the Scripps campus in a brightly lit open garden, this slowly pans across a scene with limeted color depth but bright colors. Little is moving or changing except the frame itself.

ERROR Results

After each of the clips had been processed using the SCIELAB algorithm, the output was fed into MINITAB, a statistical analysis program, where the best codec for each clip was determined using an ANOVA test. A summarry of the results are below. The complete information is available in the appendix. A short summarry of the information in the appendix is on the right.

Clip	Codec	Error Mean	S.D.	Comments
Action	WM 8.0	12.978	3.825	The MPEG4 standard was designed to handle large amounts of motion - this result is consistent with those claims.
Bender	WM 8.0	7.313	1.400	This cartoon also had many instances of quick moving scenes, thus giving the edge to Mircosoft's codec.
Kids	Indeo	3.448	1.239	There was no clear codec with the lowest error - Cinepack, Indeo, and Sorenson had overlapping confidence intervals. The limited color range helped these codecs.
Moon	Cinepak	0.8433	0.0778	WindowsMedia's confidence interval also overlapped for this simple animation.
Light Talk	Cinepak	0.737	0.107	Indeo's confidence interval also overlapped. These two codecs performing well is consistent with their evolution from teleconferencing codecs.
Out	Cinepak	9.731	1.135	WindowsMedia's confidence interval also overlapped.

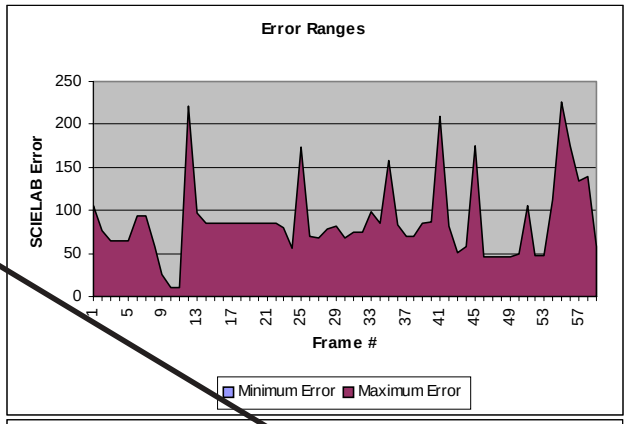
WindowsMedia had four clips where it was the leading codec (Action, Bender, Moon, and Out), as did Cinepak (Kids, Moon, LightTalk and Out). Despite equivalent performance, there seems to be a definite preference for WindowsMedia within the market.

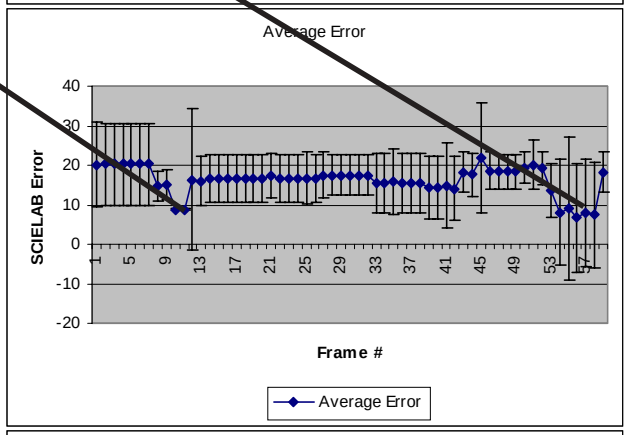
Graphs

Frames

Frame 9, 55

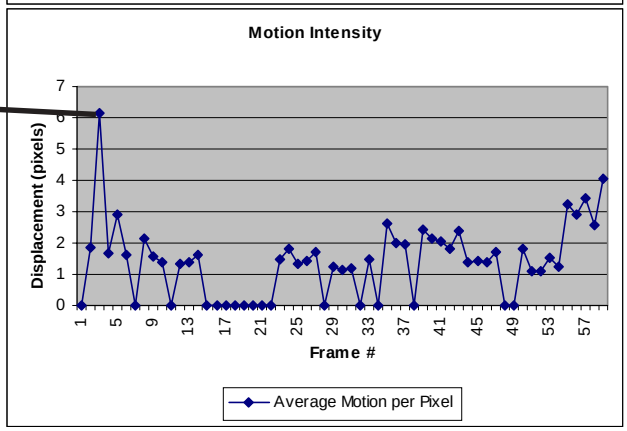
As the frame washes out or decreases color depth, the error decreases dramatically.





Frame 3

While very few pixels are moving, my algorithm picks up the sharp outline of the moving "mouth" and assigns a high motion value.



ANOVA

Codec ***Errors with Confidence Intervals***

Mean Error

```
Level        N     Mean   StDev
bender      59    18.66   4.758                          (-*-)
bender_a    59    16.16   3.507                       (-*-)
bender_q    60    16.32   3.601                       (-*-)
bender_m    60    23.99   5.740                                 (-*-)
bender_w    30    7.313   1.400   (-*-)
bender_r    30    15.76   3.531                 (-*-)

Pooled StDev =    4.201          6.0      12.0      18.0      24.0
```

Codec with least SCIELAB error

Results

MOTION

The R-squared adjusted values for each of the linear regressions (Error vs. Motion) is below. Those codecs with R-squared adjusted values above 5.0% are shaded.

	Sorenson	Indeo	Cinepak	Real	WM	MPEG
Action	0.0	00.	2.2	0.0	0.0	9.0
Bender	2.0	0.7	0.0	0.0	0.0	5.1
Kids	5.1	59.6	59.4	0.0	14.7	30.1
Moon	0.0	0.0	0.0	0.0	0.0	0.3
Light Talk	0.0	0.0	0.0	2.3	0.0	0.0
Out	10.5	22.2	7.8	0.0	0.0	48.3

The two movies that had panning shots and the MPEG codec showed high R-squared values, thus implying that shots where the entire field is in motion or those encoded with the MPEG codec will likely have higher error.

The sprawling corporations that were created during the seventies and eighties were unlike anything that international corporate culture had ever seen before. Not only were there gargantuan corporations straddling the globe, but these companies were also highly centralized and coordinated, with intricate supply chains dictating the course of everyday affairs. Consequently, a demand was created for means of communication that would allow every aspect of the corporation to be able to communicate across continents.

There were already methods to communicate across large distances, but as companies realized that visual communication was not just possible, but actually feasible, a substantial effort was launched to create reliable and cheap visual communication over existing networks. The result was the H.261 codec designed for transmission of images that didn't change much from one frame to the next. Unlike modern codecs, this was designed for data rates that were multiples of 64 kB/sec, relatively inflexible for modern use, where bandwidths can vary without warning *(12)*.

Despite hype about video phones, there was little possibility for this technology to come to home users for some time. These applications required the development of dedicated lines and a unified standard for interoperability. Even with the development of faster and faster connections, the residential dial-up access was still limited to 14.4 kbs until 1994 *(13)*, and with most computer users unwilling to make a leap to using multimedia - they were still figuring out the basics.

As quoted in Wired Magazine, the president of RealNetworks, then called Progressive, was focusing on audio:

"There was an overwhelming impedance mismatch between the existing consumer-infrastructure 486-based PCs and 14.4 modems and the requirements of video." (14)

Neither the computer hardware nor the bandwidth was in place. While teleconferencing in the corporate world was taking off, these initiatives were using specialized hardware like that used in television to broadcast and encode their message. The PCs in homes were designed for clerical tasks, not multimedia.

With the adoption and support of 56k modems, as well as the release of Windows 95, which caught up to Apple's support for multimedia, the technology was in place in 1996 for a provider to develop online content for streaming. RealNetworks, which had already established itself has a distributor of Internet radio entered the field with the fairly adaptable RealVideo codec. Claiming "newscast" quality video *(15a)*, RealNetworks lined up several major content distributers months after the announcement of its standard in 1997 *(15b)*.

When RealNetworks premiered in 1997, it showcased short films by director Spike Lee, a live action film featuring a tap dancer talking about his shoes in a closeup shots and a relatively short cartoon. Already, the trends of simplifying content and color depth were in play - the tap dancer only briefly danced, and Lee predominately employed closeups of his shoes and face, cutting the scenes rather than panning. The cartoon - animation has traditionally been the strong

point of RealVideo - was also rather simplistic. Still, the effort was derided by many of the critics present, who called RealVideo content "teensy, grainy, jerky pictures" (14).

Internet broadcasting became trendy, with the Rolling Stones and Major League Baseball getting on the bandwagon, but the technological limitations prevented all but a few content providers from sending out quality content. For several years, the only major form of Internet broadcasting available were newscasts from CNN and MSNBC, who directly converted their television content to RealVideo and streamed it over the Internet.

The emphasis on news broadcasting is not surprising, considering the strong performance of the Indeo codec – the oldest of the bunch – for shots with limited motion and color depth. The low quality worked for information pushers, who had a substantial user base that could transition easily from the streaming radio broadcasts which were already popular, but the low quality scared off the mainstream dial-up user.

The majority of Internet films that were made just after the release of RealVideo were either excruciatingly long MPEGS that forced users to download the entire file before viewing - a distribution strategy that only really took off in the adult entertainment arena - or animations that took advantage of their visual simplicity. It was this niche market where the majority of online film growth would emerge, straining the boundaries of technology.

Macromedia Flash, a toolkit designed to facilitate the incorporation of multimedia into webpages, was created mainly for buttons and rollovers for HTML navigation, but certainly not for longer movies. Yet, given the weak performance of the pre-existing codecs for animation, people thinking about breaking into the world of online animation thought that something better could be done.

I spoke to Lawrence Marvit, who created an online film called *Cupids* for Thrave.com, about his involvement with Internet animation. He likened the process of adapting Flash for animation and movies to using turntables for DJ "scratching," creating a new musical form by altering how traditional vinyl records are played. Flash animation has become increasingly popular, with games and cartoon series moving onto the web. The technology allows animators to stretch their wings with instant user feedback and interaction in the animation process.

Because Flash stores information about the individual layers of colored shapes and their motion across the screen, the animation is significantly smaller than most codecs could offer - without degradation in quality. Even when the Flash files are rendered, they take up significantly less space than their live-action counterparts. So while the difficulties of Internet film had been solved for animation and workable alternatives had been found for newscasts, a broader solution had not been found that would work for any type of media - the explosion in animation could not be duplicated, despite numerous attempts.

With the release of the WindowsMedia format in 1999 along with the continual improvements offered by Cinepak and Sorenson, a new wave of Internet film was made possible as these codecs did not have high correlation of error to movement - unlike MPEG - and also had relatively lower error than Sorenson and Cinepak for live action. AtomFilms, a Seattle company, began airing short films on the web. MediaTrip.com followed up with the smash hits *Lucas in Love* and *409*, which quickly brought online film the attention of the general public. The introduction of the Microsoft codecs based on the MPEG-4 stan-

dard has allowed the creation of content that worked well regardless of the type of film being compressed.

Nevertheless, the world of Internet Film has been primarily focused on films which do not stress the technology. Nussbaum and Levy's *George Lucas in Love*, a tongue-in-cheek parody of the Star Wars director's college days, featured tight close-ups to convey facial expression, often cutting off the top of the forehead and chin in their shots. Panning was done slowly, if at all, and the numerous visual gags were over the top - a vaudeville approach to ensure that the movie's message got past the codecs. While few action films become popular in online film - which is severely dominated by drama and comedy - action films like *405*, about a motorist caught in the path of a landing airliner, don't rely on intense action sequences to convey the story. Bruce Branit and Jeremy Hunt only employed two scenes that had significant motion, the rest was building up of suspense or implied action.

Additionally, a spoken narrative has become a central aspect of many of the more successful online films. Apart from helping to quickly establish the mood of a short film (a dictate of the viewing environment - mainstream viewers don't want to spend hours squinting at their computer monitors), the narrative helps to supplant the visual images of the film when the connection can no longer support quality images. Two of the more popular animations on AtomFilms were *A Letter from the Western Front* and *The Periwig Maker*, which both used extensive narratives to overlay the film's images. *A Letter from the Western Front* also used only still images with slight animation for flickering lights or drifting clouds, creating haunting images that aren't disrupted by swift changes or motion within a scene.

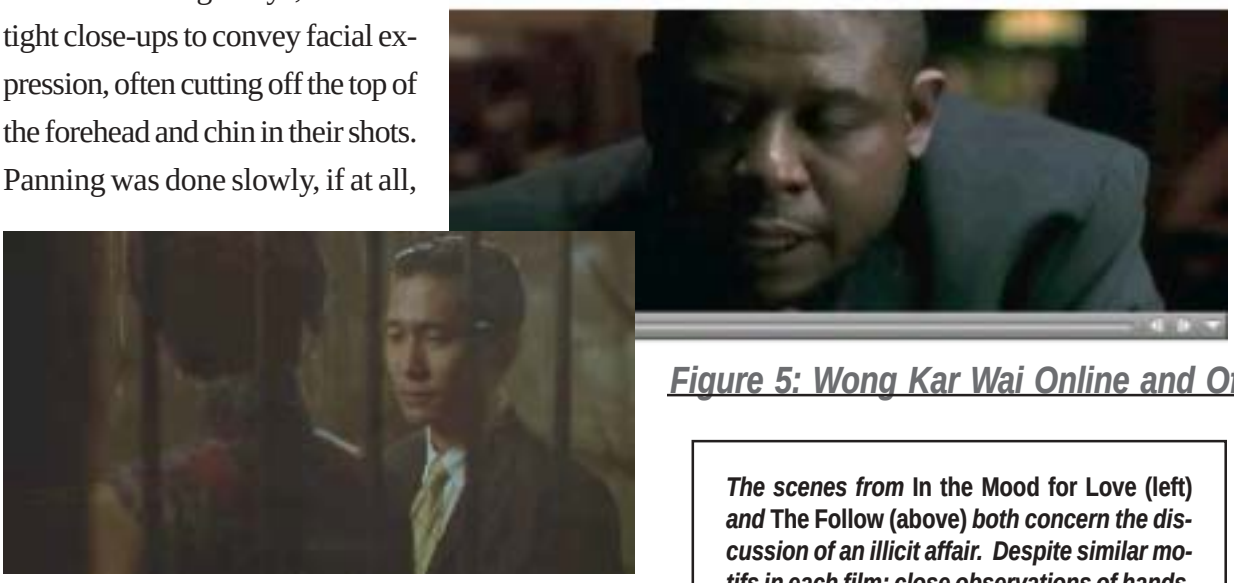


Figure 5: Wong Kar Wai Online and Off

The scenes from* In the Mood for Love (left) *and* The Follow (above) *both concern the discussion of an illicit affair. Despite similar motifs in each film: close observations of hands, choreography of actors following each other, etc., the director employs vastly different camera shots in analogous pivotal moments.

Riding high on the wave of the dot-com revolution, various Internet film houses emerged, offering varied content. PlanetOut and AtomFilms both offered a large selection of gay and lesbian films, which had heretofore been confined to the festival circuit. Likewise, Sandrine Cassidy of USC said that in December of 1999, she was "receiving phone calls every ten minutes" to put their content online. After signing an agreement with USC, AtomFilms began streaming USC's films in the WindowsMedia and RealVideo formats.

PIRACY Discussion

Codecs have also enabled piracy to flourish. Just as the mp3 codec allowed music to be transferred online with ease, video codecs have created a large piracy community comparable to the more infamous Napster in depth if not breadth of files exchanged. Like the more conventional Internet film community, pirates have moved with each major codec release. While the early days of video file trading were mostly pornographic MPEGs minutes long, RealVideo has allowed massive archives of *The Simpsons* to find their way online, and the WindowsMedia codec - albeit in the hacked DivX ;) form - has allowed for the major Hollywood blockbusters to emerge online. In an attempt to stem the tide, the major studios will soon roll out an alternative to piracy - essentially the same movies encoded in the same way - for limited rental.

Internet Relay Chat, or IRC, grew as a way that people could talk to each other without connecting to centralized servers. A user would connect to a central server, which serves as only a directory for the rooms that users have created on their computers. Once a user creates a room and other people connect to it, the role of the server is finished. Once in a room, the people can talk to each other - such chat rooms became the forums of Internet discussion as connectivity spread across the nation.

People used the IRC and mIRC (a slight derivative) software to discuss their favorite programs, and once file sharing was added to the software, the same revolutionary programs and hardware that enabled movie makers to go digital with just a home PC also allowed home users to record programs from television or videocassettes just as easily as they had done with VCRs. Rather than just talking about the shows in the chatrooms, people began sharing the shows.

Such means became the only reasonable way for people outside of the united states to watch popular American programs, as many nations only can watch US shows after they've gone into syndication. Likewise, East coast users can put out a television program two and a half hours before fans in the Mountain and Pacific time zones could watch it legally.

The concept of IRC is still the primary means of distributing pirated material - but it has become much more decentralized and more accessible to the technological neophyte. Just like Napster created a popularization of the mp3 format and music piracy, there is now a critical mass of users populating the distributed file sharing systems of Gnutella, allowing users to share files over the Internet instantly, but unlike Napster, there is no centralized agency that can be held responsible for the actions of the users of the system.

Piracy, however, presents an intriguing way of analyzing which codecs users prefer to use. Often, multiple users will create versions of a popular television program for trading online - when users download a work, they too become distributors. Users can now download the same file from them as long as they have there Gnutella program running. Thus, demand instantly creates supply, resulting in the most popular format becoming readily available.

Moreover, we need not worry about the relative prices or availability of codecs, as the people involved obviously have little regard for intellectual property. Since Internet pirates are relatively unencumbered by the constraints of licensing costs as well as

distribution annoyances (they are creating content for themselves more than others - sharing is an afterthought), those interested in codec adoption have an opportunity to see which formats are preferred by the community as a whole.

It is perhaps naive to overlook factors such as ease of use during the encoding process, but many encoders support multiple formats seamlessly (such as Terran's Cleaner), and the encoders available from the top codec makers are all fairly easy to use for someone savvy enough to unlock a DVD using DeCSS or a capture card.

Based upon a quick survey to support an overwhelming trend that has been reported by countless Gnutella users, animated media seems to overwhelmingly use RealVideo for encoding, short clips make use of Cinepak, AVI, and mpeg encoding, and longer full-length action movies use Microsoft's more advanced codecs or derivatives. A table summarizing the results is below, which supports the trends discussed in the results section: Windows Media handles action and animation well, while movies requiring less motion have a broader range of codecs.

Codec	*Gnutella Hits*
Microsoft, including DivX ;)	230
MPEG	47
Real	36
Indeo	14
QuickTime	7

Figure 5: Error and Motion

A Gnutella search for "Simpsons," a popular pirated television series, revealed the following distribution of codecs, consistent with the quality analysis.

Discussion

The Critic, an acerbic animated comedy starring Jon Lovitz, has been picked up by ABC, Fox, and Comedy Central before finally finding a new life on the Internet. Here, it has moved to shorter formats with fewer characters, yet still maintaining its scathing parodies of popular films. The Internet has given a new life to a franchise that was - to all observers - dead for the third time. Yet with the decreased costs of production and distribution, the Internet might be able to create a media item that couldn't exist before the Internet.

But the impact of digital film is felt far beyond the computer. The popular, if critically panned, *The Blair Witch Project* capitalized on all that the new digital age had to offer. Film makers Dan Myrick and Eduardo Sanchez shot and edited their film on inexpensive computer equipment and generated valuable word of mouth advertising on the Internet, which translated into a big release by a major motion picture studio (22).

Lucas in Love created an instant hype in online communities, all while working within the confines of Apple's Cinepak codec. Subsequently, the film moved onto Amazon.com where it was sold as a cassette and DVD, moving away from its Internet roots and landing its creator a job within the traditional movie Industry. With the essentially free nature of making and distributing a movie to the

world, it is possible to bypass the traditional avenues of film production and promotion, which is outside the scope of this project - the crucial aspect is that creative talent is emerging behind Internet film.

Moreover, Internet film is being realized as a marketing tool by big money as well as big names. LucasFilm has adeptly fostered "FanFlicks," short, not for profit films that encroach on copyrights but ultimately create interest in the Star Wars universe. BMW Films, however, has rolled out the big guns in for online film, bankrolling Guy Richie, Ang Lee, and Wong Kar Wai to produce films that star Clive Owens as a professional driver (of BMW cars) for hire.

Despite being the epitome of consumerism - television ads and product placement encourage viewers to watch a seven minute car commercial while banner ads flash at the top of their screen - it has created professional films from professionals that have permeated the medium, as well as overcoming the limitations of codecs. The films look wonderful in both QuickTime and WindowsMedia, and take advantage of proprietary technology to create a DVD-Like experience (23).

Despite the implosion of the dot-com craze, Internet film continues to be a growth area. The initiative to create online movie rentals is growing, just as Korean film makers attempt to use the Internet to secure funding for ambitious projects (24). Internet film, with its low entry costs and wide visibility, remains an excellent way for films to achieve wide visibility almost instantly, making it the route of choice for activists and ambitious auteurs alike.

Unfortunately, the development of intellectual property rights on the Internet obfusified, preventing smooth development of the medium. Lawrence Marvit expressed concerns that he felt were typical of media authors during the dot-com craze – there were so many people trying to get as much content as possible onto the Internet that often the traditional contracts that would have been used in more traditional spheres were overlooked.

The legal ambiguity inherent in a field that is imperfectly handled by our copyright system is only exacerbated by the growing problem of piracy online – trading of illegal files has become almost ubiquitous, but the dichotomy of an overly harsh legal penalty along side non-existent enforcement has created an atmosphere of free-reign in the underground community tinged with fear. The DMCA, passed by Congress in 1999, has created an atmosphere of suspicion strong enough to prevent openness in the bootleg community, but has not been enforced enough to curb the alarming trends.

As this project demonstrated, codecs perform differently for varying genres of video content. As a result, a bitter turf war is brewing between the major suppliers of codecs. Despite the Redmond origins of Glaser, the founder of Progressive Networks, and Microsoft's investment, Microsoft has repeatedly tried to edge out competing multimedia providers from their Internet Explorer Browser, most recently by attempting to remove "Netscape style" plug-ins from their upcoming version of their browser (25).

Because of the growing Balkanization of online video, users must either install a handful of plug-ins for their browser from Microsoft, RealMedia, and Apple to successfully browse the web or pick and choose content from those that support their chosen plug-in. As a result, several groups have attempted to hijack Microsoft's adaptation of the MPEG-4 standard. DivX ;), a codec

that uses Microsoft encoding for video and the ever-popular MP3 format for sound, has gained significant ground in the bootleg community because of its high quality, illegal nature (accompanied by appropriately subversive dogma), and ease of modification.

The trends of codec adoption would seem to suggest that given Microsoft's dual domination of both quality and marketing presence, the future of online Multimedia is theirs, since standards are quickly adopted when released and dropped when surpassed technologically. While a single provider of encoding would prevent a segmentation of the Internet film community, many would be concerned about the future of a medium controlled by Microsoft.

While Microsoft has gained a superior codec at fairly large transfer rates, the move to handheld devices creates a new opportunity for superior codecs at smaller data rates – such as Sorenson and Flash – that would change the focus from quality to that of compressibility, as it was at the dawn of Internet multimedia.

Refinement and Extension

Discussion

This study only considered mainstream codecs at a single bitrate. Because many codecs are designed for a specific bandwidth range, a refinement of this study would certainly need the scaling of the codecs to work over ranges that would be typical of Internet transmission. This would be especially critical as emphasis is placed on the development of codecs effective for wireless appliances that would typically have bandwidths consistent with early modems.

The quantitative aspect of this research also neglected many codecs that are currently on the periphery, focusing on the mainstream codecs that have dominated the industry. There are many competing codecs out there, and perhaps their limited penetration is due more to marketing than to technological brilliance. A more robust investigation would include a broader array of codecs, especially those that differed substantially in basic principles from the ones investigated here.

A greater refinement of the qualitative algorithm is also warranted. The SCIELAB calculations, while taking color depth and viewing angle into account, are designed for static images and do not consider the effects of rapidly shifting color fields - while a checkerboard pattern in an image would have a high error rating when compared with a solid color field, a rapidly shifting checkerboard pattern would appear similar to that of the static color field.

Of course, this is a plastic arena, and the technology as well as the players involved are constantly changing. The author feels that the growing emphasis on low bandwidth, comparatively less sophisticated handheld systems would be an interesting direction for this research to explore further, tackling the new move toward sprite-based multimedia systems that would take considerably less overhead than existing systems - encoding the information one element at a time, and the corresponding impact this would have on the content created.

Bibliography

1. "Weekend Boxoffice for Aug. 10 – Aug. 12, 2001" (Cinema 1, http://www.cinema1.com/cgi-bin/rankings.pl?0101).
2. R. Ebert, "Movies on the Net" (Yahoo Internet Life Winter 2000, http://www.zdnet.com/yil/content/mag/0004/movies.html).
3. G. Miler, "Era of Short Film Reborn on Net." (LA Times 19 June 2000, http://www.latimes.com/news/state/updates/lat_short000619.htm).
4. M. Smith, Journal of Popular Culture 33.2, 90 (Fall 1999).
5. D. Birchall, "Thieves Like Us," (Sight and Sound October 2000, http://www.bfi.org.uk/sightandsound/2000_10/thieves.html).
6. S. Chase, "Internet film delivery will spawn sequels" (*The Globe and Mail* 25 Jan. 2001. http://www.globeandmail.com/offsite/Film/20010125/TWMOVI.html).
7.
    a. Codec Central, "Codec Central Indeo 3.2" (Terran, http://www.icanstream.tv/CodecCentral/Codecs/Indeo.html).
    b. - - -. "Sorenson Video" Terran. 4 Aug. 2001 (Terran, http://www.icanstream.tv/CodecCentral/Codecs/Sorenson.html).
8. Brady, Russell, Dupart, "Apple Licenses Sorenson Vision's Leading Video Technology for QuickTime 3.0" (Apple Computer, http://product.info.apple.com/pr/press.releases/1998/q2/980106.pr.rel.sorenson.html).
9. S.J. Solari, *Digital Video and Audio Compression*. (McGraw-Hill, New York, NY, 1997).
10. M. Ghanbari, *Video Coding: an Introduction to Standard Codecs*, C. J. Hughes, D. Parsons, G. White Ed. (Institution of Electrical Engineers, London, England, 1999).
11. "Progressive Networks Announces RealVideo" (Progressive Networks, http://agassiz.prognet.com/company/pressroom/pr/97/realvideo.html).
12. P. Cherriman, "H.261 Video Codec" (Mobile Multimedia Networking, http://wwwmobile.ecs.soton.ac.uk/peter/).
13. R. Arnold, *A Brief History of Computing* (War Baby, http://www.warbaby.com/FG_test/comp_history.html).
14. R. Reid, "A Real Revolution" (WIRED Magazine, http://www.wired.com/wired/archive/5.10/progressive_pr.html).
15.
    a. RealNetworks Press Room, "Progressive Networks Announces RealVideo Server Pricing Starting at $295." (RealNetworks, http://www.realnetworks.com/company/pressroom/pr/1997/rvpricing.html).
    b. - - - , "RealVideo Wins Wide Industry Support From Content And Technology Partners" (RealNetworks, http://www.realnetworks.com/company/pressroom/pr/1997/rvpartners.html).
16. L Marvit, Personal Interview.
17. "George Lucas in Love" Online Film (MediaTrip.com, http://www.mediatrip.com/ent/films/lucasinlove.html).
18. "405: The Movie" Online Film (http://www.405themovie.com/Home.asp).
19. "The Periwig-Maker" Online Film (AtomFilms.com http://atomfilms.shockwave.com/af/content/atom_627).
20. "A Letter from the Western Front" Online Film (AtomFilms.com http://atomfilms.shockwave.com/af/content/atom_192).
21. S. Cassidy, USC Film Distribution. Personal Interview.
22. S. McMillan, "Shaky cam means solid profits" (Apple HotNews, http://www.apple.com/hotnews/features/blair/).
23. "BMW Interactive Film Player" (BMW Films, http://www.bmwfilms.com/site_layout/player.asp?FilmID=7).
24. C. Alford, "Korean pics look for 'Net gains" (*Variety* March 20-26, 2000).
25. Associated Press, "Microsoft releases Explorer 6.0 without Java support" (*Salon* August 28, 2001, http://www.salon.com/tech/wire/2001/08/28/microsoft/).
26. Cover: J. Boyd-Graber
27. Figure 1: R. Straton, "Why Web Advertising Doesn't Work" (E-Prarie, http://www.eprairie.com/analysis/viewanalysis.asp?newsletterID=2079&page=1).
28. Figure 2: Media Players, Software (Apple, RealNetworks, Microsoft).
29. Figure 5:
    a. W.K. Wai *The Follow.* Online Film (BMW Films, http://www.bmwfilms.com/site_layout/film_synopsis.asp?FilmID=3)
    b. - - - *In the Mood for Love.* Film (Mirimax).

Lucas in Love really isn't an original film in any respect, but in taking its references from so many sources and combining them in a novel fashion, it emerged as the first real success in the Internet film arena. The film works on the same premise as Shakespeare in Love - a brilliant writer only gets his big inspiration when he finds his true love.

As George Lucas meets his muse, who bears a striking resemblance to Princess Leia, the viewer meets his friends who inspire the Star Wars universe. As the film opens, the music we hear bears a striking resemblance to Warbeck's score with Lucas pounding on his typewriter in his USC dorm room. We're immediately introduced to his stoner roommate who is expounding his theory of a "cosmic force" that is produced by all living things and his towering asthmatic neighbor clad in a black cape who shows off his newly completed script.

After Lucas is confused by his diminutive professor who uses inverted syntax, we're treated to one Star Wars reference after another. Lucas develops his plot further, with the assistance of his new companion, only to realize at the close of the movie that she's his sister.

From the AtomFilms website:

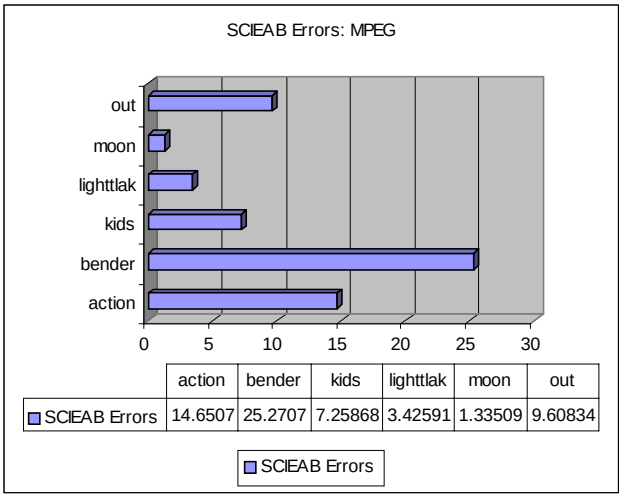
Deep in the trenches of Belleau Wood, France, love confronts death. A young soldier struggles to finish what may be his final dispatch to his beloved wife. Will his pen finish prior to his company's march across "no-man's land?" Find out in this state-of-the-art, award-winning animation.

A Letter From the Western Front was produced using Adobe PhotoShop, Adobe AfterEftects, and good old-fashioned Winsor & Newton watercolor paints. Director Daniel Kanemoto scanned his original paintings into the computer, and then used the software to composite and transform each element into the unique "multiplane" environment of the story. A 25-piece orchestra performed the original score, composed by Ryan Shore.

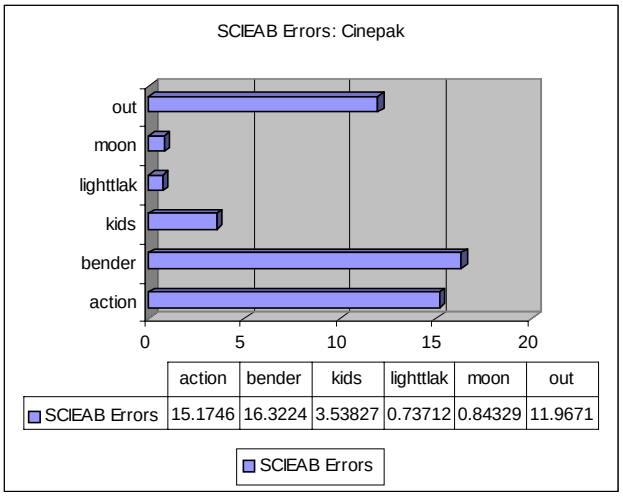
The Critic, starring the voice of Jon Lovitz, started on ABC, and headed to Fox after its cancellation. It was later picked up by Comedy Central, who then opted not to make original episodes. Jay Sherman, the central character, bears a striking resemblance to both Siskel and Ebert. Episodes usually begin by panning a recent film and then working on character development. Al Jean and Mike Reiss are back as producers, who were at the helm of the network version and have been affiliated with The Simpsons.

Wong Kar Wai's *The Follow*, like his more popular *In the Mood for Love*, concerns the question on infidelity and its visibility in the outside community. Clive Owen is hired to follow a movie star's wife and find out why she's gallivanting across the nation. A narrative discusses the techniques of "a follow" while we see the choreographed artistry of traffic as "the driver" pursues his prey. The scene used in figure 5 is when "the driver" is hired, comparable to the scene used in *In the Mood for Love*: the spouses of the two having the affair confront each other on whether their spouses are cheating.

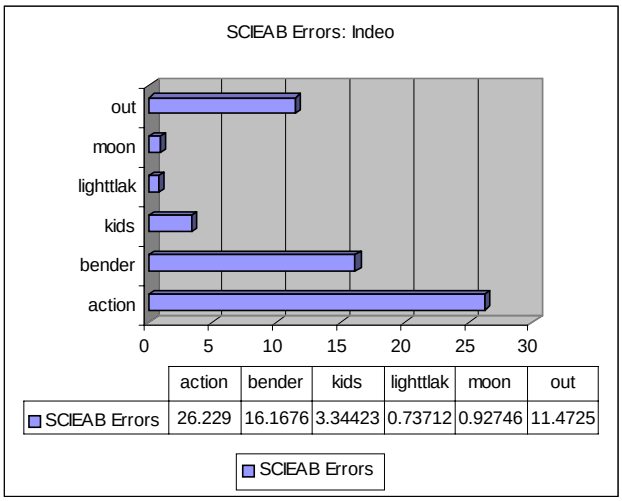
Appendix
Error Graphs



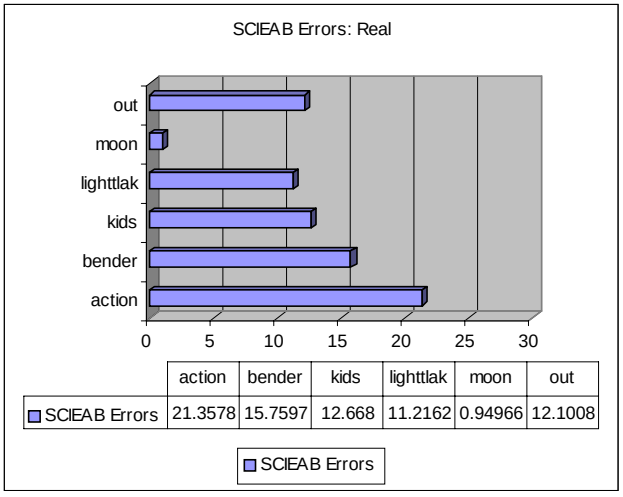
	action	bender	kids	lighttlak	moon	out
SCIEAB Errors	14.6507	25.2707	7.25868	3.42591	1.33509	9.60834



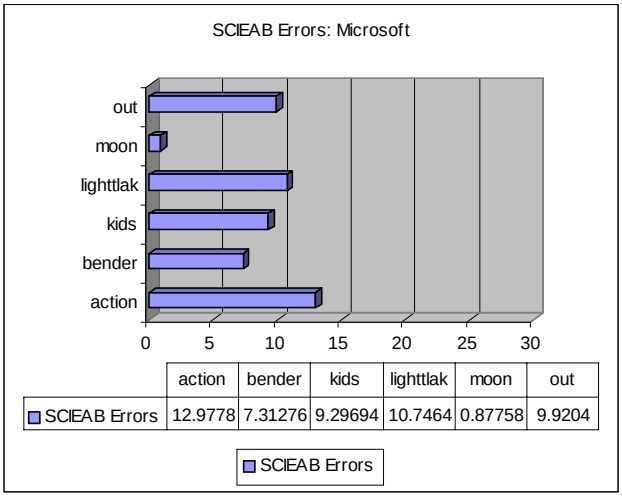
	action	bender	kids	lighttlak	moon	out
SCIEAB Errors	15.1746	16.3224	3.53827	0.73712	0.84329	11.9671



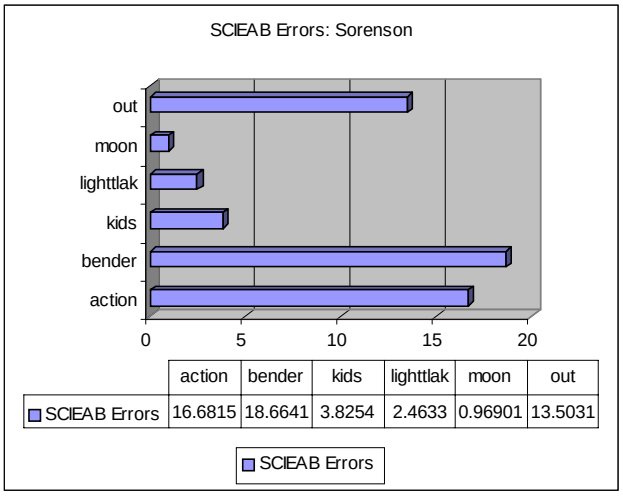
	action	bender	kids	lighttlak	moon	out
SCIEAB Errors	26.229	16.1676	3.34423	0.73712	0.92746	11.4725



	action	bender	kids	lighttlak	moon	out
SCIEAB Errors	21.3578	15.7597	12.668	11.2162	0.94966	12.1008



	action	bender	kids	lighttlak	moon	out
SCIEAB Errors	12.9778	7.31276	9.29694	10.7464	0.87758	9.9204



	action	bender	kids	lighttlak	moon	out
SCIEAB Errors	16.6815	18.6641	3.8254	2.4633	0.96901	13.5031

MATLAB OUTPUT

Appendix

One-way Analysis of Variance

```
Analysis of Variance
Source    DF      SS      MS      F      P
Factor     5  6357.91  1271.58  134.50  0.000
Error    288  2722.75     9.45
Total    293  9080.66
                          Individual 95% CIs For Mean
                           Based on Pooled StDev
Level     N    Mean   StDev ---+---+---+---+---
action    60  16.682   0.954        (*-)
action_a  60  26.229   4.810                    (*-)
action_q  54  15.175   0.878     (*-)
action_r  30  21.358   5.121              (-*-)
action_w  30  12.978   3.825  (-*-)
action_m  60  14.671   1.152     (*-)
                        ---+---+---+---+---
Pooled StDev =   3.075           15.0    20.0    25.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source    DF      SS      MS      F      P
Factor     5   5996.0  1199.2   67.94  0.000
Error    292   5153.9    17.7
Total    297  11149.8
                          Individual 95% CIs For Mean
                           Based on Pooled StDev
Level     N    Mean   StDev -+---+---+---+---
bender    59  18.664   4.758               (-*-)
bender_a  59  16.168   3.507            (-*-)
bender_q  60  16.322   3.601            (-*-)
bender_m  60  23.996   5.740                      (-*-)
bender_w  30   7.313   1.400  (-*-)
bender_r  30  15.760   3.531          (-*-)
                       -+---+---+---+---+---
Pooled StDev =   4.201        6.0     12.0    18.0    24.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source    DF      SS      MS      F      P
Factor     5  2978.80  595.76  286.81  0.000
Error    294   610.70    2.08
Total    299  3589.49
                          Individual 95% CIs For Mean
                           Based on Pooled StDev
Level     N    Mean   StDev ----+---+---+---+---
kids      60   3.845   0.985   (*)
kids_avi  60   3.448   1.239 (*-)
kids_qtc  60   3.538   1.277  (*)
kids_rm   30  12.668   0.972                     (*-)
kids_wm   30   9.297   2.711              (-*-)
kids_mpg  60   8.182   1.462           (*)
                       ----+---+---+---+---
Pooled StDev =   1.441             6.0     9.0    12.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source    DF      SS      MS      F      P
Factor     5  9.1214  1.8243   64.35  0.000
Error    292  8.2775  0.0283
Total    297 17.3989
                          Individual 95% CIs For Mean
                           Based on Pooled StDev
Level     N    Mean   StDev ----+---+---+---+---
moon      57  0.9690  0.1205       (--*-)
moon_avi  61  0.9275  0.2793     (--*--)
moon_qtc  60  0.8433  0.0778 (--*-)
moon_wm   30  0.8776  0.1850  (--*--)
moon_mpg  60  1.3354  0.1074                    (-*--)
moon_rm   30  0.9497  0.1611     (--*--)
                       ------+---+---+---+---
Pooled StDev =  0.1684              0.96    1.12    1.28
```

One-way Analysis of Variance

```
Analysis of Variance
Source    DF      SS      MS      F      P
Factor     5  4318.56  863.71  269.68  0.000
Error    293   938.41    3.20
Total    298  5256.97
                          Individual 95% CIs For Mean
                           Based on Pooled StDev
Level     N    Mean   StDev ----+---+---+---+---
lt       60   2.476   0.192      (*)
lt_avi   59   0.742   0.102  (*)
lt_qtc   60   0.737   0.107  (*)
lt_rm    30  11.216   0.411                     (-*-)
lt_wm    30  10.746   5.640                    (-*-)
lt_mpg   60   3.560   0.360        (*)
                       ------+---+---+---+---
Pooled StDev =   1.790             3.5     7.0    10.5
```

One-way Analysis of Variance

```
Analysis of Variance
Source    DF      SS      MS      F      P
Factor     5  522.95  104.59   29.76  0.000
Error    292 1026.34    3.51
Total    297 1549.28
                          Individual 95% CIs For Mean
                           Based on Pooled StDev
Level     N    Mean   StDev ----+---+---+---+---
out      59  13.503   2.830                   (--*--)
out_avi  59  11.473   1.353          (--*--)
out_qtc  60  11.967   1.413            (--*--)
out_mpg  60   9.731   1.135  (--*--)
out_rm   30  12.101   2.261            (---*--)
out_wm   30   9.920   1.981  (--*---)
                       ----+---+---+---+---
Pooled StDev =   1.875            10.5    12.0    13.5
```

Appendix

ACKNOWLEDGMENTS

Robert Rosenstone
Leslie Maxfield, Caltech Digital Media Center
Wayne Waller, Caltech Digital Media Center
Carolyn Patterson, Caltech Digital Media Center
Toni Boyd
Jess Osbaldeston
Ryan Culpepper
Elizabeth Davis