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Neutralizing the piracy of motion pictures: reengineering the industry's supply chain

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Abstract

Faced with the challenge of distributing digital product in the digital realm, the American film industry is acutely aware of its increasing vulnerability to piracy and is currently considering two solutions to protect its copyrights—a legislative solution (e.g., the Digital Millennium Copyright Act of 1998) and a technical solution (e.g., digital watermarking). We suggest that a better way of dealing with piracy is an economic solution, such as neutralizing piracy by reengineering the supply chain across all three sectors of the motion picture industry: distribution, exhibition, production. In distribution, the industry can make legitimate downloading of high-quality movie files easier and cheaper (than pirating) by strategically locating "e-Blockbusters" (i.e., digital movie libraries) at or near Internet service provider (ISP) sites and making them attractive through feasible pricing schemes. In exhibition, innovative digital theaters could offer virtual reality viewing experiences and flexible windowing systems that maximize revenue for each feature film. In production, work would be done primarily or entirely in the digital domain. Digital film reservoirs would provide universal naming and indexing functions for easy access, reuse, and extension, and the industry would achieve a new diversity of quality and quantity. In addition, dynamic cross-media convergence can be expected as a function of the complementarities created by content digitization. To prosper in the new digital economy, the motion picture industry must closely collaborate with the information industry to achieve a new supply chain rather than competing with it to the detriment of both.

Keywords: Piracy; Digital rights management; Motion pictures

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1. Introduction

The American motion picture industry's production and distribution of feature films generated nearly US$ 40 billion in revenues worldwide in 2003[1] [1]. But the industry is also losing hundreds of millions of dollars a year to film piracy[2] [2], and the loss continues to increase with the spread of broadband Internet access, improvements in video compression technology, and advances in peer-to-peer (P2P) networking. To fight this loss, the motion picture industry is planning to commit heavily to Internet distribution[3] [3], but it is still debating how to implement such a plan to include proper digital rights management (DRM).

Historically, the industry has tried hard to inhibit replication technologies by holding manufacturers responsible for copyright violation (as when Universal and other major studios filed suit against Sony Betamax in November 1976 for copyright infringement, arguing, as the Disney lawyer put it, that "the videotape machine would be used to steal our property" by copying feature films off the air [4]).

A similar logic is involved in the current debate in which the entertainment industries are demanding that the information industry build DRM technology into its products. A recently proposed Consumer Broadband and Digital Television Promotion Act (CBDTPA) is the boldest attempt so far by the entertainment industries to compel the information industry to include anti-piracy technologies in all software and hardware that process digital entertainment content.

The motion picture industry seeks to assign to the information industry legal responsibility for copyright violation and then saddle it with the financial burden of preventing it. However, there are legal precedents militating against this approach. For example, in 1984, the Supreme Court ruled in favor of Sony in the Betamax case, accepting Sony's argument that VCR makers were not committing "contributory [copyright] infringement" since the users could choose to employ the machines in non-violating ways (e.g., for "time-shifting"). This was consistent with earlier legal decisions that had defined audio tape recorders and copying machines as "dual-use devices", thus making it the responsibility of the user rather than the manufacturer not to use the device illegally [5]. (Ironically, losing the case opened up a whole new revenue stream for the studios in the sale and rental of

[1] This figure represents box office grosses only and excludes revenues from licensing films for video sale and rental.

[2] Piracy of feature films includes illegal digital recording of theatrical films directly off the screen, illegal duplication of DVDs, and illegal downloading of movies from the Internet as digital files. In the latter case, it is estimated that this occurs as many as one million times a day in the US alone.

[3] In late 2002, the five major studios—Sony Pictures, Paramount Pictures, Universal Studios, Warner Brothers, and MGM—launched ⟨http://Movielink.com⟩, an Internet website where movies can be downloaded or streamed in real time for a fee of about US$ 5 each. A rival web-based service for major studio releases, ⟨http://CinemaNow.com⟩, was inaugurated the following year. Although In-Stat/MDR researchers have predicted that 7.5 million North American broadband users will subscribe to such services by 2006, neither has to date been notably profitable.

pre-recorded films on videotape, which would soon become larger than the market for theatrical films itself.)

Although the entertainment industries regard piracy as worse than shoplifting, and the chairman and CEO of Turner Broadcasting has called users of digital video recorders (such as TiVo) "thieves" [6], the industry will be unable to stop further development and use of new media technologies. The present legal protection against digital piracy is controversial and not accepted by all stakeholders. Even if there is a consensus in the future, enforcement will still be as hard as finding the proverbial "needle in a haystack" because of the distributed, anonymous, and global nature of the Internet.

On the other hand, there are substantial doubts whether technically achieving DRM is feasible. Every time a new copy protection technology (such as Macrovision) is developed, pirates quickly develop a counter-technology to defeat it [7]. Putting aside which industry should finance the development of DRM, it is uncertain if consumers would accept computing systems with DRM restrictions. As security measures become more stringent, computing systems will need to be even more powerful and consequently more expensive.

When there is a lack of suitable legislation, effective enforcement, and feasible technology to fight against illicit acts, one can search for solutions based on economic mechanism design. An incentive-compatible economic model should not only deliver social surplus but also discourage illicit economic behaviors. Hence, we believe that a more effective approach to neutralizing piracy of motion pictures is to reengineer the industry's supply chain in such a way that it can offer legal, cheaper, more convenient, and more enjoyable entertainment than anything illicit copies can provide. However, this change in strategy will require the motion picture industry to overcome its historical inertia and techno-phobia in order to work with technology providers to offer better legal downloads and exhibitions as well as innovative content that is difficult to pirate.

In this essay, Section 2 gives an overview of the present motion picture industry supply chain (production, distribution, exhibition). Section 3 analyzes current steps taken by the motion picture industry to "cure" and, hopefully, to prevent the piracy epidemic from taking place via the Internet. Section 4 identifies measures against piracy in the motion picture industry supply chain, mainly from an economic perspective. Section 5 concludes with the contributions and limitations of the research.

2. The present supply chain of the motion picture industry

Since the mid-1970s, the major studios have acted as both financiers and distributors for feature films produced largely on an ad hoc basis by others (projects are packaged by agents who put together teams of celebrity talent sufficient to "greenlight" production funding and distribution deals) in a manner similar to outsourcing in other industries [8].

Motion pictures are currently produced in analog format, i.e., positive prints duplicated from photographic negative stock, so even digitized content needs to be recaptured into the analog format (e.g., many scenes in *Star Wars, Episode II: Attack of the Clones* [George Lucas, 2002] were produced digitally, and then scanned onto negative film stock to produce prints for theatrical release).

Motion pictures are primarily distributed as cargo through physical channels to theatrical exhibitors (and in video form to cable TV providers and rental shops). This mode of distribution is not only cumbersome and expensive, but also introduces time delays between production and exhibition, which makes it difficult to quickly amortize investment.

Motion pictures today are, for the most part, run via 35 mm projection in brick-and-mortar theaters, a process that is semi-automated, mechanical, and labor-intensive. A secondary mode of exhibition involves home theater playback via digital (DVD) and analog (videocassette and laserdisc) media. Although serialized windowing (e.g., theatrical exhibition, Pay-Per-View, videocassette, DVD, cable TV, rentals, broadcast TV, and international licensing) aims to maximize returns on investment through price discrimination over time, it not only makes viewing inflexible but also further increases the delay of return on investment (that is, DVDs are not released until weeks after the theatrical exhibition) and may even shorten the time available for ROI (e.g., a hit movie has a limited run time even with today's dynamic contracting between distributor and exhibitor).

At present, the motion picture distribution and exhibition sectors are structurally distinct and economically discrete. Over the years, the two sectors have worked out norms on how to interact and split profits. The division, however, introduces more intermediation cost and less incentives for innovation. For instance, exhibitors expect distributors to finance the conversion to digital projection because distributors will benefit from reduced distribution cost; yet, distributors expect the exhibitors to absorb all the cost for change.

Weaknesses in the current supply chain of the motion picture industry reflect the industry's inertia toward adopting new technologies. Without a timely reengineering of this supply chain, the industry remains vulnerable to structural destabilization and piracy in ways that can threaten its very existence.

3. Present battles against piracy

The motion picture industry is well aware of the criticality of protecting proprietary rights of ownership when distributing its products digitally over the Internet. Currently, two major solutions to piracy—legislative and technical—are deployed, but unfortunately, both have inherent weaknesses.

3.1. A legislative solution

The copyright arm of the industry, led by the Recording Industry Association of America (RIAA) and the Motion Picture Association of America (MPAA), has long pursued legislative solutions for copyright protection, but the results have been only

vague regulations and ongoing controversies. The Digital Millennium Copyright Act (DMCA), passed by Congress in 1998, has triggered many debates. The DMCA forbids tampering with technological restrictions that control access to copyrighted works and outlaws the dissemination of information and technology that could be used to access or copy works controlled by such technological restrictions. The DMCA not only "chills free expression and scientific research, jeopardizes fair use, impedes innovation and competition" [9], but also weakens the security of the technological restrictions. It provides incentives to produce systems with weak security measures; that is, under DMCA anyone who discovers a security weakness is not allowed to publicize it—somewhat akin to seeing a fire burning near a gas station and not being allowed to call the fire department. Many controversial rulings involving the DMCA were never intended by Congress[4], and it is likely that the DMCA will continue to be applied in unforeseen ways that hinder the legitimate activities of innovators, researchers, the press, and the public at large [10].

Protecting copyright becomes even more difficult given the openness of the Web and the ease of digitizing content. Faced with today's new technical environment, many lawmakers are debating how to revise existing copyright legislation to properly compensate copyright holders but still allow fair use of copyrighted material. There is even a bill proposing that if the private sector cannot agree on copyright protection methods within 2 years, the government will determine the standard. But there is a serious doubt that the government can better the private sector in technological innovation.

A recent effort in the private sector to protect copyright is the new Digital Media Device Association (DMDA), formed in early 2002 with 40 member organizations. However, DMDA has yet to disclose any information to the public. In January 2004, a global consortium of technology companies, known as Project Hudson, made up Intel, Nokia, Samsung, Toshiba, and Matsushita, laid the groundwork for a solution that would combine both legislative and technical fixes [11].

It must be said, however, that even after feasible legislation on copyright protection is established, a huge barrier will remain: how to enforce it. With the ever-increasing number of virtually anonymous Internet users and the large and ever-increasing volume of traffic, monitoring and controlling the use of copyrighted content is a huge task.

[4] Dimitri Sklyarov, a Russian programmer, was among the first to be prosecuted on criminal copyright charges based on DMCA. Similarly, a Princeton professor, Edward Felten, was threatened by lawsuits if he presented his paper disclosing weaknesses in the Secure Digital Music Initiative (SDMI) at conferences, although his study was a response to a challenge set up by SDMI itself. Contrary to its goal, SDMI has not been able to deliver any secure and feasible mechanism for protecting digital music. There are also many not-so-well-known DMCA cases. For instance, in Oklahoma, an outsider who told the manager of a bank that there was a security hole in the bank's computing system was apprehended by the FBI.

3.2. A technical solution

Technical solutions are currently implemented either by software or by a combination of both software and hardware.

3.2.1. By software

The software solution for protecting copyright content is to encrypt content before transmission and then decrypt it after authenticating an authorized use of the content. Encryption and decryption are done by software.

There are two problems: (1) most software is not bug-free or hacker-proof; and DRM software is no exception; and (2) hackers can intercept plain-text content after decryption by the software, and during transmission to the display hardware.

Fundamentally, the very principle of a software solution to piracy can be criticized—its premise is based on the unavailability of plain-text content to the users. However, current exhibition devices (e.g., TVs and monitors) can process only plain-text content. Decryption often occurs in computer memory, and then the plain-text content is saved or cached in memory or a hard drive and transmitted to the exhibition device. A hacker can intercept the plain-text signals during storage or transmission unless the exhibition device is equipped with tamper-proof hardware modules for decryption near the final stage before exhibition. This requires fundamental changes in monitors and TVs and undoubtedly a corresponding increase in price, which would not be welcome either by manufacturers or consumers.

3.2.2. By software + hardware

Most DRM today is a combination of software and hardware solutions, such as digital watermark technology[5]. The watermark generally contains information telling the exhibition device how to play the content, whether to allow copying and, if so, to what degree. But the watermark does not work without an exhibition hardware device that is able to understand the information and limit copying accordingly.

Another possibility is to manufacture tamper-proof hardware. The simplest example is smart-card technology, with each smart card having a tamper-proof chip that stores the cardholder's information. In general, it is more difficult and expensive for a hacker to damage or break into hardware-based DRM. And the hardware industry has simulation and formal verification tools to maximize its guarantees of chip quality, unlike the software industry which does not hold itself responsible for its product liabilities.

However, there remain concerns about the technical principle of digital watermarking. Watermarks intend to change content in an invisible/inaudible way, whereas compression[6] omits anything in the content that is not essential to the

[5] Digital watermarks are imperceptible additions to the digital content, which convey hidden data.

[6] The aim of compression of digital content is to reduce the size of the content for easy storage and transmission with little perceptible quality loss.

final visual/audio experience, which means that compression changes the content in some invisible/inaudible way. The goal of compression is to eliminate redundancy, while the goal of watermarking is to add redundancy. Since watermarks are invisible/inaudible and are not essential to the viewing experience, the ideal compressor would remove them. In other words, a good compressor would produce a single small file from two copies of the same movie that look and sound identical, but digital watermarking would add information to the two copies of the same movie because each watermark would contain information about the intended authorized user. This is the main reason why the Secure Digital Music Initiative (SDMI) challenge failed, and why many technology specialists argue that it may be impossible to design a robust watermarking system. It seems that such a watermarking system can only work if its design is kept secret (this is why the entertainment industries push to make "reverse engineering" illegal), but "security by obscurity" is a bad strategy.

In summary, neither the legislative nor the technical solution effectively defends against piracy. Therefore, we suggest approaching the issue from an economic perspective, which will complement the legislative and technical solutions in the battle against piracy.

4. An economic solution: reengineering the motion picture industry supply chain to neutralize piracy

The production, distribution, and exhibition of pirated movies take different routes. For instance, piracy of motion pictures in the US differs from piracy in China. In China, pirated DVDs and VCDs are mass-produced by underground factories and then distributed by street vendors. A crackdown on the production sites would consequently cut the major source of piracy. In the US, pirated DVDs are seldom in a physical form or sold on the black market, but instead are usually stored on private servers available to individual Internet users. The search for pirated movies is facilitated by P2P programs like KaZaA, Morpheus, Gnutella, LimeWire, Grokster, and Bit Torrent, which dynamically index distributed underground (and pirated) copies.

Although the underground community does exist, it has not grown exponentially, partially due to current technology limitations and partially due to fear of being caught. This gives the motion picture industry a window of time to fight back. So, let us examine further the supply chain of pirated motion pictures and suggest some remedies against piracy in order of their relative economic importance.

4.1. In the distribution sector

There are two categories of distribution—theatrical exhibition and home viewing. The motion picture industry has long talked about the US$ 2 billion in savings it could reap by beaming films into theaters rather than shipping them by courier [12], so in the future it is expected there will be distribution via satellite downlink

directly into theaters for digital projection [13]. In fact, distribution to any exhibition venue can be carried out digitally via the Internet, cable, or satellite in real time or quasi real time, even on a global scale. Pioneers like Time Warner-On Demand, In-Demand Network, and Direct TV already do this. Since in the US, piracy occurs primarily for use in home viewing rather than theatrical viewing, we will focus on how to fight home piracy.

At present, it is cumbersome to create pirated movies, even with up-to-date in-home computing power. It takes from one to four hours to burn a two-hour DVD[7] in MPEG4 format (e.g., DivX) and still maintain quality comparable to the DVD but in a relatively smaller file (~700 MB) for storage on a single CD. It is also not easy to watch a pirated movie in real time. For a moviegoer with broadband Internet access at home, downloading and watching a movie in MPEG4 takes several hours, so watching a pirated movie requires both planning and patience.

Broadband ISPs call subscribers who are constantly connected to the Internet and subsequently download huge files "bandwidth vampires". Especially for shared-bandwidth cable modem users, a vampire can greatly reduce the Internet access speed of his/her neighbors. Even the Internet backbone could be vulnerable to these bandwidth vampires if there is no control.

Most ISPs still charge their subscribers a flat fee for unlimited connection time, which provides an added incentive for vampires to ride free. To add some measure of control to this activity, ISPs in the US reduce the maximum download speed for a single subscriber from 33 to only 1–3 Mbps and the maximum upload speed from 768 to only 128–500 kbps. Typically, an MPEG4 video requires 1–2 Mbps transmission speed for real-time viewing, similar to video-on-demand services. In P2P video sharing, the content provider is often a home user, so the home user's upload speed becomes a transmission bottleneck (because overall speed is only equal to the slowest link in the entire route). This explains why downloading a movie through P2P takes several hours rather than minutes. Even when upload speed is not an issue—for instance, the MPEG4 video source is the ISP itself—it still takes about an hour to download a movie, which makes it hard to watch a high-quality movie in real time over the Internet. Thus, at present, the reduction in speed adopted by the ISPs works at present to restrain the bandwidth vampires and reduce piracy activities. However, it also diminishes the full potential of the technology and does not maximize social welfare.

We have two suggestions for neutralizing piracy through distribution.

4.1.1. Establish convenient e-"Blockbusters"

For the US market, with its relatively high in-home broadband penetration and widely diffused, up-to-date, in-home computing power, the motion picture industry could serve these users and also discourage piracy by offering legal digitized entertainment. The industry can mitigate—perhaps eventually eliminate—the decision to

[7] DVDs use the MPEG2 format. Currently, digital cable and digital video broadcasts also use MPEG2. MPEG stands for Motion Picture Experts Groups. MPEG is a committee in the International Standard Organization (ISO).

pirate by making it cheaper and more convenient for users to legitimately rent a high-quality digital movie than to pirate it. Once it becomes feasible, most users will take the honest and legal route.

Currently, a DVD movie costs around US$ 20 to purchase and US$ 4 to rent from Blockbuster. However, a DVD rip costs only about US$ 1, and a 160 GB hard disk, which can hold 150–200 digital movies, costs about US$ 100. To be competitive, digital rental charges should be cheap relative to file size (which correlates with image quality) and download time (peak vs. non-peak).

To be convenient, the distribution should be logistically efficient. In order to provide movies-on-demand in real time, we suggest that the digital movie library and its mirror sites be as close as possible to users, that is, within the "last mile" to home moviegoers. The library or its mirrors can be stored either at an ISP site—what we call "e-Blockbusters"—or at a hub close to adjacent ISPs where each ISP can cache popular movies. The locations for the library mirror sites and caches should be selected to fit individual market needs. There are startup companies that plan to bury huge digital storage boxes in neighborhoods, just like telephone and cable wires. e-Blockbusters should have a special pricing scheme solely for downloading motion pictures, separate from broadband Internet home access, thereby eliminating the activities of bandwidth vampires and the fees for normal broadband access.

Ensuring quality is another value the motion picture industry can provide. Currently, it is impossible to verify the quality of underground digital content over the Internet. Many underground moviegoers are free-riders for downloading rather than creating and uploading quality digital content. As a result, they often have to tolerate long waits, viruses, and be willing to wrestle with corrupted files [14]. Media companies can enjoy a competitive advantage by distributing clean digital content quickly and easily.

4.1.2. Control centralized production and consumption of pirated movies

For international markets in countries that lack broadband home access and sufficient in-home computing power, piracy most likely will take the form of illegal screening at underground digital theaters and the sale of illegal physical copies. Building e-Blockbusters at ISPs in these countries will not work due to the lack of home technology to support them and the lack of control over the ISPs. Fortunately, the relatively more concentrated viewing of pirated movies and production of pirated physical copies may, in fact, be easier to control. The motion picture industry in the US, which has huge demand from international markets, should prevent international piracy by some sort of digital copy protection (e.g., regional encoding) and enforcing copyright laws to secure revenues.

4.2. In the exhibition sector

In addition to technically imbedding DRM modules in exhibition devices, there are other ways to economically alleviate piracy in the exhibition sector.

4.2.1. Adjusting the windowing scheme

At present, theatrical exhibition is stratified as first-run, second-run, and sub-run, with repeated screenings for Oscar-nominated movies and other special events. The duration of a run is based on demand—distributors and exhibitors have dynamic contracting to determine the run's duration.

The first-run/sub-run clearance system of windowing may still apply to future releases in theaters, but consumers will also be able to watch a movie anytime at home through Internet downloads or video-on-demand via cable or satellite. But not all feature films will have to follow a similar windowing scheme. Movies that do not have many special effects like *In the Bedroom* (Todd Field, 2001) may not be released to theaters at all. A digital home theater and a plasma-screen, flat-panel, high resolution TV or computer monitor can deliver the quality of these films as well as or even better than theatrical projection.

Currently, the rental and retail sell-through markets for motion pictures are derivatives of the theater market because of the present windowing system. The better the box office is at the theater, the more rentals or sales of DVDs and videocassettes are expected. In the future, the sequence of windowing, however, can be adjusted or eliminated according to each film's characteristics. Home viewing of a DVD may trigger the desire to see the movie in a digital theater. For each film or category of film, the producer and distributor may need to design a customized market windowing scheme for revenue maximization.

4.2.2. Offering differentiated digital viewing experiences

Piracy and the development of digital films, digital home theater systems, digital cable, HDTV, and all-digital TV channels pose threats to brick-and-mortar theaters, which may become obsolete if they cannot convert to digital technology, or may be replaced by purpose-built digital theaters. At this writing, the rate of change remains unclear. George Lucas originally envisioned his all-digital *Star Wars Episode II—Attack of the Clones* as opening in thousands of digital-projection theaters nationwide. But as of May 2002, there were only 19 US theaters where films could be projected digitally, largely due to the US$ 150,000 to US$ 200,000 per screen cost of converting to the new exhibition technology [15]. In 2003, many industry experts were predicting that a complete transition to all-digital projection would take at least another 7 years [16].

Currently, movies shown in theaters run without pause from beginning to end, and audiences are passive consumers. But in a secondary-storage format, movies can be paused, rewound, fast-forwarded, (videocassette) scenes selected and, in some formats (laserdisc, DVD), randomly accessed. Another major site of exhibition, computer displays, allow viewers to watch movies while surfing or doing other computing work. As digital home theater technology and plasma-screen flat-panel television begin to drop in price, they will become more widely diffused for in-home playback of digital movies. (Besides, home screening saves on concession expenses.)

Thus, without some timely changes, brick-and-mortar theaters may soon lose their attractions. But, assuming that digital theaters are either built or converted

from analog, the question becomes how to differentiate them from home theaters. Bigger screens, better sound systems, a place for group outings are all advantages, but they may not be enough to generate profits—apart from concession fees.

Digital technology offers a further means of differentiating the viewing experience from both conventional theater and home theater—i.e., virtual reality shows. The prospects that 3D computer graphic imagery (CGI), combined with coordinated motion control and other kinds of perceptual simulations, will someday create a range of illusion that engages all the human senses is a very real, if expensive possibility, but certainly not beyond the finances of the media conglomerates that currently control the motion picture industry.

4.2.3. Developing fast-access storage to reduce portable media

Videocassettes will eventually become obsolete, due to low resolution and limited accessibility of content. Both retail sales and renting can be online and in real time. In the future, traditional physical rental shops and sell-through markets will be gone. Once bandwidth is no longer scarce for transferring multimedia content, and convenient and reasonable e-Blockbusters are available, we will seldom see rentals and sales of movie in physical containers like DVDs. For those who prefer tangible collections rather than computer files, DVDs and/or memory cards will remain viable media for the foreseeable future.

An ideal networking environment and fast-storage technology will prevail over physical media, in the same way that CDs and CD-Rs have replaced floppy disks and zip disks—and that DVD and DVD-R will replace CD and CD-R. In the near future, we believe that memory cards like those in digital cameras will replace DVDs and DVD-Rs, and portable devices like laptop and PDAs will have large capacity, fast-access storage that can store feature films. Peripherals, such as built-in DVD drives, require computer power to operate and consume battery life; hence, they will be deleted from lightweight portable devices. Without the portability of physical media, piracy through physical exchange can be eliminated as well.

4.3. In the production sector

Changes in distribution and exhibition will also have an impact on production. Just as many manufacturing industries have moved from mass production to customization, their supply chains will also have to adjust. For instance, the chino pants producer Land's End has built a new factory in Mexico with an innovative production sequence to tailor customized pants, separate from its mass-production factories in China. For the motion picture industry, where future exhibition will be digital and innovative, and future distribution can be in real time for both download and upload, production will also have to change to satisfy the new demands and fully utilize the new advantages offered. The following features we think will characterize future motion picture production:

4.3.1. Digitizing production

At present, almost all motion pictures are in analog form. In conventional filmmaking, physical scenes are shot with 35 mm cameras and post-production work is done on the original camera negative; sound is recorded in analog form and manipulated digitally in post-production [17]. Because current theaters can only exhibit films in analog format, even the mostly digitized *Star Wars II—Attack of the Clones* (2002) had to be converted to an analog signal and scanned onto a 35 mm photographic film for distribution.

In the near future—and, incipiently, the present—not only will CGI be created by software, but also physical (practical) scenes will be recorded by digital equipment, saved in digital format, and edited by software. Soon live actors and real scenery can be reduced to a minimum, because all scenes may be created digitally, including those involving human interactions. All post-production of image and sound will be digital and online (e.g., CGI and post-production work on *The Lord of the Rings* trilogy [Peter Jackson, 2001-03], which went on simultaneously in New Zealand, Hollywood, and Germany over a twelve-month period; CGI and post-production work on *Gladiator* [Ridley Scott, 2000], which was able to proceed in London and Hollywood 24h a day thanks to secure satellite linkage and the time differential [18]). The production of digital effects will be decentralized, and Hollywood—always an imaginary place, as well as a real one—will become virtual in the digital sense as well. Post-productions will not need to be carried out in centralized locations like Industrial & Magic in Marin County or Digital Domain in Los Angeles; but can be parceled out (in packets) or outsourced to subcontractors at individual workstations all over the world. Indeed, this is already beginning to happen and causing concern within Hollywood's labor lobby [19].

The production sector's imperative to work completely within the digital domain will blur the distinction between production and post-production, and within the post-production process itself, the distinction between creating CGI and editing will begin to fade. The integration of production and post-production will accelerate delivery of the finished product, and the time-to-market can be reduced [20]. Quicker delivery will enable an accelerated amortization of investment, which in turn can stimulate more production.

The cumulative effect of these changes for production will be to totally integrate all filmmaking functions into the digital realm, while at the same time decentralizing such labor-intensive tasks as modeling and rendering, which are farmed out to subcontractors as piece-work (very much like the practice of the garment industry in 1990s, except there are no transportation costs involved in final assembly).

4.3.2. Developing digital resource reservoirs

Like *iTune.com*, which holds the digital library for music, the motion picture industry needs to establish a digital resource reservoir for movies. Recent progress in journal publication has established a prototype to follow. For new journal articles, more and more electronic submissions, reviews, publications, and distribution are encouraged (e.g., *Management Science*). If existing journal articles, published in recent decades, do not have an electronic version available, they are scanned to

image files and saved as .pdf files available for electronic access (e.g., *jstor.org*). Although these files are relatively large, searches, previews, and downloads are still much less cumbersome than going to brick-and-mortar libraries.

To establish a motion picture digital reservoir, the industry should follow a similar path. Archived movies should be revived and transformed into digital files, and new productions should be directly generated, processed, and saved in digital format. The American Film Institute has already sponsored Le Giornate del Cinema Muto in Pordenone Italy in its digital restoration of pioneer one- and two-reel films created between 1909 and 1913 [21]. Also, Ted Turner purchased MGM/UA in 1985 mainly to gain ownership of the nearly 3300 titles in MGM's film archive (including not only MGM/UA movies but both the RKO and pre-1949 Warner Brothers libraries). He did so in order to set up the cable channels TBS, TCM, and TNT and to avoid paying royalties. Turner realized the importance of content and might have foreseen the possibility of building motion picture libraries [22]. Currently there are a few underground servers that provide movies in VCD, DVD, and MPEG4 formats, but their resources are not comparable to those of the motion picture industry and most of the movies are pirated.

Digital motion picture libraries should store not only digitized film content but also relevant production, distribution, and exhibition information about the films. The format of digital movies should facilitate the exercise of reusing the entire or partial content but still retain the creators' rights. Furthermore, the motion picture industry should collaborate with the technology sector to establish a standard naming and indexing service that labels film content, content components, and other parameters of a film. Such services would place the search, access, and reuse of film content at the fingertips of Internet users, just as Internet resources are accessed and as other industries (such as the automobile industry) have moved from HTML- to XML-based[8] web pages to facilitate the communication and integration of data generated in different information technology systems and companies. Naming and indexing should describe a film in terms of meaningful, atomic components to encourage component reuse and extension. Just like object-oriented programming and the movement of financial reporting toward XBRL-based schemes[9], where components (e.g., cash flow) are searchable, meaningful, and easy to cut, paste, and extend. In addition, authorization and authentication should be added to make it possible to charge for the use of the motion picture libraries.

4.3.3. Creating diversity

The production of future feature films will be more diverse than at present. Such diversity can be achieved from two perspectives:

[8] XML stands for Extensible Markup Language, which offers a more flexible way than HTML to create common information formats and to share both format and data over the Internet.

[9] XBRL (Extensible Business Reporting Language) is an XML-based language being developed specifically for business reporting.

4.3.3.1 In quality. Although the motion picture industry may still need to guess about audience taste and estimate the financial payoff of a potential blockbuster, the collected data on viewing of previous movies and on-line audience feedback can provide more detailed and accurate information for data-mining. This will enable the industry not only to develop timely movies that fit with the audience's tastes (and hence increase their quality) but also to migrate from a one-to-many to a many-to-many film–audience relationship, and from passive screenings in a predefined sequence to interactive random access to movie scenes.

A blockbuster feature film may be designed to deliver various forms of virtual reality to its audience if digital theaters are widely introduced to the market. Quasi-realistic thrill rides or adventures may no longer be something found only in theme parks but become an integrated part of any digital theater experience.

4.3.3.2 In quantity. For a single movie, the production can be diverse as well. Many producers have achieved capacity and flexibility in DVDs in a way theatrical features cannot have and hence they can put more film-related content, such as production trailers, directors' commentaries, alternative endings, deleted scenes, behind-the-scene interviews, and additional footage into the DVD edition of a film. A DVD can have a version for collectors and may even have a version with a related computer game targeting a particular community. Also, a movie can be produced in many versions based on different resolutions, sound effects, color vs. black-and-white, etc., and tailored to many consumer groups with different tastes and preferences (e.g., length of the movie, spoken language, subtitles).

Hence, enabled by technology, the motion picture industry can move away from creating a monolithic film product and move toward refined product differentiation—a practice that has been enjoyed by other industries over the years and resulted in huge profits.

In addition, the motion picture industry may change its oligopolistic structure. Digital shooting, editing, distribution, and exhibition can reduce costs considerably and enable smaller and more independent filmmakers to enter the market and compete against major studios. Better consumer product quality and lower prices will allow consumers to produce amateur videos of vacations and anniversaries—even feature films for their families, friends, and communities. The development and adoption of digital video technologies will be analogous to the way digital still-cameras have been mainstreamed. It has not taken long for consumers to become familiar with digital cameras and to edit digital images cost-efficiently to an extent that has nearly eclipsed traditional analog photography. Thus, not only will major studios and smaller independent players produce more movies, but consumers will introduce a variety of motion pictures of their own.

4.3.4. Embracing convergence

There have been many discussions on the convergence of Internet content (TV, cable, and web information), distribution (cable, dial-up, satellite), and exhibition (TV, PC) for home users. There is another fledgling content convergence that requires more innovation—the convergence of digital entertainment, which takes

advantage of the complementarities among books, movies, games, images, and music and the convenience of multimedia editing provided by digitization.

Interchangeability and reuse of entertainment products are not new. Many movie scripts come out of best-selling novels. Recently, there have been several movies based on best-selling video games (e.g., *Tomb Raider*) and vice versa (e.g., the *Star Wars* games). Not only can digital content be put into different formats and settings but multimedia contents are supportive of each other and can be distributed in a variety of ways.

But the dynamic features offered by digitization have not been fully explored. The reason computer games have attracted players who sit in front of computer screens for hours is partially due to the interaction with the players and the dynamic settings tailored to each player. The sports entertainment industry has recognized that computer games have become a phenomenon, so it has begun to link computer games with real baseball games, and a cable TV game channel is currently under construction. Movies, with their traditionally passive content, are not dynamic or flexibly linked with other entertainment products yet. However, with the threat of large-scale piracy, the motion picture industry should create content that makes piracy of existing material unfashionable or obsolete. Games can be intertwined with CGI and real actor/actress performances. Input from game players can become the source of movie plots. Many modes of interchangeability can be explored dynamically. Movies can ultimately become a virtual reality product that links with viewers' senses and provides reality experiences like those imagined in the film version of *Total Recall* (Paul Verhoven, 1991).

The complementarities of digital products and the convenience of exploring such complementarities, not only create more avenues for the motion picture industry to generate profits but also form network-positive externality among all digital entertainment industries. For instance, a blockbuster movie can automatically serve to promote a game based on it. Hence, consumers can be attracted and retained through cross-marketing, just as Japan designs cell phones and accessories to converge with fashion and artificially generate demand and supply for seemingly durable goods.

5. Conclusion

Motion picture producers want to create films completely in the digital domain without having to scan them onto analog 35 mm film stock which must be transported on multiple reels (8–10 per feature film) in bulky containers all over the country. When the completed feature remains in the digital domain, it can be distributed instantaneously via Internet download or streaming technology. So the ideal would be that production, post-production, distribution, and exhibition will all be carried out in the digital domain. But at the same time, the threat of illicit digital copying looms.

Fearing uncontrollable piracy facilitated by new technology, leaders in the motion picture industry have strenuously lobbied Congress for anti-piracy legislation [23],

but because the Internet is a distributed environment and users can be largely anonymous, enforcement of such legislation is exceedingly difficult.

If the motion picture industry cannot devise a feasible solution to distribute its movies digitally over the most convenient infrastructure quickly, the industry may soon be faced with real competition for the first time in its hundred-year history. Especially after the arrival of universal broadband accessibility and effective compression and network technologies, companies in the information industry stand poised to take over some or all of the practices of the motion picture industry. For instance, Microsoft has long-standing plans to be a content provider, and Gateway and Dell are also considering entering the digital music business.

Faced with threats from consumers and other industries, the motion picture industry may have to break with tradition and find new profit avenues that take advantage of the new technology directly. It seems clear, therefore, that the motion picture industry must overcome its historical inertia and technophobia and change its strategy to work *with* technology instead of against it.

Our suggestions for reengineering the motion picture industry supply chain—establishing convenient e-Blockbusters, building digital theaters with the potential for virtual reality, creating dynamic, film-centered entertainment content—in an effort to neutralize piracy require close collaboration between the motion picture and information technology industries. Digital technology has become and will continue to be essential to the production, distribution, and exhibition of feature films.

This essay discussed our views on reconfiguring the motion picture industry's supply chain. Future research should study how such changes would affect the organization of the industry in areas such as industry concentration, competitive models, and pricing strategies, and their influences on other sectors.

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References

[1] Vogel HL. Entertainment industry economics: a guide for financial management. 5th ed. Cambridge: Cambridge University Press; 2001, p. 62.
[2] Dekom P, Sealey P. Not on my watch...Hollywood vs. the future. Beverly Hills: New Millenium Press; 2003 [p. 40].
[3] Movie downloads fail to generate much traffic. The Charlotte Observer 12 January 2004:C3.
[4] Universal City Studios, Inc., et al. v. Sony Corp. of America, Inc., et al., 480 F. Supp. 429 (C.D. Cal 1979).
[5] Sony Corp. of America, Inc., et al. v. Universal City Studios, Inc., et al., 464 US 417, 104 S. Ct. 774 (1984).

[6] Kremer SD. Content's king. Cableworld 29 April 2002:18.
[7] Lardner J. Fast forward: Hollywood, the Japanese, and the onslaught of the VCR. New York: W.W. Norton; 1987 [p. 171–175].
[8] Litwak M. Reel power: the struggle for influence and success in the New Hollywood. New York: William Morrow; 1986 [p. 233–234].
[9] Passmore D. Lobby Hollywood, not Washington DC. Business Communications Review 2002;April:16–7.
[10] Unintended consequences: three years under the DMCA. Electronic Frontier Foundation 2002 (May).
[11] Markoff J. Five giants in technology unite to deter file sharing. New York Times 5 January 2004:C1.
[12] La Franco R. Digital content and distribution—entertainment struts and frets its way into the future. RedHerring 2000;November.
[13] Matthews AW. Cinema's digital divide. Wall Street Journal 29 March 2002:B1.
[14] Blum J. Peering into the future: can peer-to-peer networking survive the consumer market? RedHerring 2000;November.
[15] Baker C. In a theater far, far away...wired 29 April 2002.
[16] Taub E. Digital projection of films is coming. Now, who pays? New York Times 13 October 2003.
[17] Vaz MC, Duignan PR. Industrial light and magic: into the digital realm. New York: Ballantine; 1996 [p. 227–228].
[18] Martin KH. A cut above. Cinefex 2000;82(July):27–8.
[19] Farewell, my lovely. Financial Times 4 April 2002:13.
[20] Manovich L. What is digital cinema?. BLIMP 1997;37:38.
[21] de Groat G. Rediscovering Norma Talmadge. Griffithiana 2000;71:105.
[22] Cook DA. A history of narrative film. 4th ed.. New York: W.W. Norton; 2003, p. 859.
[23] Harmon A. Piracy or innovation? It's Hollywood vs. High Tech. New York Times 15 March 2002.

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