Insight into animation industry: a summative report

Abstract

In recent years, rapid development of the modern sciences and technology has facilitated animation’s development. Computer animation has been one of the most booming and prospering industries. From the early ages of the disk machine to the translucent cels and current CGI animation, technology has been driving forward animation revolution. However, due to the rapid growth rate, there are currently obvious gaps between the animation production needs and research development. The most noticeable issue is the challenge from the exponential growth of animation data in current animation industry. And in the future, computer animation will rely more heavily on technology and data processing than ever before. Next generation technology is expected to meet the need of computer animation production. To provide a better insight into the current circumstance and predict the future needs of the next generation animation industry, a systematic analysis of its development is expected. There are currently some studies have investigated different aspects of animation industry, such as 3D technology, remarkable movies or policy impact analysis. However these studies hardly delivery a general view of the whole computer animation industry. In contribution to theories on the computer animation, this study delivers a systematic analysis on the computer animation industry by using a proposed theoretical model which consists of four primary dimensions, namely, technology, content, users, and community. The challenges existing in current animation production are discussed in detail further. Both the present solutions and possible solutions facing these challenges are studied. Finally, the future trends for animation research are addressed to facilitate the research and innovation of the computer animation industry. We hope that our research could provide a systemic knowledge of the development the computer animation and more important, have a clear cognition on the big challenges in current animation industry. Possible solutions that will benefit industry and practitioners, as well as the predictions of the research trends are provided to give guidance for future research development in computer animation.

1. Introduction

1.1 Brief History of Computer Animation

Animation has a long history. One early example is the paint on old pottery bowl discovered in Iran, 5000 years ago. Five images were painted around the bowl to depict the procedure of a goat’s leaping to convey the perception of motion [Animation Magazine, 2008; The Visual Linguist, 2006]. In the 19th century, the early animation means the process of creating the illusion of motion or shape deformation by rapid switching a sequence of images. The *phenakistoscope* is a kind of disk machine [Britannica, 2000], which could produce an illusion of movement from a series of discrete images arranged radically at that time. Zoetrope, or wheel of life, is one of the most well-known early animation devices, which worked in the same way of the *phenakistoscope*. It is a cylindrical spinning device. A sequence of drawings is painted around the inside of the cylinder. When it spanned, a sequence of slits passed in front of observer’s eye to present an illusion of motion of the sequence of the drawings [Wheel of Life, 2013]. In ancient China, there were some devices, called magic lantern, which used the light emitted from an oil lamp or candle to project a serious of paintings on the lamp shade to achieve simple animation by moving and merging images [Needham, 1965].

These early examples illustrated the movement of a series of static images by using different devices, which provided a foundation for the development of the animation art. Under the limitation of the existing technology at that time, the motion was presented at a rather low frame rate which was far away from the true animation. As a result, these devices could not be used in large scale entertainment industry.

Ever since then, there were several notable technological developments driving the progress of animation during the early years. One famous innovation was the projector (called the *cinematograph*) by the Lumièrè brothers
who were the first to present the commercial film publicly in 1895 [New York Times, 1948.]. The emergency of this kind of device enabled artistes to development and project film and make lifeless things appear to move.

*Enchanted Drawing*, is the first standard picture film, which included sequences of animated picture in 1900 [Crafton, 1993.]. As early as in 1908, the earliest traditional film animation, *Fantasmagorie*, appeared as an animated short film in France [Crafton, 1993]. There are also some examples of traditionally animated feature films including *Pinocchio* (United States, 1940) and *Animal Farm* (United Kingdom, 1954).

The most important animation technical development could be related with John Randolph Bray, the most successful producer at the time, who laid the foundation for traditional animation produce. He and Earl Hurd patented the use of translucent cels in animation producing process. In 1933, Warner Brothers Cartoons was founded. In the animation movie *Flowers and Trees* made by Disney Studios in 1932, three-color method was firstly used, which won an Academy Award for the work [filmsite, 2012]. And then colour animation soon became the industry standard.

During that time, each frame of a traditionally animated film was normally created by drawing on paper first. And then, the animators' drawings were shot onto cels. The completed cels were photographed one-by-one against a painted background by a rostrum camera onto motion picture film. The production of the hand-drawn animations at that time required the animators draw each frame manually. To create the illusion of movement, each frame differs slightly from the one before it. In this phase, animation films had become an industry of its own and were produced for showing in movie theatres.

As the digital successor to the traditional animation, computer animation used computer graphics to generate animated images instead of hand-drawn. There are significate differences between how computer animation and traditional animation create animation. Benefited from the development of computer technology, encompassing a variety of techniques, animation figures could be created or edited digitally on a computer. By using high-quality techniques in the production stages, the animation could be produced in a cost-effective manner with higher quality. We can say that computer technology revolutionized animation.

In the early years, from the 1940s, computer graphic technology was experimentally used in animation production. Between the 1940s and 1950s, John Whitney, one of the fathers of computer animation produced a series of experimental films as the first examples of motion control photograph [SIGGRAPH Whitney Profile]. From 1960s, the application of digital computers stimulated the development of the animation production. By using the computer *BESM-4* (the name of a series of Soviet mainframe computers built in 1950–60s), the sequence of the motion of a walking cat was created and filmed, which created the first computer animation of a character [YouTube, 2007] Thus, the first computer animation was created. Mid-1970s - 1980s: 3D technology emerged. *Hunger*, the first computer animated film was produced in 1974.

The time before the 1980s could be called “the early days” of computer animation. During this period, the animation production mainly took the form of traditional production mode. Only until the 1980s, there saw a great expansion of the computer animation production, which was greatly accelerated by the development of computer hardware, such as the appearance of the buffer technology and the improvement of computational capabilities. In this report, we take the 1980s as the first development phase and therefore the history of the computer animation development is broken down into four phases: phase 1 (the 1980s), phase 2 (1990s–2005), phase 3 (2006–present) and the next phase. By using the theoretical model proposed in the following section, we systematically analyse the evolution process of the computer animation production.

**1.2 Motivation**

Through a relatively long history of development, computer animation has been one of the most prospering industries in the world with a high growing speed, which is changing the world in many ways. Not just restricted to movies, current computer animation industry could also find employment in other areas including military, medical simulation, video game, virtual reality, advertisement etc. The computer animation market is also a rapidly growing sector on a worldwide scale today. The global animation and gaming market reached total market revenue of $122.20 billion in 2010. This market revenue will grow to $242.93 billion in 2016 and
the estimated annual rate will reach up to 12.94% in recent years [www.marketsandmarkets.com, 2011; Deloitte, 2010].

However, due to the rapid growth rate of the computer animation, there are obvious gaps between the industry needs and research development, which was evidenced in the case of the movie “Avatar”. The movie was delayed for ten years while the necessary technology was being developed. The cost of production for “Avatar” was over $300 million; on average, animation cost more than $1 million for one minute on screen, mainly due to the heavy involvement of manual preparation. This cost is unsustainable in the long term, especially as realistic animation and visual products will be used increasing with a wider range of products, such as interactive graphics, computerised training and simulation, in addition to blockbuster films. Replacing manual work largely by computers is a timely alternative, which requires the creation of next generation computer animation production with new technology. In addition, million dollars were invested in the hardware and software to store and manage the data (over one petabyte) produced during the making of the film “Avatar”.

Even for the short animation films, for example, Lune et le Loup [www.dwarf-labs.com, 2014], a French short animation film in 2014, the animation data of all the frames reaches up to about 1.5 TB. In 2015, Interstellar scooped the 87th Academy Award for Best Visual. The film is successful at the box office with a worldwide gross of over $675 million. This is a fact that further cements the importance of VFX in today’s movie landscape. To create the best effects, taking the creating the wormhole and a supermassive rotating black hole for example, theoretical physicist Kip Thorne served as scientific consultant and executive producer, who collaborated with visual effects supervisor Paul Franklin and a team of 30 people at the visual effects company Double Negative. Thorne would provide pages of deeply sourced theoretical equations to the artists, who then wrote new CGI rendering software based on these equations to create accurate computer simulations of the gravitational lensing caused by these phenomena. Some individual frames took up to 100 hours to render, and resulted in 800 terabytes of data. The resulting visual effect provided Thorne with new insight into the effects of gravitational lensing and accretion disks surrounding black holes, which led to the publication of two scientific papers. Ultimately the film contained 850 visual effect shots at a resolution of 5600 x 4000 lines: 150 shots that were created in camera using digital projectors and another 700 were created in post-production.

The boosts of current animation is growing the demand of new technology and raising a number of difficulties for current production status. The most noticeable issue is the challenge from the exponential growth of animation data in current animation industry. And in the future, film animation will rely more heavily on technology and data processing than ever before. Both the current status and the future animation production urgently call for novel design and new solutions to tackle the emerging challenge of handling huge amounts of the animation data. New resolutions for creative activities and reshaping the landmarks of technology are expected by pioneering research and novel development to save the time and costs in next generation animation production. Unfortunately, up to now, existing analysis studies only focus on a certain aspect of computer animation, such as 3D technology or policy impact analysis. Current research works seldom investigate the aspect of systematic theoretical analysis of the industry and fall short of delivering an overview of the evolution of computer animation, let alone to conduct an instructional prediction of its future development. Also, the critical current challenges existing in the animation industry such as the emergency of the huge animation data and new technologies desired by the animation production, as well as their corresponding solutions, are also expected to be investigated.

Our main purpose is to provide insight to the industry needs and give guidance for the next research development. This report delivers a theoretical model analysis to review its evolution process on the base of different periods of the computer animation development to serve the evolving industry, address existing challenges and predict trends to facilitate the research and innovation of the computer animation industry.

Our main research work and contributions include:
1 Systematic analysis of the evolution of computer animation is conducted based on a proposed theoretical model toward a better understanding on the entire industry landscape.
2. The major challenges and requirements in current industry, especially the effect of the huge animation data, new platform and trends, are identified and highlighted to provide insight to the industry needs for the next generation animation production.

3 The existing and possible solutions to the challenges in current animation industry are studied.

4 Trends analysis are provided to give guidance for the future research development.

The rest of this report consists of four parts: the next section discusses the theoretical analysis model for the computer animation production. The challenges faced by the industry are presented in the following section as well as the possible solutions as well as the new trends in current animation industry. Finally, the report is concluded. We want to draw a road map so the recent innovation in IT can benefit animation.

2. Theoretical Model Analysis of Computer Animation Production

2.1 An Open Production Model

There are some literature researches studying the development of animation industry, which mainly devote to introduce the specific technologies, animation companies, or focus on the introduction of the glories of animation products. However, the systematic study of the animation introduction is left untouched, which is expected to be helpful for the researchers by providing an overall understanding of the feature of the industry. We could also know how important this theory analysis is to provide insight to the industry needs for next generation technology and furtherly give guidance for future research development in the relevant areas.

In the field of creative and media production, e.g., the Open Production Communities, there are already several theoretical frameworks are delivered to provide understanding in a systematic way [Ziaie, 2013]. ZIAIE defined a theoretical framework deliver a general view of the OPCs. His research could shed light on the insight into the computer animation industry.

Inspired by ZIAIE’s work on the model analysis of the OPCs [Ziaie, 2014], a theoretical model for animation production is proposed in this report to conduct a better understanding on how computer animation has evolved during the decades. In our research, animation product, animation industry, technology and human are defined as the four consisting dimensions of the animation production model and, the corresponding attributes of these dimensions are discussed in detail also. This proposed theoretical model is expected to present the cornerstone of computer animation industry and facilitate the analysis of the computer animation industry to have an overall understanding of the feature of the industry. During the model designing, much attention is paid to the great important factors that fundamentally shape the essence of the whole computer animation industry, which are summarized into four dimensions: technology, animation product, human, and animation industry.

**Technology** Technology can be taken as an abstraction layer which provides the development methods and environments for the animation production with numerous technological layer related contents including algorithms, software, hardware and infrastructure etc. The development of new technology is playing a major role in the rapid expansion of the global computer animation and game industry. Technology has proved extraordinarily influential in computer animation industry. Once new technology has been developed, deployed, accepted and used, there is usually a significant promotion of the animation production. To some extent, it is technology that drives the animation forward, just like the Industrial Revolution had promoted the world industry.

**Content** Animation products vary in different developing periods. In the early age, as the initial form of animation product, there were only 2D animation movies shown in the cinema. And then the 3D animation film and video game entered into normal life on TV or were sold in the form of DVD. With the development of the computer animation, current animation and gaming market offer a wide variety of animation products, which are broadly used in education, business design, and animation entertainment mainly (such as animation movies and
visual games). Animation movies include 2D animation and 3D animation and, visual games generally consist of computer games, console games and mobile games etc. [Lin, 2013].

**User** In our model, there are four main kinds of actors related to the human dissension, which include the author and developer, producer, broadcaster and, consumer. Known as the screenplay, the author starts the process of the innovation and then the developer enhances this creation progress as the movie development. The producer plays a central role both in the creation and dissemination activities involving in innovation and funding. Broadcaster limits market access and capture a large share of the income. Consumer is a person or organization that uses animation services, which plays a vital role in the industry. Without consumer demand, the producer would lack one of the key motivations to produce: to sell to consumers.

**Animation Community** In our report, animation community is a term of Ecology, which could be taken as a kind of social, religious, occupational group sharing common interests or a common heritage in computer animation area. Animation Community involves three aspects: the industry, research community and education.

- **Animation industry** is the production of computer animation products or services within an animation economy, in which based on the technological platform human perform certain activities to produce animation products to reach specific goals, such as chasing commercial profits in animation markets. The overall animation markets correspondingly involve Education, military, entertainment, medicine etc. on the basis of product segments. The global animation industry consists of four geographies: North America, Europe, Asia, and the rest, among which North America takes the leading position, whereas Asia grows fastest [marketsandmarkets.com, 2011].

- **Research community** is a group of researchers who emerge and develop area in computer animation. They exchange ideas and discuss issues with each other. With the help of the Internet, the community can adapt to almost any research need, show creative stimulus material, and gather ideas for innovation and co-creation.

- **Education** Considering the tremendous market demand on animation professionals, within the last few years, computer animation programs are broadly offered in higher education, which are interdisciplinary and involve film arts, computer science and fine arts etc. However some students are found unable to handle the job in animation studios after graduation [Flaxman, 2003]. That means currently the improvement in animation education is expected to meeting the expanding employment need of the animation industry.

**2.3 Phase 1 of Computer Animation (the 1980s)**
In this phase, technological innovation in computer science greatly stimulated the development of computer animation production. A most important advance is the development of the computer hardware, which significantly promote the computing power and provide a solid foundation for the development of computer animation production.

In the early 1980s, Silicon Graphics, Inc was founded in California by Jim Clark. Geometry Engine, a powerful semiconductor chip and the IRIS (Integrated Raster Imaging System) were initially produced to give the graphics workstations great computing power to produce sophisticated three-dimensional graphics. [SGI, Company Overview]. LINKS-1 Computer Graphics System is a supercomputer consisting of 257 microprocessors developed by Osaka University in 1982. LINKS-1 was able to render realistic 3D graphics rapidly with the help of new algorithms [Osaka University]. Marked by the appearance of the IBM PC, a great expansion of the developments of workstations for computer graphics was seen during this time, e.g., workstations by SUN, HP, and DEC. These greatly advanced the computing ability and affordability for computer graphic and also, provided possibility for producing the cost-effective computer animation films and vision games.

With the help of the fast development in computer hardware, computer graphic was becoming a more popular tool in movies to animate computer generated environments. Computer graphic algorithms, such as anti-aliased
ray tracing [Turner Whitted, 1978], fractal terrain [Vol Libre, 1980] and particle systems [Reeves, William T, 1983] were implemented in commercial animation tools and companies. During this period, Commercial software products were also getting more and more sophisticated and professional for animation production and lots of computer graphics companies were founded, such as Digital Pictures (an American video game developer) [http://segaretro.org/Digital_Pictures], Lucasfilm [http://lucasfilm.com/], Digital Production [A Critical History of Computer Graphics and Animation, http://design.osu.edu/carlsom/history/lesson6.html#dp] etc. In 1986, Autodesk’s first animation package-AutoFlix was used with its CAD software AutoCAD. And its first full 3D animation software 3DStudio was released to the public in 1990 [Dave Baker, 2010]. Alias Research was founded in 1983 focusing on software for SGI workstations [A History Lesson on Alias 3D Software, 2011]. Wavefront was founded in 1984 developing produce computer graphics software used in Hollywood motion pictures and other industries. [“Wavefront Technologies”, the Internet Movie Database]. And Softimage was founded in 1986. Its first product was published at SIGGRAPH’88 in which the 3D processes including modelling, animation and rendering were firstly integrated [Softimage 3D, Digitalmedianet.com. 1999].

3D computer animation starts to appear at that time. Disney’s TRON (1982) was a remarkable movie, in which extensive graphical objects and virtual environment were generated by computer animation technology. Another example is The Last Starfighter (1982). In this film, computer animation special effects were involved instead of creating props in which the graphics were supported to look realistic. Many notable products used 3D computer animation to replace 2D conventional animation production and also made great achievements. For example, Red’s Dream (1987) is a computer-animated short film produced by Pixar, which received general enthusiasm at its SIGGRAPH premiere at [Price, David (2008)]. Tin Toy (1988) won the 61st Academy Award for Best Animated Short as the first computer animation [http://www.oscars.org/]. Technological Threat (1988) is an early animation short film integrating 3D computer graphics technology into animation production and nominated for Academy Award in the same year with Tin Toy.

### Table 1: Dimension Features in Phase 1

<table>
<thead>
<tr>
<th>Technology</th>
<th>Fast development in computer hardware stimulated the primary development of computer animation. Computer graphic was becoming more popular due to the appearance of many notable new commercial software products.</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>Main young children. Watch in the theatres/ on TV.</td>
</tr>
<tr>
<td>Community</td>
<td>Lots of computer graphics companies were founded, such as Digital Pictures, Lucasfilm, Digital Production.</td>
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</table>

### 2.4 Phase 2 of Computer Animation (1990s~2005)

The 1990s saw the beginning of the impact of computer animation on the entertainment industry, during which technology had undergone enormous changes. The hardware became cheaper and energy-efficient, different kinds of platform infrastructures were built, software and algorithms in computer animation kept developing. Computer animation began to be widely used in common human life taking the form of TV programmes,
movies, visual games, online/console games etc. New digital techniques had created a revolution in animation production.

Digitalization is the most important technological revolution in this phase, which changed the production method of the traditional cel animation. Shot by using digital technology, animation movie is easily to be stored in digital form. That means the movie is also suitable for processing digitally. To enhance the visual impacts, digital special effects are easily to be added in and edited. For example, the simulation of the hot air distortion out of the engine in the movie *True Lies* (1994) and the curling progress of the hair in the movie *Interview with a Vampire* (1977) etc.

More complex models of virtual characters were created with the breakout development CGI technology in animation production. In the movie *Terminator 2: Judgment Day* [box office, 1991], CGI technology was used to create a deformable liquid metal robot. By using CGI special effects, the character could morph into anything shapes. [Jefferson, David, 1993] In *Jurassic Park* [box office, 1993], 3D dinosaurs as well as other digital elements such as water splashing and digital face were created by using CGI. First all CGI movie was produced by Pixar in 1995, *Toy Story* [box office, 1995]. In this ground-breaking film, complex models and animations were created using only computers including elaborate lighting, different textures, and realistic facial animations. And then followed by some notable animation movies, such as *Kung-Fu Panda* [box office, 2008, 2010]and *Ice Age* [box office, 2002, 2006,2009,2012].

New CGI technologies were wildly involved in the production, such as flocking, motion tracking and motion capture etc. Taking motion capture for example, in the 1990s, this technology was widely used to animate the motion of digital character in 2D or 3D computer animation for visual effects. *Final Fantasy: The Spirits Within* (2001) was the first photorealistic computer-animated feature film fully made with motion capture [World Records]. The first real-time motion capture feature film is *The Lord of the Rings: The Two Towers* [box office, 2002]. The actions of the actor were captured and used to drive the motion of the computer generated character Gollum to deliver a complex movement and realistic interaction. Motion capture was also often wildly used in visual games to animate athletes and other by mid-1995. 1995 The arcade fighting game *Soul Edge* firstly used passive optical motion capture system for CG effects [Ron Fische, 2013].

In 1990s and later, professional animation software were furtherly developed and widely used for animation production in film, broadcast, game development, corporate and industrial design, education, medical, and web design. Enormous development has been made in 3D animation software. After 3DStudio, Autodesk developed 3D Studio Max in 1996. With a cheaper price, 3D Studio Max was quickly accepted and widely used by professionals. Later its name was changed to “3dsMax” and then rebranded as the current “Autodesk 3ds Max” [History of Autodesk 3ds Max]. In 1998, Maya 1.0 was released by Alias as the new 3D flagship product and then Maya soon became the most important animation tool in computer animation industry. In 2003, Alias was honoured with Academy Award for Technical Achievement for the development of Maya. Later, the name of “Maya” was changed to “Autodesk Maya” after Maya was bought by Autodesk [wikinews, 2005].

The Internet, possible the most important digital revolution in human history, had a tremendous impact on computer animation by providing a more convenient dissemination media. With the rapid growth of cable, taking the advantage of the Internet, more and more animation companies distributed their animation contents through internet services. At the same time, the users began to adapt and then addicted to the ubiquitous Internet to consume animation products which furtherly fertilized the quickly extending of the animation on the Internet consequently. Represented by the Internet, new platforms of computer animation greatly changed the human life as well as the computer animation production.

During this phase, CGI technology significantly promoted the animation production, which uses computer graphics to produce each frame instead of using human hands to draw and colour. Animation production remains one of the most labour-intensive ones where quality moving imagery relies heavily on manual operation from a large number of animators. For example, the jobs of character modelling and motion creation normally take many skilled animators much more time than the produce of traditional cel animation does, which led to a bigger budget and high barrier to for animation companies’ entry. Also, the rendering task of the whole feature
filen could normally take more than one year for computing without interruption [The Economist, 2005]. For example, in the production of the Jurassic Park [box office, 1993], the rendering dinosaurs within one frame often took two to four hours. All of these technological limitations existed as great challenges in animation production.

<table>
<thead>
<tr>
<th>Table2 Dimension Features in Phase2</th>
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<tbody>
<tr>
<td>Technology</td>
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<tr>
<td>technology had undergone enormous changes</td>
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<tr>
<td>hardware became cheaper and energy-efficient,</td>
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<tr>
<td>Different kinds of platform infrastructures were built, e.g., Internet</td>
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<td>Professional animation software was furtherly developed and widely used for animation.</td>
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<tr>
<td>CGI technology significantly promoted the animation production</td>
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<tr>
<td>Digitalization</td>
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<tr>
<td>Content</td>
</tr>
<tr>
<td>Films and games wildly involved New CGI technologies</td>
</tr>
<tr>
<td>Final Fantasy: The Spirits Within (2001) was the first photorealistic computer-animated feature film fully made with motion capture</td>
</tr>
<tr>
<td>Soul Edge (1995) The arcade fighting game firstly used passive optical motion capture system for CG effects</td>
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<tr>
<td>User</td>
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<tr>
<td>Game player</td>
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<td>TV viewer</td>
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<tr>
<td>movie audiences</td>
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<tr>
<td>internet users</td>
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<tr>
<td>Community</td>
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<tr>
<td>New platform: Internet</td>
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<tr>
<td>Remains one of the most labour-intensive ones where quality moving imagery relies heavily on manual operation from a large number of animators.</td>
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<tr>
<td>Enormous development has been made in 3D animation software with the developments, mergers and deals in the computer animation companies</td>
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<tr>
<td>Autodesk</td>
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<td>Alias</td>
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2.5 Phase 3 of Computer Animation (2006–present)

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<tr>
<th>Table3 Dimension Features in Phase3</th>
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<tbody>
<tr>
<td>Technology</td>
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<tr>
<td>The emergence of novel platform: mobile devices, social network mobile applications</td>
</tr>
<tr>
<td>Content</td>
</tr>
<tr>
<td>there has been a significant decline in these traditional form of products due to technological advances and changes in consumer preferences</td>
</tr>
<tr>
<td>More products tightly focus on mobile platform and are made more available for online watching (e.g., YouTube)</td>
</tr>
<tr>
<td>On-line app stores, such as the App Store and Google Play</td>
</tr>
<tr>
<td>User</td>
</tr>
<tr>
<td>Both the consumption pattern and the consuming habit of the public have changed with the revolution of the new digital technology;</td>
</tr>
<tr>
<td>Through new platform, animation consumers share and exchange their favour with others;</td>
</tr>
<tr>
<td>More adults, even the whole family, become animation consumers</td>
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and lovers.

<table>
<thead>
<tr>
<th>Community</th>
<th>mobile platform</th>
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<tbody>
<tr>
<td></td>
<td>social network</td>
</tr>
<tr>
<td>Animation companies are adapting their animation production and products to consumer preferences and expand global animation market by novel channels.</td>
<td></td>
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<tr>
<td>Globalization, international exchange and cooperation</td>
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Since the 2006, computer animation has undergone many profound changes, among which innovation is the most significant in the development of contemporary animation industry.

Firstly, novel platforms inject new vitality to the world computer animation industry growth. The latest trend in animation is toward the experience on new interactive platforms, such as video to mobile devices and to the Internet and social network [Cardillo, 2006; Raugust, 2007]. New communication platforms, such as the smart mobile phone and iPad, are becoming popular among consumers. Animation companies create entertainment and products significantly depend on the current state of the technology and consumer’s preferences. The sales of DVDs and TV programs are the traditional main revenues and profitability coming source for the long time in animation industry. But over the last decade years, there has been a significant decline in these traditional form of products due to technological advances and changes in consumer preferences. More products tightly focus on mobile platform and are made more available for online watching (e.g., YouTube). One kind of typical application on the mobile platform is mobile application, also commonly call APP, which are computer programs developed to run on mobile devices (e.g., smartphones and tablet computers). The on-line app stores, such as the App Store and Google Play provide variety of applications to different mobile devices operation systems users for downloading. This mobile platform also provides a new way for developing, downloading, and updating computer animation contents in modern mobile devices.

The emergence of novel platform has great effect not only on computer animation production but also on the consumption. As a consequence, both the consumption pattern and the consuming habit of the public have changed with the revolution of the new digital technology. Through new platform, animation consumers share and exchange their favour with others. Some animation fans even partly participate in the animation creation procedure with the help of the up-to-date animation technology on the novel platform, which significantly promote the development of computer animation. Passive animation consumers are turned to active animation users with the expansion of new technologies [Benkler, 2006; Flowers, 2008]. Also the structure of animation consumers is also changed. With the rising popularity of the novel platform, more adults, even the whole family, become animation consumers and lovers. But in the past few years, the target audience is main young child, which is evidenced by the success of the Simpsons and King of the Hill on prime-time TV in in America [Digital Vector, 2015].

Both the trend of animation consumers’ tending to spend more time on the innovative platforms and the rapid evolution of technology provide computer animation industry precious transmission chance. Animation companies are adapting their animation production and products to consumer preferences and expand global animation market by novel channels. Globalization, international exchange and cooperation have inevitably become the popular modes of animation production. According to the Global Animation Industry Report 2014, the output value of the global animation industry in 2013 was approximately 222 billion USD. International exchange and cooperation, partnership and co-production between different countries have become a popular strategy [Research and Markets: Global Animation Industry Report 2014].
3. Data challenge in current animation production and possible solutions

3.1 Fast data growth in recent years

Just as the Industrial Revolution created an entirely new way of life, the big data and analytics are changing the landscape of the whole world. The related market of Big Data is expected to grow at an annual rate of 41.4% from 2012 to 2018. Accompanied by the booming of the global animation and gaming market in recent years, more challenges arise in the computer animation, especially the way we manage the animation data. The exponential growth of animation data is urgently requiring the development of advanced technology and tools for handling.

Despite over 30 years history and the ability to produce stunning visual effects for many block buster movies, the computer animation industry remains one of the most labour-intensive ones where quality moving imagery are generated by a large number of animators. There’s no doubt that the animation industry is currently experiencing an extraordinary accelerating increase of hybrid animation data. The amount of the data generated during the last few years exceeds the sum of the pervious digital data [Bipin, 2014].

To generate huge fortune in annual sales, normally hundreds of employees would be employed by one animation company to handle everything from 3D modelling and lighting to feature films, animation, and IT. Handling 3D model files for instance, computer programs, such as Maya, render these models into video images in a resource-intensive process. Images must then be received and stored continuously into production, and archived weekly into storage repositories. All of this places unique big data management requirements in the animation industry.

However, movie animation and rendering firms like DreamWorks and Rainmaker can’t accomplish any of this work without a well-developed strategy for managing chunks of big data that come in the various forms of heterogeneous data files including video clips, audios, 3D geometry shape, texture, motion files etc. Take DreamWorks for example, by the end of 2014, DreamWorks employed approximately 2,700 people and its feature films have grossed $12.9 billion worldwide [Dreamworks annual report, 2014]. The production of an animation movie normally takes about several years and creates billions of different kinds of digital files. Almost all the people working in this production processes have to face the issue of rapid data expanding. A feature film usually runs for 90 minutes and is shot at 24 PFS. The data of each frame reaches up to 50 MB or even more than 100 MB. The rendering task is very heavy which leads to the render farm has to handle thousands of jobs per day. [Techrepublic, 2014].

Beside the huge amount of the animation data needs to be handled, there is also the requirement of managing terabytes of big data in real time due to the expanding production schedule. When several hundred video animation engineers and artists are simultaneously working on shows, each individual requires real-time access to multiple renderings of the project he is working on. The object-based files in movie animation and rendering systems can be as much as 256 terabytes of storage, and in a daily movie production environment about 100 terabytes of big data is “in play” at any one time during the day.

As a result, current circumstance is terabytes of big data produced by the rapidly expanding market animators need to be handled and storage. Animation data for modelling and creation which takes up a significant period of time repeating preparations at different stages of production exist as the most challenge in animation production. Conventional tools, e.g., the relational database management system do not have the capability to manage surging volumes of the hyper type animation data. New technology such as “smart data solutions” is expected to address the problem with two aspects, aiming to halve the production time and reduce the overall cost.

3.2 Possible solutions

Big Data is on the horizon, which drives the revolutionary collaboration models of today’s e-Infrastructure to make it more broadly accessible and applicable. Conventional tools such as Relational Database Management System do not have the capability to manage surging volumes of unstructured data. The European Commission’s Digital Agenda highlights that immediate action needs to be taken - “The Strategic Coordinating Committee for Information and Data (SCCID) recommendations highlight the need to adopt a best practice guide to data management, clearly define “open access” to data in science, explore the merits of regarding data as a publication and provide support on data management for science” [CORDIS,2011].
3.2.1 Current Data Management System

The management of digital data is an increasing concern in all stages of the animation production. This animation data, often treated as some kinds of “assets”, exists in wide variety of forms, such as text files, audio files, video files, texture files, graphic files, 3D model files, motion files, scene files, and many other types. Also, within each of these types of file, the file may even be in different formats, such as a graphic file could take the formats of the JPEG, TIFF or BMP etc. and the 3D model files could be the formats of *.ma or *.mb for MAYA and *.max for 3DMax. As the core of the animation production, these assets are expensive to create or acquire. Thus, the reusability of animation data is also an important concern. Once the digital asset is created, it is necessary for that asset to be securely stored and indexed in a fashion that allows it to be easily retrieved. The asset also must be maintained to ensure that any revisions to the asset are only done in an authorized manner. The management of numerous types of digital media data has created extensive problems in the management of the animation data created for animation production.

A number of applications have attempted to address some of these issues. Examples of these systems often used in animation industry include the production workflow management toolset and the digital asset management system (DAM) etc.

Digital Asset Management system (DAM), a typical data management system currently used in computer animation industry, natively manage file likes images, audio, video, and the like, and offer thumbnails, streaming previews, metadata extraction, and other special features to make working with such files easy. This kind of system can track all assets, view thumbnails of that asset as well as being able to search for an asset based on tags. There are also serval solutions for the broadcast industry and TV news specializing in the management of animation products for archival/retrieval, creation, and broadcasting. Existing solutions, like “Alienbrain”[18] is more or less a classic file store and sharing system without intelligent features to promote efficient extract and reuse of information, inhibiting flexibility and increasing complexity of the creativity practices. Current research in this area does not suffice to meet demands in industry, where large studios spent over million dollars to develop and maintain complex proprietary systems whose function is limited.

Shotgun Software is “A production tracking, review, and asset management toolset for VFX, animation, and games teams of all sizes” [https://www.shotgunsoftware.com/]. Shotgun is more of a production tracking system rather than an asset management system. It appears more suited to production workflows (task management, scheduling, high level breakdowns etc.) rather than integration with artist applications to load assets from disk.

One thing to point out is that current applications systems fail to adequately address the issues discussed above. The ability to manage digital assets is less than satisfactory. An outstanding issue, for example, is that these systems are short of the support of specific content-related functionality. Such content-related features include content-based retrieval, the ability to generate low-resolution thumbnail images from high-resolution data, to easily elaborate different multimedia objects generated in different computer formats or to manage individually stored digital content in a single multimedia document. Current searching is text-based, which index the metadata such as keywords, tags, or descriptions associated with the data files and rely purely on metadata are dependent on annotation quality and completeness. Having humans manually annotate digital assets by entering keywords or metadata in a large database can be time consuming and may not capture the keywords desired to describe the desiring data.

The content-based retrieval is the most important function that the intelligent data management should provide for the purpose of animation data achieving and reuse in a higher efficient and more user-friendly way. Content-based retrieval could provide the facility of searching the animation data by analysing the contents of the animation assets rather than the metadata such as keywords, tags, or descriptions associated with the data files. The content used for retrieving might involves colours, contour profile, textures, motion trail or any other information that can be derived from the animation files. The content-based retrieval is desirable because it allows the user to customize the search queries for digital assets stored within the system and also, allows the user to customize the display of the results of the search queries in order to optimize the search routines.
Current animation data management, e.g., digital content/asset management systems and production management toolset involving asset management have helped animation companies streamline text-based, content-based workflows and processes. But with the expansion of the animation production, the next evolution of managing data is expected to be established as an important part of solving the growing challenge of big data in animation production.

3.2.2 Cloud platform Distributed network

Another issue is the prior applications fail to provide a distributed architecture to balance the load and usage of the digital assets between different locations in an efficient and optimal manner. The prior applications fail to allow for local storage of the assets at high-use locations while still maintaining central control of the assets and their use. The prior applications also fail to provide the capability to automate many of the tasks necessary to organize the assets. Organizations, particularly in modern animation industry, are often geographically separated. There may be offices needing to pool resources that are separated by great distances. The transfer of animation data resources between these offices frequently creates many problems in tracking the digital assets.

Normally big animation studios currently have a worldwide distribution. The animation data needs to be shared and processed corporately through network. The render farm, where the main calculation takes place, for example, needs to copy files for sharing. But this may lead to the latency problem even the different sites are connected through high speed pipes (10 GB e.g.). One possible network solution is to use NFS as the main file system to cache across wide areas by making the data local, which reduces the latency and greatly affects the productivity. However, with the rapid expanding of the computer animation, as a result, the complexity of animation data makes it hard to maintain, resulting in considerable costs and development risks. With increasing demand of high precision, managing growing volumes of hyper type animation data becomes a big challenge, which cannot be overcome by simply adding new servers on the network, such as the NFS.

Cloud platform is an emerging solution focusing on providing a scalability and high performance network environment, which could be consider as an ubiquitous, convenient, on-demand data computing and storage solution for the animation industry. On this platform, the main services provided for animation industry include cloud computing and online data storage. Via the Internet, cloud computing and cloud storage provide users and enterprises convenient solutions to access animation data resources and computing services from cloud services providers.

One successful example is the usage of cloud platform for the production of one DreamWorks film, How to Train Your Dragon 2. The creation of this animation generated half a billion files and the animation data reached up to about 250 TB. It needs thousands of computing cores to keep working corporately on the rendering task for 75 million hours. For the huge animation data processing, DreamWorks’ private cloud platform is used, which consists of three distributed data centres and 20,000 computing cores [www.telegraph.co.uk, 2014].

Pursuing the better animation experience, a higher resolution and more life-like motion are required in the animation products, which will inevitably result in the data expanding for rendering and storage. The animation data generated during the creation process of the animation movies and visual games will keep growing at a high rate in the future.

By buying or leasing cloud service from the service providers, animation companies now could conveniently access the capacities of cloud computing and storage. It is expectable that, in the near future, provided with faster cloud computing and larger cloud storage capacity, the stress of the huge animation data will be relieved with the help of the cloud platform.

3.2.3 Hand over data management to the professional

Currently most of the animation companies have their own data centres to handle the large amount of data created by computer-generated images. Normally consisting of numerous powerful servers, data centres enable animation companies to process and manage the huge volumes of hyper type animation data.
However, nowadays the data is growing fast for the purpose of providing better visual effects. *Lune et le Loup* ([www.dwarf-labs.com, 2014](www.dwarf-labs.com, 2014)) is a French short animation film in 2014. Its running time is only 4 minutes but the summary of the animation data of all the frames reaches up to about 1.5 TB. The data demands of the feature animation films are even bigger today. Almost all the feature films runs for 90 minutes or even longer and are usually shot at 24 PFS. The production of each frame involves the usage of hundreds of digital asset files. As a result, the creation of a feature animation film could often generate as much as 500 million files ([www.telegraph.co.uk, 2014](www.telegraph.co.uk, 2014)).

To meet these big data production needs, as a result, some animation companies have started to outsource their animation data management to the professionals. One typical example is DreamWorks’s handing over its data centre to HP. The global director of infrastructure operations at DreamWorks Animation, Michael Cutler considers that the data outsourcing enables the company to just focus on animation creation rather than on the maintenance of IT infrastructure. He said: “Data centre management comes in and lifts up all the daily routine things that we do; the inventory, the asset management, the configuration management database,” “These kinds of aspects in our infrastructure are taken care of; we don’t have to think about them anymore. It allows us to take time and our engineering resources to work with the people at HP to drive innovation even further.” ([www.telegraph.co.uk, 2014](www.telegraph.co.uk, 2014))

To reduce the data managerial costs, outsourcing animation data to foreign/domestic or to the offshoring professional contracting may be a wise choice considering the difference between the amateur and the professional.

In the future, the expansion of animation industry inevitably contributes to the rapid growth of animation data. There is no doubt that the Big Data revolution is dramatically altering the ways of the animation industry. As a result, the animation companies should get into the active management of big data. Advanced technologies and tools on novel platforms, such as mobile computing, cloud services and intelligent data management will surely shed some light on the future development of handling animation data.

### 3.3 research trends on next generation data management

The research on the next generation novel intelligent data management solution for animation production with the capability to handle huge amounts of animation data and analyse/summarise information is beginning in some institutes in Europe, which is tailored to promote the reusability and accessibility of vast data created in animation production to facilitate human creativity. The related research include information extraction, document summarization, semantic web, visual analytics, the development of next generation techniques related to computer animation and its applications etc. Intelligent data management frameworks with the capability to handle huge amounts of data and analyse/summarise information for reuse of data to facilitate human creativity will be the hot point of the research of the next generation data management in computer animation industry. Additionally, beside the consideration of the requirement of the huge animation data, the mobile computing is one of the most promising platforms contributing the acceleration of the animation industry.

### 4. Discussion

And in the future, film animation will rely more heavily on technology and data processing than ever before. Both the current status and the future animation production urgently call for novel design and new solutions to tackle the emerging challenge of handling huge amounts of the animation data. New resolutions for creative activities and reshaping the landmarks of technology are expected by pioneering research and novel development to save the time and costs in next generation animation production.

Our research aims to propose a research guide to fulfil the existing gaps and prospect new solutions for the future of the animation industry. The field of computer animation takes a distinctive path which marries art and design with mathematical and computer science. Not only is it serving the creation of images in Hollywood blockbuster films and interaction in games, but more importantly and usefully, it has been applied to other fields such as manufacturing and design, health care, education and science. It has been a golden era in the past twenty
years for the ever evolving field of computer animation, where with novel hardware and gadgets numerous techniques have been developed, or adopted from other disciplines, redefining the shape of its landscape and boundaries. We are approaching a point where the breakthrough of technologies occurs to fulfill a need in the world of digital creation and design, where the industry seeks more realistic visual artefacts and dynamics, more immersive experience, more sophisticated interactions and more complex models to handle and manage increasing data storage. We hope our research will not only contribute to presenting and defining knowledge in the academic community but also will map its outcomes and influence to industry and therefore bring profound influence and benefit for the stakeholder, including individual practitioners, companies and policy makers.

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