BIM PRINCIPLES TO PRACTICE: USING BIM TO CREATE A NEW MODEL FOR PRODUCING ANIMATION

A Thesis

by

NICHOLAS D. NAUGLE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2011

Major Subject: Visualization Sciences

BIM Principles to Practice: Using BIM to Create a New Model for Producing Animation

BIM PRINCIPLES TO PRACTICE: USING BIM TO CREATE A NEW MODEL FOR

PRODUCING ANIMATION

A Thesis

by

NICHOLAS D. NAUGLE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Chair of Committee,	Tim McLaughlin
Committee Members,	Mark Clayton
	Fred Parke
Head of Department,	Tim McLaughlin

December 2011

Major Subject: Visualization Sciences

ABSTRACT

BIM Principles to Practice: Using BIM to Create a New Model for Producing Animation. (December 2011)

Nicholas D. Naugle, BFA, Brigham Young University

Chair of Advisory Committee: Prof. Tim McLaughlin

Computer animation projects, specifically feature film productions, require large teams of artists to manage and coordinate the use of enormous amounts of data containing both aesthetic and technical information within a specific time frame and while using finite resources. Mismanagement through information loss or inefficiency can result in both a compromised artistic vision and a financial loss. This thesis presents the conceptualization of a work management system based upon a successful system used in architecture and construction called Building Information Modeling, or BIM. BIM principles are adapted for use in animation production through the use of images as containers of information. The thesis does not include implementation of the management system described but does predict, based upon comparisons with architecture and construction, that a significant level of information carry-through can be achieved from concept art to final frames and we expect a positive gains in the efficient use of production resources. Adoption of this proposed project management structure could reduce production budgets, improve the communication flow between directors

and artists, and develop an empirical based record for predicting the resource usage requirements for proposed projects in the future.

DEDICATION

I dedicate this to my loving parents who have provided me with wonderful opportunities to learn and to my thesis committee for their patience, and guidance.

TABLE OF CONTENTS

Page

Page

Page

Page

Page

LIST OF FIGURES

Page

Page

LIST OF TABLES

Page

1. INTRODUCTION

The production of large scale computer animation projects requires a large team of artists, a specialized tool set, and a process able to retain the artistic vision of the project from concept to completion. The act of film making started in 1895 but production processes continue to vary widely within the industry . Few standardized systems for conveying information, integrating tools, or methods for learning from past projects exist; except through the experience of individuals and accountant's ledgers. Even among the small group of large studios producing computer animated feature length films, such as Pixar Animation Studios and DreamWorks Animation, tools and processes vary widely. Information about effective techniques is lost from project to project and the use of diagnostic tools within a project is minimal. The results of these short comings include wasted time, money and difficulty maintaining artistic direction.

The industry lacks a standard comprehensive project management system to maintain data from the beginning to end of a production. Information loss between phases of the project often results in revisiting and reworking different elements. Loss of information occurs because of miscommunication or data loss when information moves from one department to another. Information and artistic vision sometimes does not reach the right people. The loss of information impacts production time, cost, and the ability to meet the director's goals. Inefficiency is the main problem in producing animation today

---

This thesis follows the style of *ACM Transactions on Graphics*.

affecting budget and time constrains of productions. Miscommunication, improper documenting techniques, inefficient communication, and a general misuse of resources all contribute to inefficiency for the animation industry.

This thesis deals specifically with data and information management for the computer animation industry. It looks at other successful system implementations of managing large projects for possible solutions to address animation's weaknesses. Specifically, I look to solve the problems within the animation field by examining the building construction field and how they resolved similar problems. This thesis develops a theoretical working model of what an ideal animation management system requires for the future. The thesis goes no further then suggesting what an ideal system includes and is only a theoretical model. Some visual examples given illustrate how such a system might look if implemented but this paper does not implement a working prototype. It's main purpose is to explore and reveal what areas of animation require the most improvements and look for principles and practices outside of the animation field to solve these problems.

The approach taken here differs from other investigations because I chose an outside discipline to model a new production system tailored specifically for animation. Other systems have approached the problem of managing animation projects based on project management solutions for film production. Although animation is a medium within the film industry it differs from live action films which require less front end development. This thesis includes the understanding that animation works within the limits of film making and also requires an approach unique to the medium of animation to solve its problems of wasted time and money.

The organization of this thesis first explains the animation movie industry and it's related costs and how these variables affect the motivation of the paper. Then I discuss related works within the animation field to develop our understanding of the current working processes and methods used to complete full-length animations today. Next the discussion turns to why adopting a process from outside the animation field is worthy of our attention. Then I implement what I learned from the systems outside animation and how the principles apply to the animation process. I also present the issues related to implementing these new technologies and how they may progress in the future. Finally, I discuss the possible impact of this new system on the future of the industry.

2. MOTIVATION

2.1 Economics of Animation Production

2.1.1 Why Movies Get Made

Movie making requires artistic vision, collaboration, and business direction. Movie viewers attendance provides revenue and a potential for a return on the studio's investment. Revenue from movies allows people to pursue their desire to create movies, and funds development for new projects.

Although film making started in 1895, with the Lumiére Brothers, it remains a largely organic process[Wikipedia 2010a]. The artistic nature of the film industry involves many teams of artists and technicians. The management departments within the industry work to make sure that projects stay on schedule and on budget. Higher management makes decisions on whether ideas make it in to production. Like all business enterprises movies require test audiences, marketing and refining of the final product before release. Ultimately movie making occurs because movies make money. When done right they return large profits to their studios and allow people to work creating something they enjoy.

2.1.2 Typical Budget Range

Published online reports provide information about how much films cost to produce. However, studios rarely release financial breakdowns of production costs. Little data exists about how much films go over or under planned studio budgets. Lacking the data of how a project budgets itself creates a problem when trying to determine a more economic approach for the industry. So determining how much money is allotted to artists making the movie versus how much voice talent costs remains unknown. This kind of data could provide researchers the information to make better estimates about the economic impact of new production techniques.

Wall•E (2008) by *Pixar Animation Studios* cost $180 million, while *Finding Nemo* (2003) cost $94 million to produce[Box Office Mojo 2011a,d]. The industry needs to find more efficient production techniques due to the current financial decline in the industry. In 2009 the revenue growth rate in the post-production industry declined 6% from 2007. During 1999, 756 films were produced versus 453 films in 2007, which illustrates the downward trend of film production[IBIS World, 2009]. Clearly the declining industry needs to consider new methods to reduce cost.

In 2010 the animated film Toy Story 3 became the first film to gross over 1 billion USD at the worldwide box office. The cost to produce the film, 200 million USD, became eclipsed by a more than 863 million USD profit [Box Office Mojo 2011c]. Although the film cost 1.9 USD million per minute to make it made more then 11 million USD per minute. Some films don't make that in an entire release. *Fly me to the Moon* cost only 25 million USD to produce and made 41.7 million USD at the worldwide box office, Recent Trend in Domestic Film Production

Year	Units Theatrical Films Produced	Units
1997	767	N/C
1998	683	-11.0%
1999	756	10.7%
2000	683	-9.7%
2001	611	-10.5%
2002	546	-10.6%
2003	593	8.6%
2004	611	3.0%
2005	699	14.4%
2006	485	-30.6%
2007	453	-6.6%

Source: Motion Picture Association of America

Fig.1. Downward trend of films produced per year[IBIS World, 2009].

making only 16.7 million USD after production costs [Box Office Mojo 2011b]. Compared to Toy Story 3, *Fly me to the Moon* cost over 3 million a minute. So although a lower budget movie, it also made much less per minute, only 0.192 million USD. These two movies represent the typical spread of animated movie box offices.

2.1.3 Box office vs. Collateral Impact from Intellectual Properties

Profits made from the movie tickets sales do not account for all profits made by a movie. Even before a movie releases the marketing department conducts studies to determine what markets the film may find success in outside of the box office. For some films this includes licensing agreements, toys, product placement and commercial deals. Although the box office may account for the highest earnings for some movies, good marketing leverages the film to continue producing revenues for the production company when the movie stops playing in the theater.

Shrek's licensing shows the power of using intellectual property to further company profits after the movie stops playing at the theatre. As of the release of *Shrek Forever After,* on May 21, 2010, the Shrek franchise earned more then 2 billion USD in merchandising worldwide[Loveday 2010]. Dreamworks™ is extending their franchising to produce a musical, *Shrek*, to extend the life of the franchise. Even though box office sales represent the main measurement of success, good marketing allows films to produce more income for a studio after the film stops playing in theaters.

2.2 Preservation of Artistic Intent Throughout Project Development

2.2.1 It's All About the Story

The animation process begins with an idea for a story. The story is created by a group of artists skilled at story telling. Full-length feature animations use the story to drive the decision making process for the rest of the project. The story influences all departments downstream including, art, modeling, animation, shading, and lighting. Some artists contribute verbal material such as scripts and others contribute with visual reference for the story.

2.2.2 Process of Making a Movie Transforms from Verbal to Visual

The director works with story artists to develop the story-line for the film. Most story ideas begin in verbal format. It all starts with a story pitch (or presentation) to executives. The pitch often takes a format where the director explains the story idea by performing it or explaining it to executives. If the idea interests executives then the director works with story artists and writers to refine the story. Then the director assembles a team of concept artists to develop the visual look of the film.

The story and concept artwork dictate the creation of the assets and shots (a *shot* is an edit of film made of multiple frames). The assets and shots combine to determine the final images viewed by audiences.

2.2.3 Process of Making a Movie Requires Years

Initially the process of creating and refining the story takes years. For full-length animation the time for production is longer than live-action films. Animation requires more pre-production, or planning, than live action. Animation requires fabrication of the entire environment where the film takes place. Everything about that world needs producing. The physics of the natural world are unknown in the computer environment and needs defining. Artists build the entire environment and construct the characters with the ability to perform. Live-action sets include real actors, real locations, or fabricated sets to altar reality, but they mainly depict the physical world which you and I experience. Animation, unique from live action films, occurs in a world constructed from scratch. The animated world, if patterned after our own, still does not actually exist. The amount of work to achieve the illusion of reality requires the management of large amounts of data, information, resources and people.

Another reason for animation's longer pre-production time includes the cost of revisiting work. More time is spent in animation preproduction then on live-action films to make sure more work does not have to be redone later. You can imagine the time and effort required by the animation crew if they want to change the set or even something as simple as dialogue. It can take a lot of time to reanimate a character or create an entire new set. Live action allows for the actor to improvise dialogue and even try different acting scenarios while on set. Live action allows for improvisation. Animation tries to lock the story in place before production begins. With better planning during pre-production less work needs revisiting while in production.

Further complicating the animation production is how the computer calculates the final product. Each shot includes a set length of time measured by frame count or the number of frames (images) the computer creates. Standard frame rate means creating 24 frames per second. Render time calculates by measuring the time required by the computer to draw an image. Generally, longer shots in terms of frame count take longer to render then shorter shots. Times may vary widely within the set number of frames for a given shot. Some shot's complexity is so great that they takes days to render. The production seeks to find ways to complete shots as quickly as possible which helps keeps costs and render time down.

2.2.4 Process of Making a Movie Transforms

2.2.4.1 Small Group of Story Pitch Artists

The director works with the story department that includes storyboard artists who help to plan each shot according to the director's vision. Storyboards refer to small drawn images representing action of a shot and changes in character movement and camera direction. Each storyboard artist draws out the part of the story they receive as an assignment. Then the artist pitches their idea to the director who reviews their storyboards and makes comments directing alternatives until the artist receives approval of their assignment. Within this group of story artists the animation first starts to take shape as a piece of story telling. This group, normally small, works very closely with the director to accomplish the director's vision.

2.2.4.2 To A Large Collection of Different Kinds of Artists

After the story artists flesh out the story the director begins to assemble other artists and technicians to aid in the creation of the film. The storyboards which the story artists created, will serve as a measuring stick for all other departments involved in the animation to determine what each department needs to do in order to finish the film.

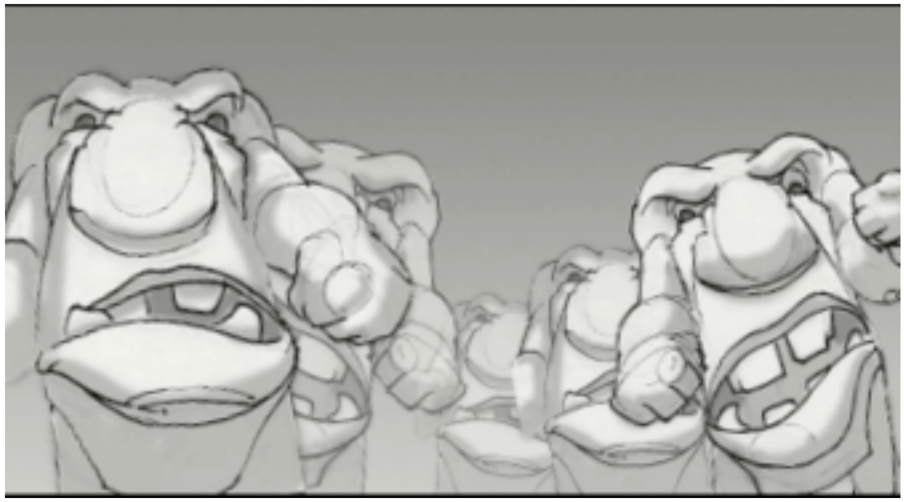

Fig.2. Example of storyboard

They aid in determining budgets for each department as department heads review which shots will require more work and attention by their department. They help animators determine timing and pacing. Storyboards help determine dialogue for the voice talent and the sets makers learn the relation of the characters to their environments. Essentially, the storyboards become a type of blueprint for the film.

2.2.5 The Impact of Time and Money on Artistic Decisions

The animation field lacks real studies with measurable data to determine what systems provide cost savings. Time and money affect animation production because of animation's role as a business as well as an art-form. Market pressures such as a poor economy, larger and cheaper High Definition TVs (HDTV's), and Blu-ray players affect

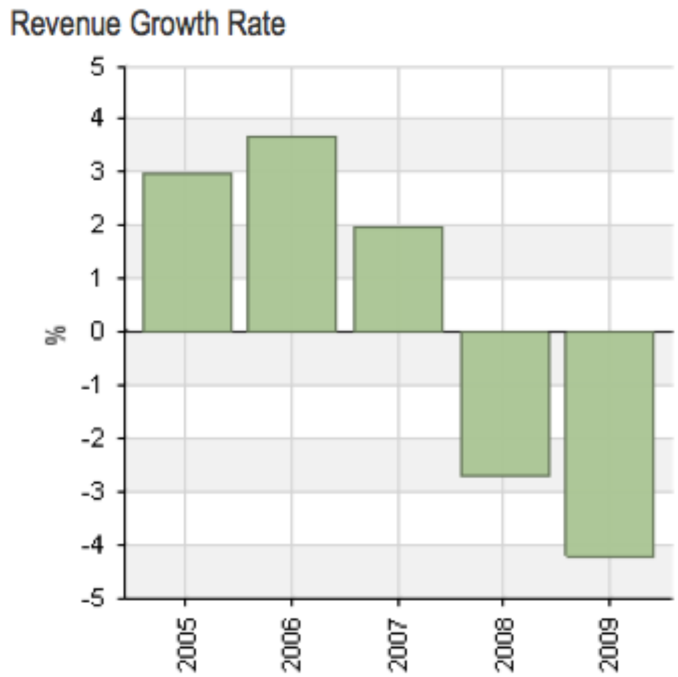

Fig.3. Movie industry revenue losses[IBIS World 2009].

the film industry's revenue[IBIS World 2009]. The animation industry now finds it necessary to look for new ways to save costs on productions. Recently the post-production industry experienced losses in revenue due to some of the previously mentioned market pressures.

Large amounts of complex data, stored digitally, creates challenges in managing virtual information while producing large projects. Some producers lack technical understanding of the specific techniques used to create computer imagery. They rely on computer graphics supervisors to bid on time for completing specific elements of the show. This collaboration between the producer and supervisor determines how much money and time is spent on certain aspects of the production.

One problem faced in the animation industry includes the loss of information between departments. With more people involved in the decision-making process loss of information and possibly artistic vision increases. The old game "telephone" is a good example. The game starts with one person passing a message to another and so on until it reaches the end of the chain of people. Normally the longer the chain of people the more the message becomes distorted or corrupted from the original message. So producers, supervisors and artists must work diligently to make sure the information is clear and unchanged from what the director wants. Producers and management use tools to aid them in keeping all communication clear and free from ambiguous instructions. If important information or artistic vision looses fidelity when passed from person to person the vision of the director is lost which costs time and money to correct. Monetary losses therefore diminish for the production when communication practices avoid miscommunication between departments. Data delivered late also creates a bottleneck in the production and causes other departments to suffer setbacks. All of these problems combine to increase time spent on a production and burden the budget.

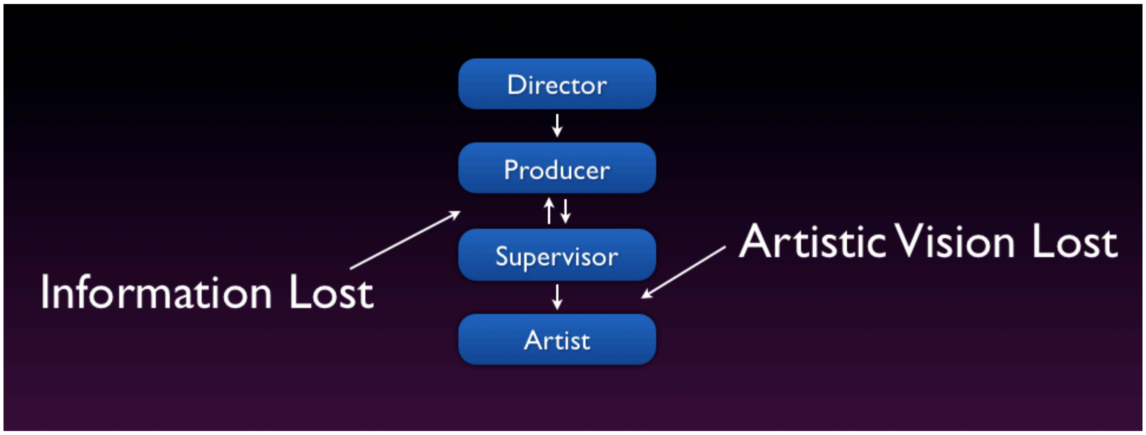

Fig.4. Hierarchy of film production and possible information loss.

The overarching motivation for proposing a new system includes the desire to reevaluate the workflow of animation and examine how the management of the current workflow affects the technical processes, and production costs of a show. An area within the pipeline which always seems lacking includes the management of different tools. With the digital information created during production, leveraging the computer's ability to store, process and organize that data increases the efficiency within a production, saving the studio time and money.

3. RELATED WORK

3.1 Overview of the Economics of Creating Animated Films

Better planning and communication between all parties involved in the production helps to eliminate errors, saving time and decreasing cost. Integration also helps maintain the artistic vision of the director. Maintaining the artistic vision of a production helps keep cost down. Minimizing communication errors helps the integrity of the director's vision and keeps the production from redoing work when miscommunication occurs.

3.1.1 Factors That Impact Profitability

3.1.1.1 Interoperability

Interoperability is the ability of a program to interact with another program and its data. “Interoperability identifies the need to pass data between applications, and for multiple applications to jointly contribute to the work at hand. Interoperability eliminates the need to replicate data input that has already been generated[Eastman, Teicholz, Sacks and Liston 2008].” Interoperability within a system increases transparency for a production. Developing a better understanding of how data flows through a production enables managers to gain new insights to keep productions on time and on budget.

Designed to work together, interoperable tools, help complete tasks as a system. Smith illustrates this point.

> In manufacturing, for example, thousands of automated tools exist that can perform simple tasks such as measuring, cutting, pouring, grinding, crushing, drilling, polishing, rolling, clamping, screwing, stamping, heating, cooling, painting, curing, or drying. Each tool is designed to do one thing very well[Smith and Tardif 2009].

Smith's example illustrates how simple tools working together define interoperability. One of the defining characteristics of interoperability states that one process inputs into the next process. The nature of architecture and animation, as information heavy collaborative projects, means both benefit from using tools that facilitate greater and more effective exchanges of information.

3.1.1.2 Communication

3.1.1.2.1 From Director to Artists

The job of the director includes inspiring his team to catch the vision he has for the story. The director of a production uses team leaders, or supervisors to carry his vision to all the artists on the show. Directors don't have the time to sit down with each artist to review their work. Instead the director uses the supervisors as a buffer to direct the crew dependent upon their individual skill set. So supervisors act as an interim director giving reviews of artist's work. This hierarchy of information handling helps to relieve the director of middling with minutia in every aspect of the show. The director and supervisor act in this knowledge sharing role to give artists the direction they need to capture the overall vision of the film.

3.1.1.2.2 From Stage to Stage of the Production Process

The creation of an animated movie requires large amounts of data to move efficiently from beginning to end in order to achieve the vision of the director. The production of an animated movie works similarly to an assembly line. Productions include a defined beginning, middle and end. Ideally, processes occur linearly one after another with one group handing off finished work for the next crew to use for their assigned task. Often though, the middle processes involve substantial overlap. The ideal production process for an animated film includes the one outlined in the diagram below.

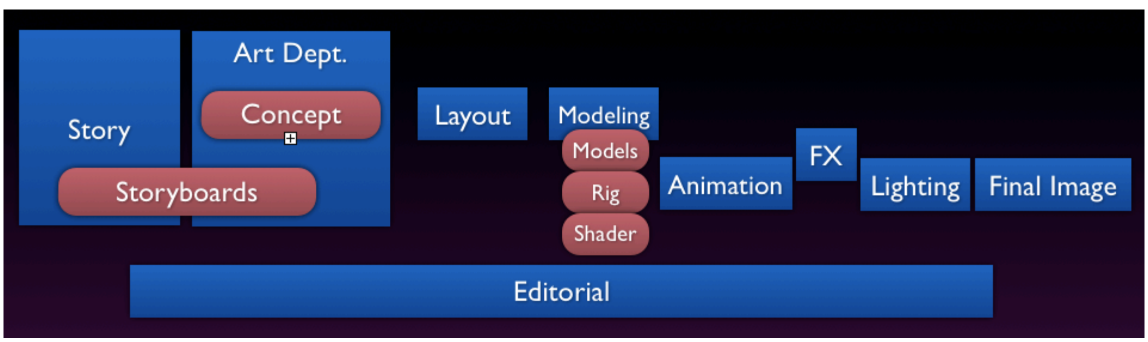

Fig.5. Lifecycle of an animation production by departments involved. Blue shows department while red illustrates assets created.

Sharing information between multiple groups of specialized people becomes a bottleneck to completing a project successfully[Nissen and Raymound 2002]. Data here is defined as values and variables. Information is data applied to a specific context. Knowledge is the information applied to a direct action[Nissen and Raymound 2002]. The flow of data from one department to another is as important as the flow of artistic vision between departments.

3.1.2 Roles Relative to Responsibility for Efficiency

3.1.2.1 Producers

3.1.2.1.1 Overview of Their Responsibilities

Producers comprise the group of people in charge of managing the film making process. Without producers, budgets and time constraints might go unnoticed. Technical supervisors meet with producers about specific departmental needs. The producer acts as mediator and notates the needs of different areas of production including animation, shading, effects and lighting departments. Producers continually update schedules, status of assets, and budgets. Producers and their assistants constantly take meeting notes and send out updated information. Producers also help to encourage morale to keep spirits high. The difficulty in their job comes from working with people and making sure those people have the information they need to complete their job.

Producers concern themselves with information that helps them manage a department or entire show. They need to know the status of deadlines, current and expected inventory, personnel, and be aware of the rate of progress.

Producers want to know the current status of their department. This requires them to keep track of personnel. They monitor said personnel's current workload and the expected date for completion of their tasks. They also need to know how much personnel to budget for and when more inventory requires more personnel.

Producers don't work alone except on smaller projects, instead they work in teams. The team of production staff is sometimes called the "production office" or "the office of the producer". These teams work together to coordinate deadlines, budgets and talent across departments to keep the entire show on budget and on schedule.

Producers facilitate the important task of passing information between departments. They want to know what work needs to happen in their department for the next department. Just as important the producer needs to know the status of the department previous to the one she manages. Knowing the status of the previous department's deadlines and production rate allows the producer to plan ahead for her departments needs. The producers also help plan logistics of setting up a department before it comes online in the production process. They involve themselves in managing the people and the resources of the production to help finish the film smoothly.

Computer graphics supervisors meet with producers to coordinate shot elements defined by their area of expertise. Some of these areas include modeling, animation, effects, cloth, hair, lighting and shading. Producers rely heavily on the experience of these supervisors to budget shots and develop a timeline for completion of a show. Therefore, producers also concern themselves with information about previous show's budgeting, and compiled statistics to determine what caused over-spending or scheduling conflicts.

Their role in planning logistics of the production means producers are some of the first staff on a production and the last to leave the production. The head producer will remain on a project for the entire length of a film. Producers assigned to a specific department finish when their department completes its production specific tasks. Producers, depending upon company practices, may stay on longer to make reports about the production within their department.

3.1.2.1.2 Producer's Tools for Information Management

Currently producers use multiple tools for managing money, time, and resources. Some tools include project management applications, email, charting tools and excel sheets. A keyword search on the web provides a large selection of project management tools, many web-based. Not all of these tools, such as Microsoft Project, suit the animation industry. Most studios use a mix of commercial and proprietary tools for creating a show.

Spreadsheets allow the organization of data based on a matrix of information. Producers use these to help track information about budgets and schedules. More sophisticated then a simple spreadsheet is a database spreadsheet. The database allows for user input and easier access for multiple viewers to receive updates about relevant information.

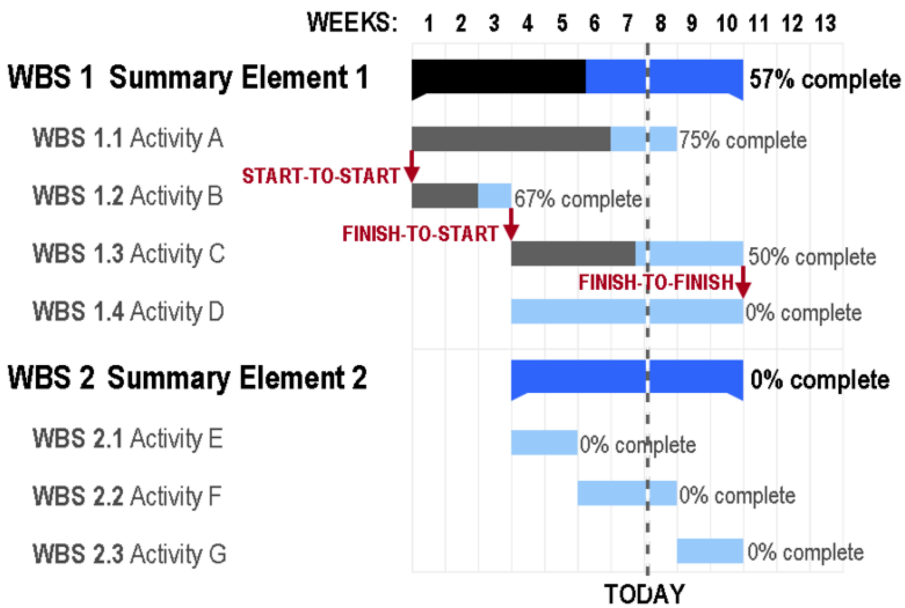

Fig.6. Example Gantt chart [Wikipedia 2009a]

Gantt charts, come from the discipline of project management. Henry Gantt developed the charting system named for him around the turn of the 20th century[Wikipedia 2009a]. Even today project management programs exploit their usefulness. They illustrate the current state of a project based on time and tasks. Their popularity comes from the ability to read them quickly and accurately in a graphical manner. The manager quickly sees a project's state, by viewing a timeline of tasks. She can see how long tasks take and see the projected deadlines too.

3.1.2.1.2.1 Communication Applications

Communicating information to artists and supervisors to keep them informed and up-to-date or to notify them of changes is one of the producers most important jobs. Producers rely mainly on email as their tool for communicating such data. Although a recent development in the business world, email remains a quick and trackable way of communicating much of the needed information artists and supervisors need in a timely manner. Used with a database emails inform users of changes to a database. The drawback of email is the inability to attach them to information with-in the pipeline. Considering the complexity of systems managed by computers today email appears archaic yet it remains the notification tool of choice.

3.1.2.2 Supervisors

3.1.2.2.1 Overview of Their Responsibilities

Supervisors use concept artwork from the art department to help define the cost and time estimations for the show, often called "bidding-out" the project. Before a production enters asset construction, technical supervisors assess artwork to determine technologies needed for the creation of specific assets such as main characters, background characters, sets and props. Supervisors act in a managerial role within a specific department. They oversee the department's artists directing them towards the director's vision, helping solve technical problems and work with producers to manage workloads within the department.

3.1.2.2.2 Information They Care About

Supervisors have the experience to know how to manage the group of artists or technicians in their department. Their supervisory role is a natural progression of working in the roles they oversee. Usually they include more technically savvy or more senior members of staff.

Supervisors want to know who their team includes. They need to know the strengths of each team member. This helps them determine how to distribute the workload across the team. Knowing their team helps them divide workloads to complete the department's goals.

The supervisor concerns himself with the current state of the department. This includes deadlines, technical huddles requiring attention, and reviewing all artist's work for approval. Of great importance to any supervisor is the state of the department upstream and downstream of his responsibilities. Before a production enters asset construction, technical supervisors assess artwork to determine technologies needed for the creation of specific assets such as main characters, background characters, sets and props. Knowing how an upstream department is performing informs the supervisor when and how much work his department expects in the future. Knowing the workload of the department downstream helps him measure if his department is pushing enough inventory to keep them working. They also want to know deadlines, and expected dates, and shots or assets left in inventory.

Supervisors want to know where the problems lie and how best to tackle them. They need to know the department's budget, keep up department morale and solve technical problems to prevent bottlenecks in the production.

Supervisors also review the work of artists with-in their department to make certain it meets the standards set within the department. This also includes checking that the work matches the vision of the director.

Supervisors usually stay on as long as the department is in production. Depending on their role they stay on a production longer than the entire department to help review information about how the department ran under their guidance.

3.1.2.2.2.1 Supervisor's Tools for Project Management

To complete all of her responsibilities the supervisor reviews data which overlaps some of the producers responsibilities. The supervisor uses some of the same tools the producer uses such as email, gantt charts, spreadsheets and database information. Most importantly is the information coming from the artists themselves. Images and statistics generated by artist processes consume the supervisors time to make certain artists stay within the technical and visual guidelines given to them to maintain visual integrity of the final imagery.

Image viewers are one of the most basic tools in the industry. They simply display stored images. The image viewers used within the industry do more than image display. Often they will provide data such as pixel value information. This kind of data helps supervisors determine how much of one color is present in any selected pixel. Specific data obtained from the image viewer helps the supervisor compare the vision of the director with each artist's work in the department.

A second type of image viewer includes an image sequence viewer. Animation is simply a series of still images strung together and played back at speed to give the illusion of movement. The supervisors also use image sequence viewers to playback a sequence of stored images. This tool is invaluable to the animation supervisor as he provides feedback to artists to match the director's vision.

Gantt chart for supervisors provide reports concerning time and task breakdowns to manage the department's status and to set deadlines for artists. The supervisor views the status of his department's progress measured against the deadline. He may even see information about individual artists and their upcoming deadlines.

3.1.2.3 Artists

3.1.2.3.1 Overview of Their Responsibilities

Artist is a broad term used within the animation industry. The term includes people who draw, but it also defines the technicians who's work includes more computer programming skills then artistic skills. For example, a traditional artist is often employed in the concept art department and an effects artist is employed to create a water or fire simulation. The effects artist requires different skills and tools then the concept artist but both are creating a visual product.

The artist cares most about completing her work and achieving the vision of the director. Any information to aid in the two above tasks is important for the artist.

The artist needs to keep in mind what the supervisor asks for and when the supervisor or producer expects the work. Studios may keep the artist from knowing the producers allowing for the supervisor to relay deadlines, or producers maybe involved. These artists work closest to the data of the production that creates the final images of the film.

The artist's main concerns include completing their tasks on time and according to the supervisor's instructions. To do this they require multiple tools. Artists need to know information regarding; color, timing, pacing, fixes. The artist requires reference material to know the director's vision. Imagery supplied by upstream departments aids the artist in reaching the director's goals. Artists also concern themselves with the information needed to complete their tasks on time, including the departments goals.

Artists' time on a production relies entirely on budget and inventory. If no inventory exists for the artist to work on then there is no room for the artist on the show. When inventory becomes available then the artists start time depends on the budget. If the budget allows for them then the artist receives inventory to work on.

The information that the artist interacts with relates specifically to his own area of expertise. Most artists work with some software to aid in the creation of the final image. The artist uses her knowledge to manipulate the information given to her to create additions to the production consistent with the director's vision.

3.1.2.3.2 Artist's Tools for Production Management

Artist use a myriad of tools for manipulating the data that finally produces the final image. Common tools in the industry include Maya™ , Shake™, Nuke™ , and After Affects™ to name a few. All of these programs aid artists to create 3D and 2D visual information. Studios also use proprietary programs which they find necessary to implement for specific tasks to get their work done.

Artists use the same image viewers as their supervisors. Their reason for using an image viewer differs though. The artists use image viewers to receive feedback. They also use image viewers to make sure they finish all notes given to them in reviews. The image viewer is a necessity for the artist.

The artists use Gantt charts to help them view upcoming deadlines and review if upstream department's work is complete. They aid the artist by informing them about what shots or assets they need to spend their time on now.

3.2 Overview of the Processes Involved in Creating Animated Films

3.2.1 Definition of Front End and Back End

The front end of an animation project defines and establishes a framework for the rest of the film. Story, storyboards, concept artwork, schedules, budgets and asset creation all comprise the front end of a project. Artists and managers work together to ensure the production is replete with documents and assets needed to define the final look of the film. The front end of the production is also sometimes referred to as "preproduction".

The back end includes all the departments creating assets within a shot; including layout, animation, lighting, effects, and rendering. Ideally these departments come online after the front end of the production completes their tasks. Realistically, there remains some overlap with continued coordination between the front end and back end departments. Throughout the production exchange between the front end and back end occurs when errors become apparent further down the pipeline. The front end departments retain a small number of staff to aid down-stream departments with work. Often problems manifest only later in the pipeline after implementation by multiple departments.

3.2.2 Front End

3.2.2.1 Story Development

The story department includes the first team of artists to work on the film. They work to aid the director in establishing the story. They create storyboards to help visualize the timing. Then the storyboards go to the editorial department where they make a rough cut of the film.

3.2.2.1.1 Story Reels

Storyboards scanned into the computer and then edited together with temporary dialogue create a story reel. These reels become one of the most important working documents of the production. Story reels define the timing, pacing, staging and shots of the film.

3.2.2.1.2 Layout

The layout department then begins populating the 3D environments for the project and places cameras into each scene. After the layout department defines the shot in the computer they pass this information on to the animation department.

3.2.2.1.2.1 What is a Shot

A shot is defined by the camera currently showing action. A shot changes whenever the camera cuts to a new camera view. Each new view from the camera is a different shot. A film is made of thousands of shots.

3.2.2.1.3 Editorial

The editorial department comes online as soon as the storyboards receive approval. The editors then cut the storyboards into the story reel. They keep the film up to date by replacing the storyboards with the most recent footage created. That footage maybe completed final frames or it may includes shots with only approved animation. Each department's progress is therefore reflected in the most recent edit of the film allowing the director to view the current status of each shot.

3.2.2.2 Visual Development

3.2.2.2.1 Artistic Intent

3.2.2.2.1.1 Asset Transformations from 2D to 3D

Eventually, front end production departments must translate two-dimensional drawings into three-dimensional objects. Creation of assets need to match artwork developed by the art department to meet the director's vision. The art department plays a similar role as an architect, trying to design for a client. Ideally, asset creation occurs after designs receive approval.

3.2.2.2.1.2 Form, Color, Texture, Mood

It remains the duty of the art department to create the documents, such as model and character sheets to define how the objects must look. These sheets define the scale and dimensional information of assets. Drawings of the assets needed for modeling provide the artists with an orthographic showing top, front and side views. These 2D renderings provide the needed visual information to begin transforming concept art in to production ready assets.

The art department provides information regarding a model's color and textures. These documents called shading packets include 2 dimensional swatches of information for the shading artist. Depending on the models they may include color swatches, texture swatches, fabric, hair, fur or other material references. All this compiled information is for the artist to create an asset within the production's defined characteristics.

Not only do modelers concern themselves with proportions and dimensions but they receive information about extreme poses the characters need to perform which helps the modeler know how to create a model able to withstand all animation extremes. Other documents define poses and facial expressions for animators. All of these documents require managing and coordination to make certain the correct information reaches the artist.

3.2.2.2.2 Reference Material

3.2.2.2.2.1 Relationship to Assets

All the model sheets and shader packets include 2D information for application in a 3D computer environment. All assets require 2D documents to define their attributes within the production. This tie between the 2D and 3D worlds is a link requiring management of data and information as they pass from one group of specialists to another.

3.2.2.3 Tools and Process Development

Each animation production requires unique solutions to problems. Teams of technicians work on how to solve best these dilemmas by developing tools to make their job easier. Artists require tools to aid in creating assets, or working documents. Supervisors require tools to monitor output and track status of shots. Both the artists and supervisors deploy multiple tools on the front end of a production such as the previously mentioned image viewers, Gantt charts, and 3D programs.

3.2.2.4 Asset Development

After the story department finishes defining the film, production crosses into the area of asset development, and then moves into a shot driven environment. Artists create assets before much work begins on the production. Assets include all materials, models, and rigs. Essentially, assets include all data not specific to a single shot but rather to a larger portion of the production, or used in multiple shots. Characters provide a good example of assets because they appear in multiple shots and scenes throughout a production. The characters often include more than one asset. Assets include the textures used on the models. Therefore assets often become hierarchal in nature.

3.2.2.4.1 Modeling

Models always populate a shot, and modeling finishes before shot centric departments complete their work. The modeling department receives modeling sheets from the art department with all of the specifications needed to model a character or other asset. The creation of each model needs special attention to ensure it stays within the vision the director.

3.2.2.4.2 Rigging and Animation - Tests and Cycles

Rigging is the process of creating controls to make the character animatable. Rigging requires knowledge of modeling so the rigger does not make control that break the models. The rigger's job is more technical in nature, but is requisite for animators to do their work. Rigging requires animator's input. The animators test the rigs and the riggers make changes based on the animator's feedback. The feedback for the riggers provides them information to make more robust rigs or more user friendly rigs. So the importance of the two departments working together is for the benefit of the entire production.

3.2.2.4.3 Texturing and Look Development

As stated before the art department creates documents to define textures on a model. The shading department receives these documents showing which colors and textures need to appear on characters and objects.

Look development is done within the art department. Concept artwork is used to develop the style and look of character, the environment and even color palette. Shaders create the color and texture of a given object. Many objects include multiple shaders. Their complexity varies between objects which also affect render times.

3.2.3 Back End

3.2.3.1 The Importance and Use of Shots

For the production the shot defines the space in which many artists work. Shot assignments given to artists allow for a division of labor and more manageable approach to completing a film. Most of a production's tracking occurs on a shot-by-shot basis. The status of a show's budget and schedule uses this measurement. Shots provide a basic unit of measure to account for the film's completion. A series of shots defines a sequence. A show's completion is broken into a hierarchy of timeline related information providing producers and supervisors with information and data on the progress of specific areas of a film.

3.2.3.2 Animation

Adding movement to the assets, like characters, adds another level of complexity to the production. The increase in complexity comes from added data. Animators add data at different points on a timeline. This additional data creates the movement of the characters. The computer then fills in between the data points and calculates how the character moves from one data point in the timeline to the next. Each character contains hundreds or maybe thousands, of controls for the animator to manipulate. Calculating all of the changes between these thousands of data points increases the time it takes the computer to process the animation.

3.2.3.3 Lighting

Lighting occurs after animation adds motion data to the shot. Lighting is the process of placing mathematically simulated lights with-in 3D space to imitate real lighting effects. The amount of lighting used in a shot dramatically changes resource requirements such as memory, disk space and render times. Lighting includes shadow creation which proves more or less expensive depending on the method used. Shadow generation using ray tracing techniques increases render time more than texture mapping techniques. Different lighting techniques also change render times. For example, simple direct lighting affects the number of lights placed in a shot. Lighting includes trade-offs and most lighting artists understand the expense of using certain lighting effects over others. A lighting artist's responsibility includes watching efficiency of render times. Currently, the industry does not track the data that the lighting artists create when editing a shot's lights.

3.2.3.4 Effects Animation

The effects department adds any elements that fall outside of previous departments such as water, cloth and other physically based simulations. The effects include animation of elements which require computer simulation and not hand animation. Effects require a lot of computer processing and memory. Often simulations can take hours to run on a computer. The effects department makes certain to optimize as much as possible to keep time and costs down.

Often effects artist and technicians work with animators and the lighting department to make sure their work fits into the already defined parameters made by those departments. For example, if a character requires a piece of clothing for simulation then effects department requires completed animation before simulating the cloth to ensure it moves with the character. This one example illustrates how backend departments require intercommunication of information and data to complete their tasks for the production.

3.2.3.5 Rendering

The computer renders all shot data. Rendering is the process of the computer reading all data and then calculating that data to produce an image. Each pixel's value and color is determined during rendering.

The speed of objects moving relative to the camera affects how long it takes the computer to render, or compute, the images. Motion blur effectively reproduces photographic realism for moving objects. Motion blur occurs when an object moves faster then the camera shutter speed and the resulting images show blurring where action occurs. Computing this information, consequently, increases render time.

Rendering uses studio computing power and requires time for computers to process information. Some studios treat rendering as a separate department while other studios include this task as the lighter's responsibility.

Rendering taxes the CPU because the computer uses its resources to translate the 3D information into a 2D image. Depending on the complexity within a shot, rendering proves more expensive on some shots than others. The longer a computer sits processing, the more money a final image costs.

3.2.3.6 Compositing

Compositing is the process of layering multiple image elements together to create a full image. The final image displayed to the audience includes a composite of multiple images. The entire image rarely computes all at once because it taxes too much of the CPU and system memory, often causing the computer to crash. Most full-length animations layer multiple elements of an image to cut down on render time.

The separation of final images into multiple elements and compositing them together into one image is standard within the industry. The details of the process occurs differently depending upon project requirements and studio practices. For a full-length animation the compositing is often done by the lighting department.

3.2.3.7 Editorial

As previously discussed the editorial department replaces the storyboard cut of the film with final images. So the editorial department stays on the project until the end to ensure all edits contain the most recent footage. The editorial department is the first shot driven department to come online during the storyboarding process. For the editorial department, the assets they use change from storyboards to rendered shots.

3.3 Current Tools Assisting Efficient Production Management in Animated Film Production

3.3.1 Production Tracking tools

3.3.1.1 Shotgun®

Currently in beta testing, a new software package called Shotgun started development in 2006. Shotgun deploys through a web OS, making it usable across multiple platforms. The development of Shotgun® focused on making a system for managing film projects.

In Shotgun® Gantt charts update interactively as producers change information or due dates. Most interestingly, the system updates automatically and allows all users to receive updates immediately after entered into the system. Intended users include producers, supervisors and artists. Managers have the ability to define users' access and restrict information from view if needed. Shotgun allows for shot, sequence, asset organization and tracking. Currently, Shotgun markets itself as an information collaboration tool for use by all staff in a studio[Shotgun Software 2010].

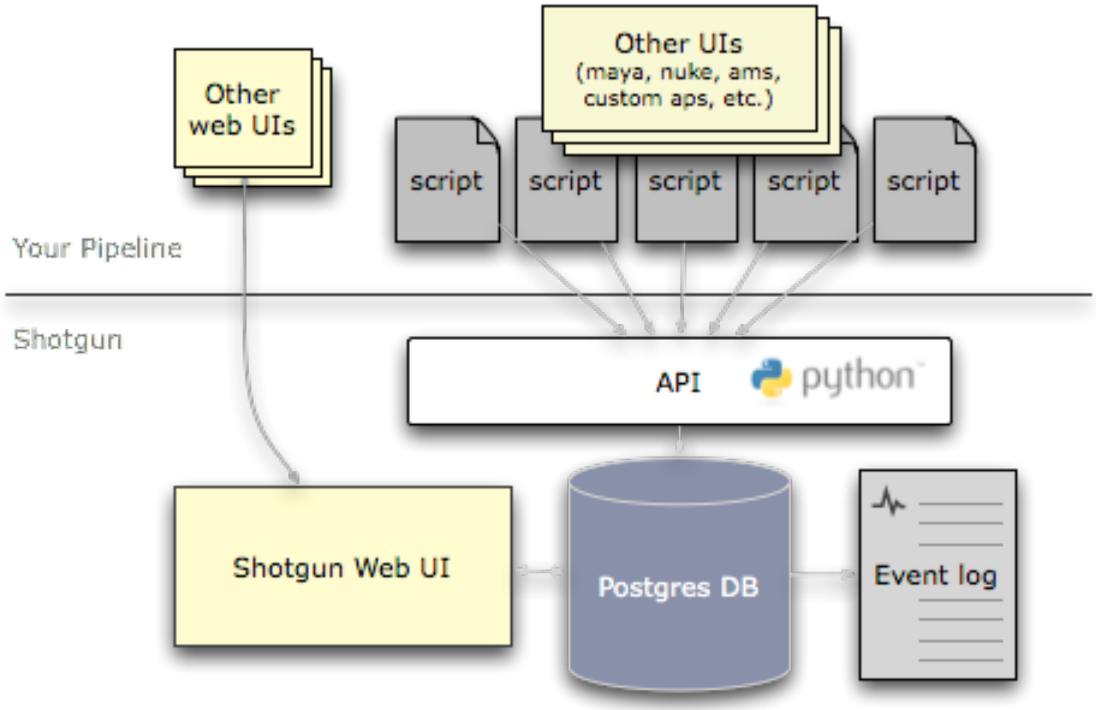

Fig.7. Image of Shotgun's integration into a current pipeline[Shotgun Software 2010].

Figure 7 illustrates how Shotgun integrates into a studio's current pipeline. Compared to other software tools, Shotgun provides a solution to help producers coordinate information and changes in the pipeline. The Python driven API (Application Programming Interface) facilitates the communication of pipeline tools to Shotgun's own interface. It communicates to tools within the pipeline and also contains the ability to communicate to other web interfaces. Shotgun provides a carefully thought out and well executed tool for organizing a production in the film industry.

3.3.2 Artist Tools

3.3.2.1 Grease Pencil

Drawing during reviews makes communicating information simple and effective. Sometimes directions become lost in too many words. Often people want to show not tell what they mean. An intuitive way of illustrating feedback directly into the program cuts down on inefficient communication, which saves time for turning around

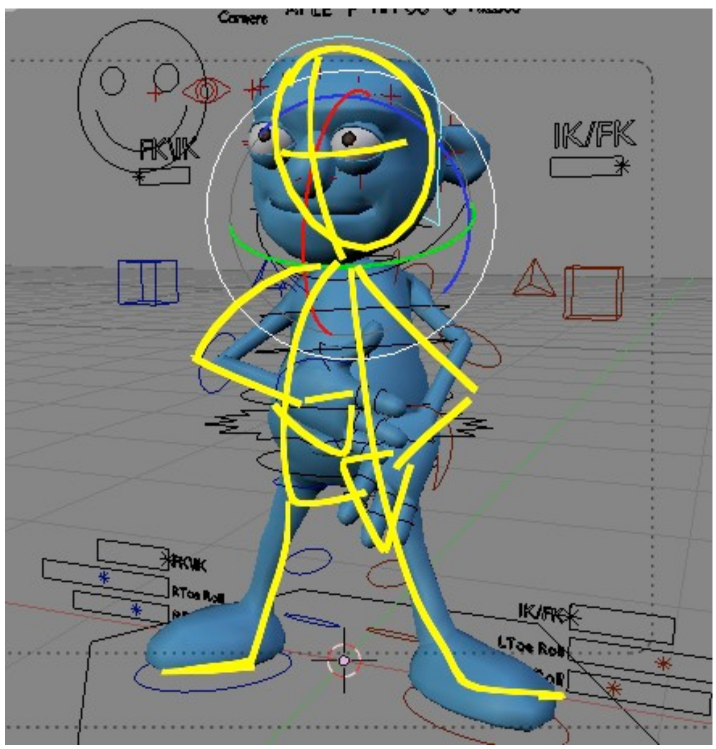

Fig.8. Grease Pencil. Example of a draw over note with-in Blender[Blender 2009].

fixes[Blender 2009]. Grease Pencil, a tool developed for use with the open-source 3D program Blender, allows a user to draw directly on the viewport windows just as an artist might draw using Photoshop. Since Grease Pencil integrates with animation software users find it easy to draw notations within the software environment. It contains the ability to function as a director's approval tool. Such a tool facilitates increased collaboration between artists and supervisors. The tool's development came out of a need to quickly show artists how to change a shot or a model[Blender 2009]. Before this tool directors drew directly on the monitor with whiteboard markers or grease pencils (thus the application's name) to show what they wanted the artist to change.

3.3.2.2 RV

RV consists of an image sequence viewer designed specifically for visual effects production. The program facilitates better collaboration during the review of image sequences. RV provides draw-over tools for annotation on the image sequence. The software contains the ability to extend RV's features into a pipeline using Python, a scripting language. This feature allows RV to integrate into a pipeline quickly and develop other tools to work with RV. Many studios find RV very effective for viewing shots and working within a production setting. ILM, Liaka, and Tippett Studios all work with RV in their pipeline[Tweak Software 2009]. New developments within RV allow it to integrate with Shotgun to provide better collaboration between supervisor and artists[Tweak Software 2009].

Fig.9. RV’s interface and example of a draw-over[Tweak Software 2009].

3.3.3 Communication Tools

3.3.3.1 Insight

Dallas based company, ReelFX Creative Studios, developed a web-based system to track and handle all of its assets, data, and financials. Their tool, also available commercially, called *Insight* uses hyperlinking to allow greater access to information with logically named links. *Insight* defines itself as a task oriented system. Artists logon to the system to see unfinished tasks, tasks completed, and tasks still waiting supervisor approval. Supervisors review an artist’s work and return it to the artist’s inbox with details on items requiring attention. Supervising artists mark shots ready for review by the director. *Insight* addresses the back and forth approval process inherent in the production of animated movies. The exchange of notes continues until the shot receives approval by the supervisor. The shot moves on for director approval and the dialogue continues. *Insight* acts to facilitate communication within the company hierarchy, eliminates unnecessary meetings and makes artists accountable for specific tasks.

A weakness of a web-based system occurs when a shot moves to the lighting phase of the production. Due to file size constraints the computer compresses most images for viewing on a webpage. Compression reduces image quality and integrity for working convenience. Lighting artists need to employ an outside viewer to approve a shot. Another drawback includes the system's inability to monitor changes inside individual working files. If a change occurs in a file, users do not know until after images render.

Insight relies on the input of technicians, artists, and supervisors for status updates. Pros and cons exist in such a management system. User driven systems require all staff to interact with it in order to create projects that deliver on time. However, with much of the system driven by the workforce errors occur. Features meant to increase productivity may prove too time consuming or ineffective for the staff to use and eventually become neglected. *Insight* depends on technicians and artists updating information to make another person's job easier.

4. APPROACH

4.1 Rationale for Adopting a Process from Outside Animation Production

Animation is a niche area within the film making industry. The end product is very similar but how animation is made compared to other films is very different. The uniqueness of animation's process led me outside of the film industry for a better system of managing a production of a full length animation film.

4.2 Overview of Project Management Approaches in Other Industries

4.2.1 Project Management

Project management is an area of study developed to solve complex problems of managing projects, like those the animation industry finds itself confronting today. This field of study provides insights suggesting how to deliver a project by “balancing competing demands” of time, scope, budget, and quality[Duncan 1996].

Many project management solutions exist for multiple industries, most in the form of software. Simply defined, projects terminate and contain end dates or final solutions. The ability of project management programs to take into account time and resources allows them to increase efficiency of teams and overall projects. Other fields of study overlap project management such as program management. Program management includes the management of multiple projects. Program management concerns itself with delivering long term improvements to an organization.

4.3 Reasons for Selecting BIM from Architecture and Construction

Building Information Modeling bases itself on studies of how people work in organizations[Nissen and Raymound 2002]. A "knowledge-intensive process" succinctly defines the construction industry[Nissen and Raymound 2002]. Sharing information between people, departments, crew, and clients creates bottlenecks for most businesses, including construction. The more routine the work, the less it necessitates information sharing for the successful completion of a project. Due to the repetitive nature of the work, less information needs processing between people. Yet for less routine work, "knowledge sharing among specialists with very different levels of skills and experience is critical to achieving organizational goals, and the flow and processing of knowledge is at least as important to organizational performance as the complementary flow and processing of information"[Nissen and Raymound 2002]. Construction requires many specialists with specific skill sets and experience. The design and construction business requires the collaboration of knowledge and information across multiple disciplines, and within disciplines. I use BIM as a model for an animation production system for effective tracking and processing of large amounts of data across multiple disciplines from concept generation through project completion.

Design and construction requires knowledgeable workers from multiple areas of expertise to form effective teams to create unique project solutions. In order to achieve building integrity architects send design information to structural engineers who review the plans and return structural specifications back to the architects. Architects then communicate this information downstream to contractors who specialize in areas such as foundation, flooring, and roofing. Working with so many experts and teams require moving information between multiple experts. Large amounts of data exchanged in a construction project makes a system like BIM a necessity. A better information management system simply makes the data exchange process more efficient, cuts down on communication errors, increases productivity and decreases the cost of the project. All cost benefits achieved through BIM appear attractive to the animation industry and its need for a more sophisticated project management tool.

BIM addresses the key problem of communicating information to different parties involved in the design and construction process. The BIM system approaches this problem by leveraging the computer's ability to store, source and compute large amounts of data quickly, based on the user and preset variables. The main principles of the BIM system include collaboration, automation, and interoperability which if applied to animation production aids in the development of a smarter, more effective, and more efficient animation production system.

The similarities between building and animation projects makes BIM an attractive tool. Both require the management of people with very specific skill sets and unique; though inter-related processes, resulting in the realization of a common vision. They both require the coordination of artistic vision while using large libraries of information. Another reason I turned to BIM stems from its ability to increase collaboration. Both construction and animation suffer from the problem of moving data, and information to people with the correct knowledge to produce services and products that culminate in the completion of the project.

Using BIM means applying principles to an entire process and within each discipline involved. Instead of analyzing the minutia of how one discipline needs changing, BIM views the macro process. It encourages all participants to work closely together in ways not considered before. Based on all these advantages, I chose the BIM system as a foundation for a new production system for animation; Animation Information Modeling (AIM).

4.3.1 An Overview of BIM

Building Information Modeling (BIM), a system of tools and information links, streamlines the entire design and construction process for building projects. BIM is not a type of software but a human activity requiring a broad process change in construction[Eastman, Teicholz, Sacks and Liston 2008]. Building Information Modeling using 3D modeling surfaced in the late 1970s and early 1980s[Eastman, Teicholz, Sacks and Liston 2008]. Simply put, BIM defines itself as “an intelligent simulation of architecture[Eastman, Teicholz, Sacks and Liston 2008].” The U.S.

General Services Administration defines the purpose of BIM to “complement, leverage, and improve existing technologies to achieve major quality and productivity improvements[U.S.G.S 2009].” It includes a digital pipeline of information that pushes data from upstream to downstream users. “All model information is stored in a single, coordinated database[Autodesk 2009a].” Design and construction of buildings rely on drawings to represent 3D spaces. More recently, since the use of CAD, architects use computer programs to create 3D virtual representations of building projects. Although helpful in the information they contain, 3D models comprise only part of the BIM system and do not include all the information required to realize the architectural design model[Autodesk 2008]. The drawings rendered “using BIM are not just discrete collections of manually coordinated lines but interactive representations of a model. [Dzambazova, Krygiel and Demchak 2009]” The smarter drawings mean a change in one view will cause updates in all other views thereby managing interactions for designers[Dzambazova, Krygiel and Demchak 2009]. Parametric modeling, a “critical productivity capability”, allows for this tracking and updating of linked information[Eastman, Teicholz, Sacks and Liston 2008]. When stripped of the automatic update features made possible by parametric capabilities it compromises the effectiveness of 3D modeling for the BIM system[Eastman, Teicholz, Sacks and Liston 2008]. BIM also includes spatial relationships, properties of building materials, and representations of production phases also stored in the visual model of the building.

4.3.1.1 Revit®

Revit®, made by Autodesk®, popularized BIM in the architecture field. Due to its rise in popularity many people confuse Revit® with BIM. Yet, Revit® only makes up part of the BIM system. It incorporates a user interface with 3D conceptual building tools and a database to define further building specifics. Architects use this program in conjunction with other software and tools.Using 3D tools, Revit® conceptualizes building practices.

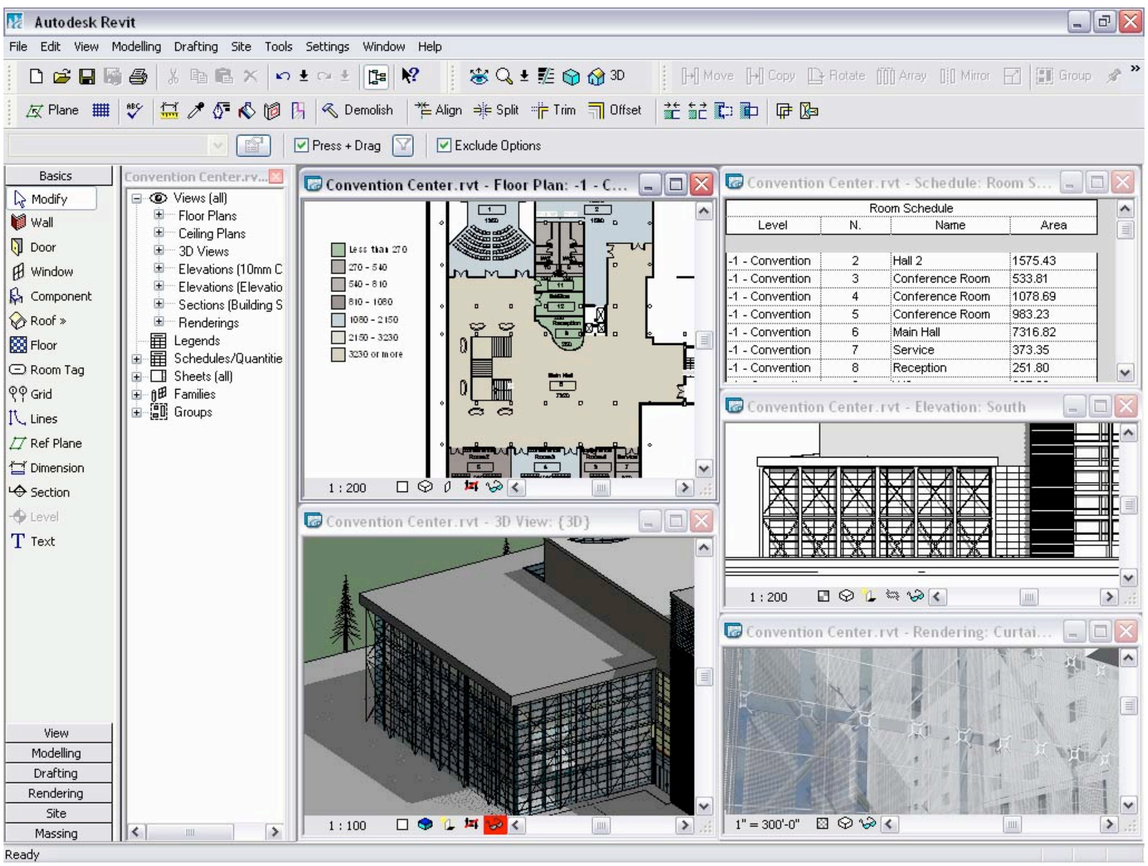

Fig.10. Revit's workspace including 3D and 2D layouts[Autodesk 2007d].

Additionally it enables a user to import models from other software packages[Autodesk 2007a]. It allows architects to start defining the specifics of the building with walls, doors, roof, and other components. Revit® contains libraries of predefined classes of doors, windows and walls from different manufacturers. Users import classes of other items such as lighting fixtures. Tracking these elements provides construction crews or sub-contractors with the most recent schedule for materials[Eastman, Teicholz, Sacks and Liston 2008].

Revit® includes an open structure for integration of multiple applications. The API (Application Programming Interface) provides greater interoperability with other applications[Eastman, Teicholz, Sacks and Liston 2008]. For example, some extensions include calendars that allow the user to stay within the program environment to view or update time sensitive information.

4.3.2 Alignment of Arch/Construction Production Processes and Animation Production Processes

The blueprint for a new animation production system needed to come from a field that contained similar process and management problems as producing an animated film. Both construction and animation activities require the coordination of large amounts of

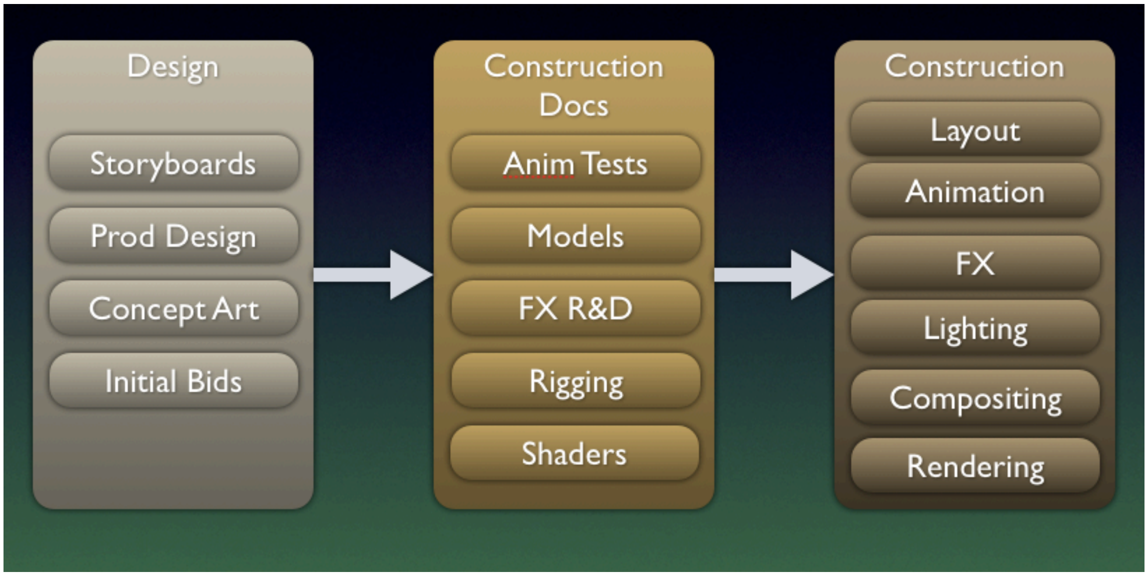

Fig.11. How Animation is similar to construction process.

information between multiple experts to finish a project. Information passes between different parties and sometimes multiple companies.

Figure 11 shows how the process of construction is similar to animation production. Designing the building is similar to the responsibilities of the story department in animation creating the storyboards and concept artwork. The front end of animation, including modeling, is similar to the construction documents created by BIM. The construction documents provide the data needed to define the final construction of the building just as asset creation gives shot departments all the information they need to complete the film. Finally, the construction is similar to the back end of the production where the application of the first two processes leads to the creation of the final product. Not only do the process between animation and construction correlate but there exist certain similarities between jobs. For example, consider the similarities of the two disciplines by showing how the architect's responsibilities translate to the animation industry. The architect designs the concept of the building and draws plans for the client. In the animation industry the story department acts as the architect. The story department, lead by the film's director, assumes responsibility for the creation of the storyline. Similar to an architect, the art department designs the first concepts of visual information for the film. The story department and the concept art department together, play a role similar to the architect. They conceptualize and develop the documents the

Table 1 How architectural duties are similar to animation, by task.

Architect	Story Department	Art Department
Design Concept	Story Development/ Script	Pre-vis Concepts
Building Plans	Storyboards	Model Sheets

rest of the project will use as its "blueprint" by creating a script and conceptual drawings.

4.3.3 What Life was Like in Architecture/Construction Pre-BIM

Formerly, architects passed off their plans and construction documents to contractors only when finalized. BIM starts the collaboration process earlier in a project. When using BIM contractors come into the process while the building still exists in the design phase. This tighter collaboration means more accurate communication of information between parties involved in the entire building process from beginning to end. It brings the entire process in-house.

BIM's included automated drafting system greatly decreases the time required for certain aspects of the architectural building design process. Previous to this automated drafting technology, architects redrew the building plans each time the client wanted to change a feature of the building. Now, "The parametric change engine ensures that a change anywhere is a change everywhere.[Dzambazova, Krygiel and Demchak 2009]" If a client wants to make a change in the plans the 3D model is updated and the drawings automatically update in the system.

BIM, a "game changer" for the architecture and construction industry, restructures the building workflow by changing the perspective of resource allocation[Eastman, Teicholz, Sacks and Liston 2008]. The construction industry runs in a sequential workflow. One action requires completion before the next. Bottlenecks in one area stifle gains in productivity further down the line. BIM sees the entire project as a whole and directs all processes to the end goal. Procedures and information display “as resources to be leveraged” instead of action items[Smith and Tardif 2009]. This means the organization’s perspective of work changes from the previous task orientated view to a view of how changes help the entire operation.

4.3.4 BIM’s Track Record for Creating Efficiency

The field of architecture is realizing large gains by using Building Information Modeling. Looking at architecture’s management solution, we see true savings for firms that take the time and effort to implement the system within their workflow. BIM increases the speed and efficiency of constructing buildings by 30% for some firms[Eastman, Teicholz, Sacks and Liston 2008]. One architecture firm noticed a 15% increase in productivity over the course of a single project[Kopczynski 2007]. Firms calculated these gains only after project completion. Sixty-three percent of BIM users reported a reduction in the length of project schedules[Autodesk 2009b]. Other firms reported 2% in cost savings[Eastman, Teicholz, Sacks and Liston 2008]. Reports of BIM’s effectiveness in the construction industry shows potential for savings with-in a new animation system. One Department of Energy (DOE) project began without using BIM. After switching to BIM they estimated a savings of 10 million dollars on a 100 million dollar project from gains realized by integration of BIM[Autodesk 2009b].

4.3.5 How BIM Handles Interoperability

Interoperability is an integral part to the BIM system. It allows computer programs to communicate information between one another. "Interoperability identifies the need to pass data between applications, and for multiple applications to jointly contribute to the work at hand. Interoperability eliminates the need to replicate data input that has already been generated.[Eastman, Teicholz, Sacks and Liston 2008]." Too much information circulates between all parties involved on a building project or animation project to not implement some strategy to manage the exchange of information. BIM includes many software packages, all part of the BIM system including Revit and Buzzsaw. What makes them unique is their ability to communicate data to one another.

BIM and programs such as Revit®, which are designed around BIM principles, employ a flat-file database for entering information and viewing data. A flat-file database's advantage stems from it's simple and straight forward readability. Popularly known as spreadsheets, these simple data tables of categorized information help the architect to quickly view data. The simplicity of the flat-file allows easy access for updating and storing information making it a good choice to keep the system interoperable.

4.3.6 How BIM Handles Communication

BIM programs such as Autodesk®'s Revit® link to project planning applications. Revit communicates bi-directionally allowing changes in the model to show up in time management software. One architect illustrates the importance of this when he stated, "I'll display all work items scheduled to be installed next week, or all components in a tight area color coded by trade, or highlight in blue all the items that are scheduled to be installed by a particular fabricator"[Autodesk 2007b]. Such integration allows users to see time represented visually[Autodesk 2007b]. Many options exist for categorizing time constraints and showing results visually. The intuitive nature of representing time visually increases the potential for greater productivity among users.

Architects consider BIM a "shared knowledge resource" because all parties of the construction process see pertinent and accurate information arranged by area of responsibility. This makes it easier for BIM to coordinate information changes than previous paper systems[USGS 2009]. A more collaborative environment enables better decision making by everyone involved.

Additionally, BIM increases the collaboration of current building projects by including more participants (such as contractors) earlier in the building process[Eastman, Teicholz, Sacks and Liston 2008]. BIM's automated drafting system includes computer graphics techniques for use during construction. These new software packages inform contractors about changes and how they effect building time, materials and cost. While using an automated system, as clients ask for changes the architects need not worry about changes getting lost from the plans to construction documents. The computer simply updates the plans itself and communicates those changes to the requisite schedules for time and materials. Schedules provide contractors with information such as materials needed, dimensions of areas, standards of materials needed and more. Automation encourages more involvement from the contractors as they receive updates quickly. For example, BIM creates two-dimensional plans of the building. These plans require approval by structural engineers. The engineers approve the plans and communicate the needed changes to the architect. Then building plans, schedules (or itemized materials lists) and construction documents deliver to the contractors and builders after the architects make the needed changes. The ability to send out current relevant data to those working on the building illustrates one of the advantages of the BIM system. "Forty-Seven percent of construction industry professionals are choosing to use BIM for its ability to improve communication with clients/others in the design and construction process[Hardin 2009]."

4.3.6.1 Buzzsaw®

Buzzsaw®, an online collaboration tool, provides construction project managers with a source to manage resources via the internet. The tool facilitates organizing and delivering information about the entire building process from initial design to completion. Buzzsaw® accomplishes this collaboration by storing all documents of a project into an online database. All document management for the life of a project stores online. All “budgets, meeting notes, schedules and approvals” contain trackable data for reference[Autodesk 2007c].

Buzzsaw® also assists with design management. Storing designs, in a central location, allows collaborators to annotate documents and comment on others’ drawings. Buzzsaw® includes the capability to manage bids with online tools. It creates a website for contractors to submit their bids electronically. Project management occurs from within Buzzsaw® by awarding bids and sending contracts and schedules to contractors via Buzzsaw®’s interface[Autodesk 2007c].

Buzzsaw® facilitates communication through the life of the construction project. Construction teams access meeting minutes, requests for information (ROI’s), and changes made to orders. All changes during the construction project automatically update so crews stay abreast of deadlines with the latest information.

The collaboration abilities of Buzzsaw® define it as “the” central command area for managing and communicating pertinent information and data about the project[Autodesk 2007c]. Individuals access stored data which they need to complete their specific tasks. When entered, updates automatically ship to the teams or individuals that require the most recent information changes.

4.3.7 How BIM Handles Preservation of Information

BIM's system tools work to facilitate the collaboration of information between multiple users. The previously discussed Buzzsaw®, by Autodesk®, collaborates information deployed specifically for use within BIM. The strength of the BIM system includes the ability to push data to the parties immediately involved in a project. If a client updates the size of a room the contractors hanging the drywall receive notification of the changes and new calculations for the amount of materials needed. Pushing updated information between different users occurs because BIM preserves the information of the model in the first place.

BIM's parametric change engine plays an important role preserving information too. "Object-based parametric modeling was originally developed in the 1980s[Eastman, Teicholz, Sacks and Liston 2008]." Objects in the 3D BIM program "know what they are, and can be associated with computable graphic and data attributes and parametric rules[Eastman, Teicholz, Sacks and Liston 2008]." These smart objects define how BIM is able to preserve information between 3D and 2D visualizations of the architectural data. As part of the engine, a large library of components include walls, doors and more complex data like kitchen cabinetry[Autodesk 2007d]. The data of the components come from the user, commercial sites, and manufacturing sites. Although unseen to the user, this technology creates the foundation and brain of the entire BIM system [Autodesk 2007d]. When architects create conceptual 3D models, sometimes called visualization models, the BIM system then translates the 3D data into 2D plans for construction. The predefined smart objects and automation allows ideas to move quickly from concept to a building model. A building model, more defined than the concept model, consists of attributes such as defined walls, windows and doors. BIM translates concepts into structures using libraries of predefined classes of doors, windows, and walls[Autodesk 2007d]. Each class contains information about how the object behaves[Eastman, Teicholz, Sacks and Liston 2008]. For example, a window must reside within a wall. This object oriented nature of BIM's modeling paradigm is called the solid modeler.

4.4 Reviewing the Key Issues

BIM is a system to help building construction better manage it's resources. "The beauty of BIM is that it manages change for you.[Dzambazova, Krygiel and Demchak 2009]" The program generates construction plans for the contractors, including exact measurements. Architects review building designs in 3D with the client. If the client's requests changes, the architects update the design and all the information propagates to the necessary documents automatically. For example, let us assume architects completed visualizing a building project with the plans already printed and sent to a construction crew. During a subsequent meeting with the client, the architects receive a request to add more space to the atrium and to add one more conference room. The architects can go back to their model and update the floor plan to create more space in the atrium and include one more conference room. The information automatically updates in the 3D rendering of the building. The architectural firm reviews the results visually and sends the update to the client for approval. The construction documents update as the system recognizes changes made to the model. Updates received via the Internet notify the crew of the changes on the same day. Integration allows all engineers, contractors and subcontractors to receive updates quickly[Autodesk 2007d]. Finally, the materials list updates because the system contains a library of materials and costs. The cost of the project then reflects the added square footage requested by the client. BIM integrates, more than ever, the design and construction process allowing for better collaboration between the client, architect, engineers, and construction team.

4.4.1 Greater Efficiency in Production (Time and Money)

BIM promotes a more integrated design and construction of structures resulting in faster completion times, higher quality, and lower costs[Eastman, Teicholz, Sacks and Liston 2008]. “Parametric modeling is a critical productivity capability, allowing changes to update to the model to automatically. It is fair to say that 3D modeling would not be productive in building design and production without the automatic update features made possible by parametric capabilities.[Eastman, Teicholz, Sacks and Liston 2008]” The enhanced integrity of information gained by using a parametric change engine includes saving time and lowering overhead costs for a production.

4.4.2 Preservation of Artistic Intent

BIM preserves the artistic intent of the architects more than previous paper systems. The reason the architect’s intent is so well preserved is founded on detailed building models. The architect is basically making a computer simulated version of the building for construction. Everything needed for the simulation means more detail up front for the architect to create and a better definition for the construction teams to work from later. The automated drafting and parametric modeling also aid in keeping the downstream teams abreast of any changes made by the design team. Keeping everyone up-to-date preserves the vision the architects create for the building.

5. IMPLEMENTATION

5.1 Story Modeler

5.1.1 Definition

The story modeler initiates the proposed Animation Information Modeling(AIM) process. The solid modeler of BIM translated into the AIM system becomes the show's

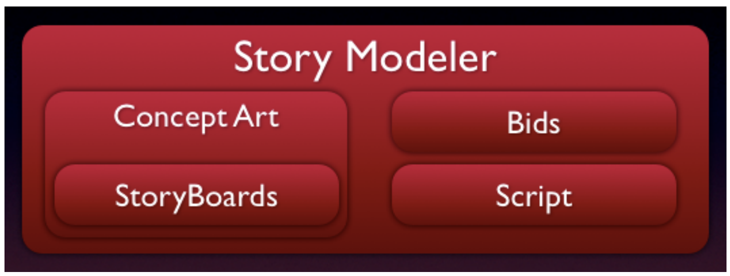

Fig.12. Story Modeler containing the story elements of the production, including the initial bids.

plan, which I call the Story Modeler. Storyboards and concept images communicate the most information about the film before production begins. After the written script receives approval, the process of story-boarding the script and creating the concept artwork begins. Often animation stories change from the written script when developed into storyboards. Sometimes sections of the story do not appear in the script but all sections receive storyboard treatment. Thus storyboards become the preferred starting point of the AIM system. However, I include space for the script in the Story Modeler to help catalogue information pertinent to storyboard artists.

The story modeler also contains early bid information. Bid information allows supervisors to begin estimating cost for their departments and track those estimates through the life of the project. The project initialization occurs in the story modeler after approval by management. Other information for initialization includes; descriptions of characters, environments, words, and the script itself.

5.1.2 Format

Animation software products, such as Autodesk®'s Maya™, incorporate the ability to save files as readable text files. It allows artists and technicians to make quick fixes to files within a text editor instead of opening a large program with bulky interface. Readability within the file allows editing files in a text editor in case of corruption or for trouble shooting. If a file experiences a problem a technician easily searches and edits errors with a simple text file rather than within a complex proprietary format.

5.1.3 Connections to Other Parts of the Plan

A viewer in the program allows us to see the storyboard of a shot and monitors the visual progression of each shot (Fig.15). References, or links, to concept art communicate the look and feeling a director wants to achieve in a scene. Image information follows a shot for reference throughout the shot's lifespan in the pipeline. An image is always associated with a shot or asset allowing artists quick reference to the artistic vision for their work.

5.2 Parametric Change Engine

5.2.1 Definition

The most important technology for the proposed animation system tracks changes with minimal or no user input. The parametric change engine forms the foundation of the proposed production management system. It must interact with multiple users over multiple platforms. A change engine at the center of this new production tool allows recording of changes automatically across the studio's networks. A notification system alerts the producer or supervisor of relevant changes on a daily, weekly, or custom defined basis. It provides producers and supervisors with the advantage of using schedules like those used in construction projects. Each day the producer sees information relating to the show's status and checks schedules most relevant for the week.

5.2.2 Format

Implementation of this system of data exchange needs the development of a standard format. In other words, we need a format on which to build the AIM system. The foundation for AIM depends on the parametric change engine. Studio work requires a system to accesses information on a network server. Several computer languages contain the ability for deployment independent of a machine's architecture. Gaining popularity within the animation industry, Java and Python both accomplish cross platform development. Programmers increasingly use Java to develop web-based programs. Java also runs on multiple platforms independent of computer architecture. The motto for Java's implementation, while in development at Sun Microsystems in the early 1990's was, "Write once, Run anywhere.[Wikipedia 2009b]" Java, an object-oriented programming language, structures itself like C/C++. The object oriented programming languages create a more robust and manageable code structure for later revisions and updates.

Python, continues to grow in popularity as a "get it done" computer language in the animation and visual effects industry. Python's main emphasis includes readability and uses a less cryptic syntax than other programing languages . As a robust computer language it allows for object-oriented programming, scripting, and imperative programming. The major drawback relative to Java involves Python's slower run-time. Yet, Python's strength includes the ability to use it as a scripting language, making it simple to add extensions and custom modules [Wikipedia 2009c]. Deciding between languages depends more on what a studio wants to implement and maintain over many years.

5.2.3 Connections with Other Parts of the Plan

The Parametric Change Engine is the one key component linked to everything else. It provides the brains of the AIM system. It works with all other information and data to track changes and updates across the pipeline.

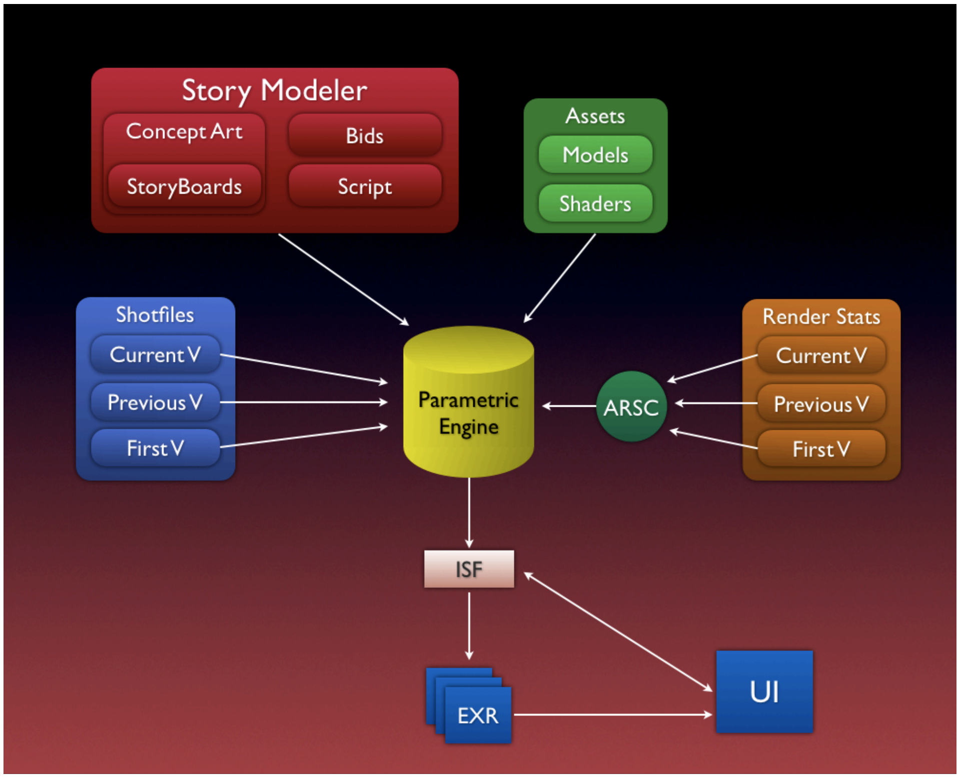

Fig.13. Parametric Change Engine at the center of the AIM system

5.3 Intelligent Shot File

5.3.1 Definition

The Intelligent Shot File acts as a storage file for information gathered by the AIM system. The ISF is a single file which contains data specific to all changes made within a shot over the last iteration. Using this shot specific information the program accesses formulas to update relevant statistics such as polygon count, department bids from the story modeler, and overall shot cost. I propose keeping the original shotfile (or initial shotfile), the current shot file, and a copy of the previous iteration to coordinate the

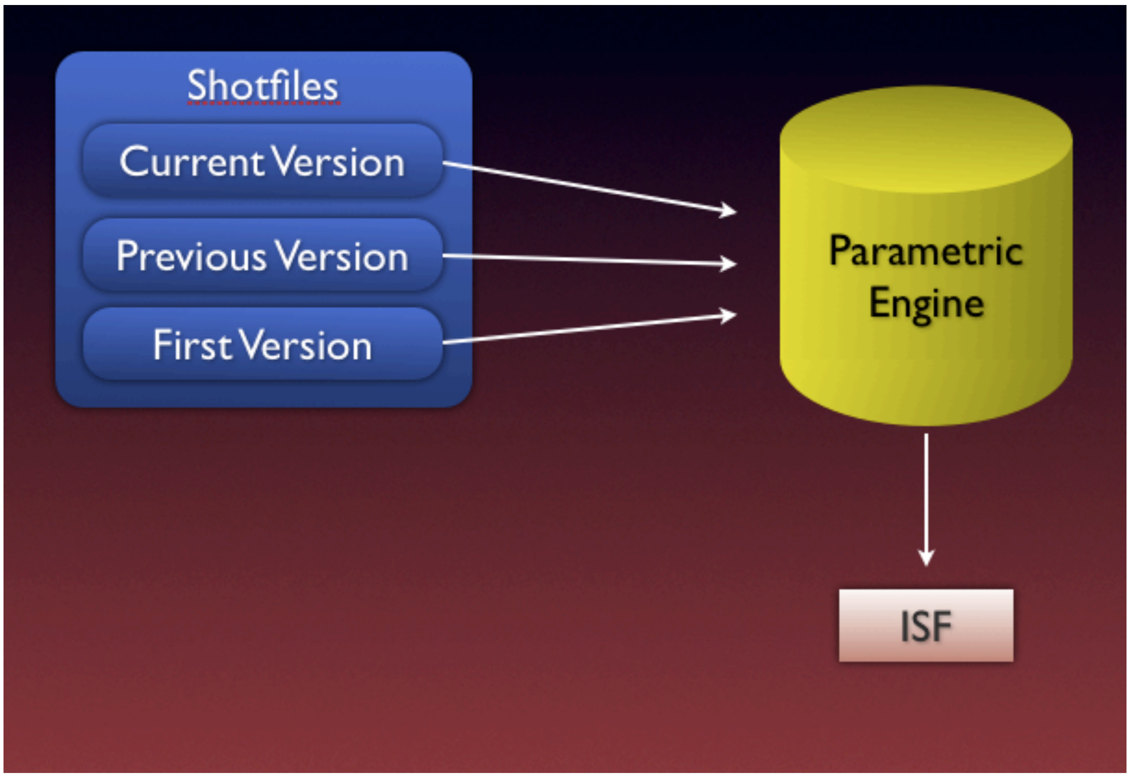

Fig.14. Flow of information from shotfiles to intelligent shotfile.

tracking of this information more efficiently. It provides a simple implementation for studios since all keep multiple iterations of files on disk in case of data loss or file corruption. The ISF stores the differences between the initial, previous and current versions of the file. The parametric change engine compares all versions of the shot and then updates the ISF with all changes between files. As previously stated the story modeler contains bidding information. The ISF contains all information on a shot's status including updates completed, fixes needed, outstanding items, departments'

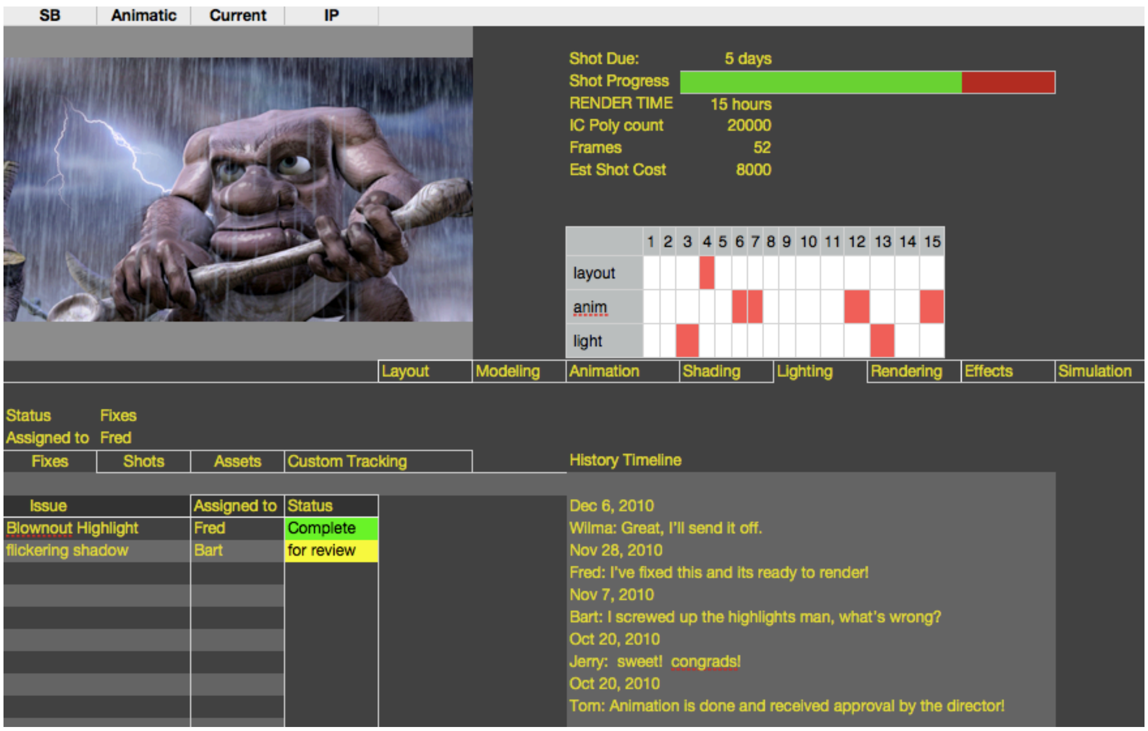

Fig.15. Mock up of an user interface for AIM.

current working status, due date, and changes made that increase the shot's cost. Additionally, the ISF contains the bid information based on specific shot or department requirements. The producer or supervisor receives updates by a user interface created to read each ISF (example of user interface Fig.15).

Not only does the ISF include iterative information of a shot, but it contains all current information on a shot including all necessary data of value for management of the shot. Artists working on shots need notification of the changes and updates which occur. The ISF updates artists on the shot's current working status and shows them recent changes made by other artists up or downstream from them. The ISF needs to contain changes of the shot from the current working file used by the artist. The file is scalable. A producer or a computer graphics supervisor enters additional trackable items when needed. Trackable issues include current status, current render time, projected render time, department status, fix requests, current departments working, shot length, and included assets.

5.3.2 Format

I propose using a simple text file for the animation information modeler. The ISF stores information in a text file that a program parses and displays in a user interface. If a supervisor notices errors in the displayed information she can view the ISF in a text editor to assess the contents. Discovering an error in the ISF requires only a simple edit in a text editor. Such emergency edits require establishing a standard file format for all ISF's generation. I propose using the extension ".isf" to all intelligent shot files to make them unique from all other files used in the pipeline. This separation allows for a more robust program by separating file types and allows the ISF easy identification.

5.3.3 Connection with Other Parts of the Plan

The ISF includes references to materials and character sheets from the story modeler. The information allows tracking updates for the shading artists and the modelers as well. Information such as polygon count and number of characters, also stored in the ISF, provide specific statistics relating to asset driven departments. The ISF stores all data changes of the show on a per shot basis. Both the ISF and the parametric change engine comprise the most important building blocks of the system's back-end.

5.4 Automated Render Statistics Compiler

5.4.1 Definition

I propose the creation of an Automated Render Statistics Compiler, ARSC, within the Animation Information Modeling system. The compiler aggregates relevant render data on each shot. The file stores information in a similar way as the intelligent shot file. The ARSC reports on a shot's render time, cpu time, real time, polygon count, shader compile time, shadow generation time, and rib generation time. The need for a separate file, that contains the render information, comes from a need to avoid overwriting the ISF during shot rendering. Keeping the statistics separate for tracking purposes in their own container provides safety from overwriting other important data.

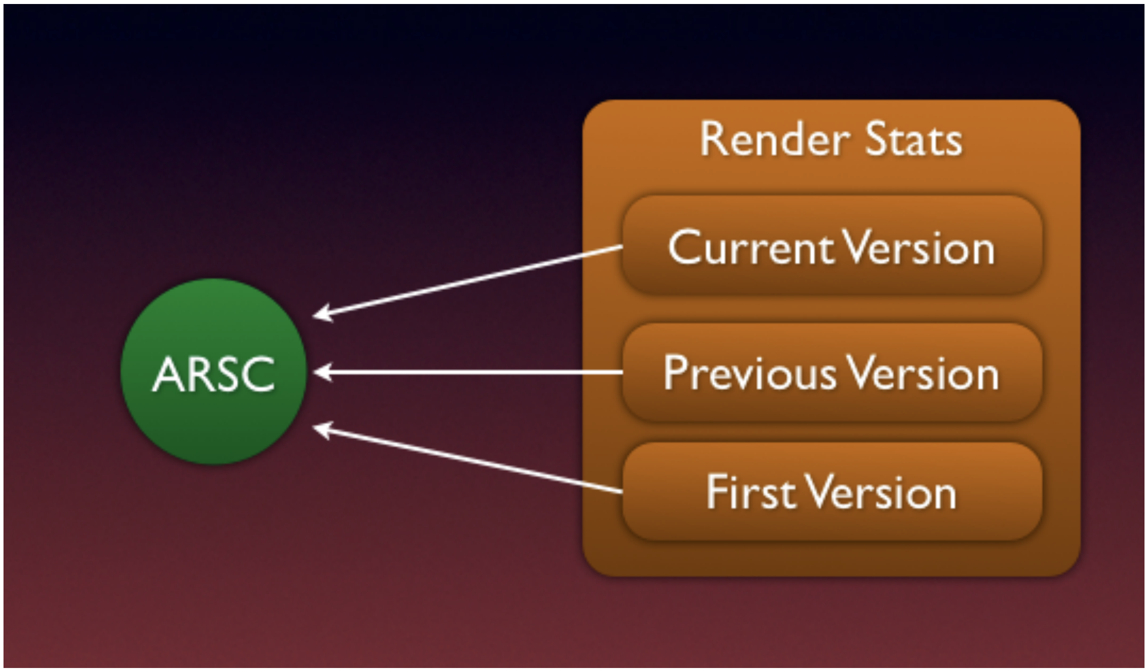

Fig.16. Example of ARSC gathering render data.

5.4.2 Format

The ARSC needs a simple format easily editable, searchable and takes up little space. A text file fits all these requirements and is quickly read by other programs. These ARSC files need their own distinction from the ISF so giving them the file extension ".arc" works to distinguish them from the other file types used in the system.

5.4.3 Connection with Other Parts of the Plan

The parametric change engine monitors changes between renders and stores that in the ARSC. The parametric change engine monitors the changes in the ARSC and then updates those changes to the ISF (refer to Fig.15). The ARSC provides the information to the ISF to determine increases in render time, how changes affect the shot's cost and what causes increases in render time per shot. The statistics provide producers and technical supervisors with the information to review which changes decrease the cost of a shot.

5.5 Visual Notes Dope Sheet

5.5.1 Definition

The principle nature of animation requires creation of thousands of images. Sometimes it takes too much time to notate, in words, what the artist needs to deliver. Therefore, as previously discussed, directors may express their ideas more effectively by drawing rather than writing about needed changes. Digital drawing tools within current applications allow for drawing in the viewport window. Drawing within the application allows for better work flow when artists need instant input. Incorporating drawing tools in to AIM provides directors and supervisors with the ability to create fast draw-overs on the currently viewed image. It allows them to quickly show artists which position a character needs to hit, how a camera should move, or areas that need fixing. Illustrating the problem to fix proves effective and concise.

Trying to keep information as simple and straight forward as possible for the user, only a single image is used, one that best represents a shot. This image is then displayed within the viewer. The AIM system also allows access to movie files for quick viewing. I also propose a feature in this system that allows the user to draw-over images to display directly in the image port window. Similar to Grease Pencil (refer to page 41), a draw-over tool facilitates greater collaboration between artist and director while alleviating some of the producer's note taking responsibilities. The draw-over tool allows the user to make visual notes. When a department notices a problem that requires another department to provide a solution; drawing notes show problems faster than text. As an example, a model may need updating after a texture artist finds a flaw. A draw-over by the texture artist showing the location of the problem directs the modeler toward the flawed area faster. I expect each image to contain many draw-overs. Visual communication such as this creates tighter collaboration between artists.

AIM includes a tool to help manage all of the draw-overs created by tracking their connections to specific frames from image sequences. I suggest creating a tool in this system called the visual notes dope sheet. This provides particularly important information as directors and supervisors want to draw-over multiple frames of an animator's work to illustrate fixes. Animators already use dope sheets to view their key frames. Similarly the visual notes dope sheet shows which frames contain draw-overs. The example above illustrates how a dope sheet displays information. Multiple

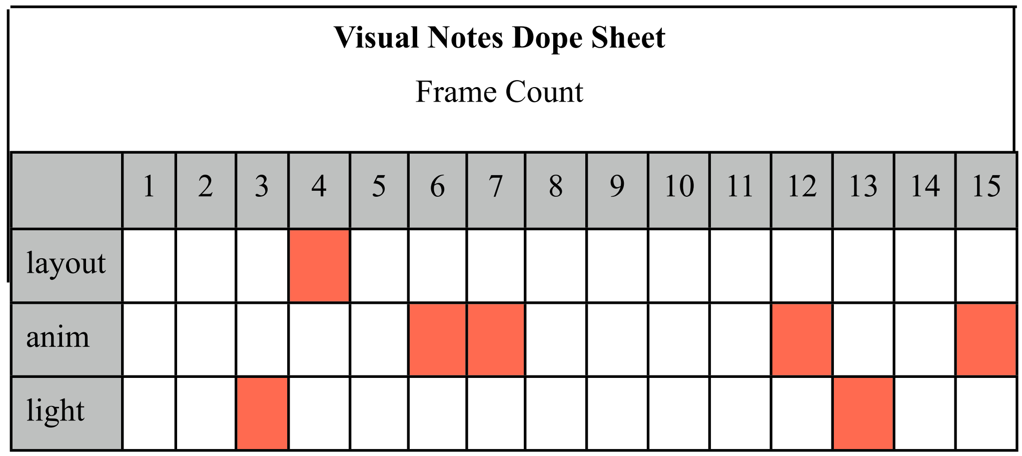

Fig.17. Example of visual notes dope sheet. Showing which frames of the shot a supervisor marked with a draw-over using red boxes to represent the fames with notes.

departments create multiple set notes. The layout, animation, and lighting departments all have multiple notes for this shot (see Fig.17). A visual, such as this, allows the artists in animation, layout, or lighting departments to quickly see where draw-overs exist and speeds the process of addressing the notes.

5.5.2 Format

Industrial Light & Magic, a visual effects studio owned by George Lucas, developed a standard image file format called OpenEXR. The OpenEXR file format allows for multiple images stored in one image file. Storing multiple images in one file makes it easier to composite special effects. Often compositors need to manipulate specific areas of an image. One image contains data for specular, diffuse, color and even custom images defined by the user. I propose implementing OpenEXR in the AIM system because of its robustness, and flexibility.

Using OpenEXR files allows the system to store draw-overs in the image displayed in the viewer. OpenEXR files eliminate the need to store a separate draw-over image, saving disk space. OpenEXR allows for more data storage within the image file than just pixel information.

> "You can also add user data, that moves with the shot, software that reads OpenEXR files automatically ignores attributes it does not understand. But for in house tools can use this user data to store additional data; for example, color timing information, process tracking data, or camera position and viewer direction. OpenEXR allows storing arbitrary extra data, of arbitrary type, in an imagefile.[Seymour 2007]"

An artist or supervisor turns on the draw-over feature to see the visual notes. More

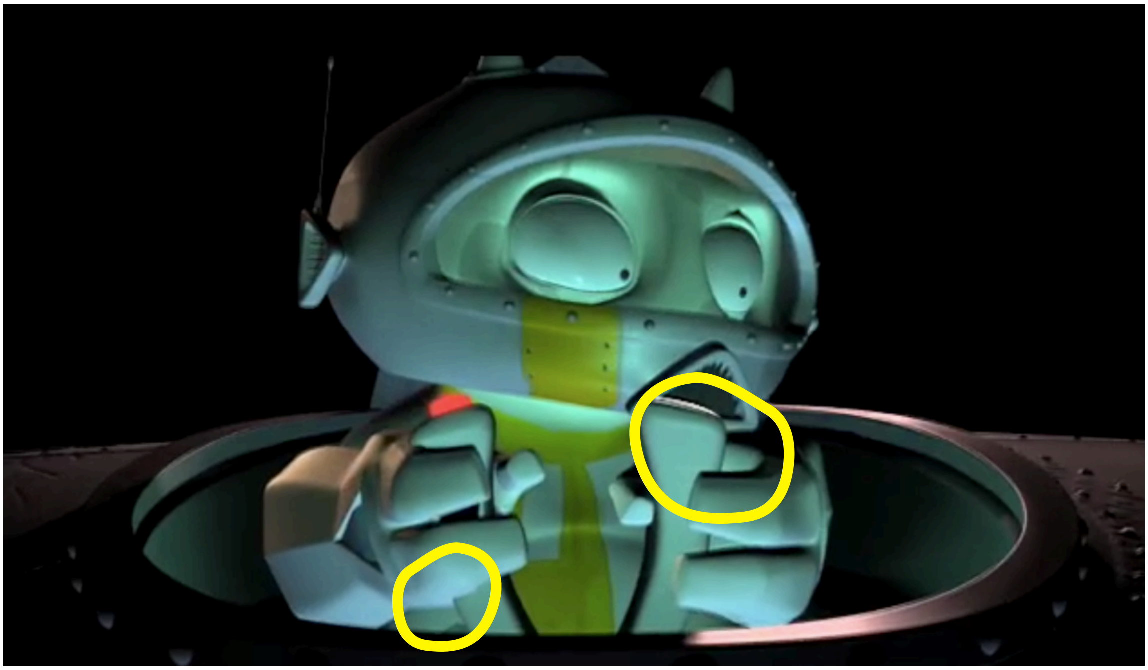

Fig.18. Image shown with draw-over notes.

importantly, images contain multiple visual notes as seen above. Visual notes prove useful for layout, modeling, shading, animation and lighting. I propose developing custom image classes to append onto the main image called; dir, layout, anim, prod, and light. Each stores information for their respective department. So the system creates layers within an EXR file automatically for each department's use. It provides a robust and updatable image communication tool allowing supervisors quick and easy review of the visual notes relevant only to their department.

5.5.3 Connection with Other Parts of the Plan

Special flags, already predefined in the EXR file type, store time-code information in the image under, “timeAndFlags” or “userData”. The system takes advantage of this “userData”, class to store information associated with a shot within the shot’s image. OpenEXR files allow the system to attach the entire content of the ISF to the image and, therefore, makes the system redundant with information for backup purposes. The parametric change engine monitors and processes the updating of each ISF into the EXR file. However, attaching this information within each image involves a lot of information. If appended to each image in a shot, the storage of images on a server increases exponentially for a film. Consider a shot of 100 frames appended with 100 kb of information, coming directly from the ISF. If each image file contains 100 mb or 100,000 kb, now each image file is 100,100 kb. The image files combined equal 1,000,000 kb, or 1 gb stored on disk, but with the ISF data appended to each image the file size balloons to 10,010,000 kb, a 10 percent increase in data size. Obviously this taxes storage space over the course of an entire film. Most studios prefer a more economical approach. Instead, AIM writes the ISF data into a few of the images within the shot. Most productions use between one and three images to define a shot for reference purposes, depending on the shot’s length. The images defined as best representing the shot receive tags with the ISF data via the OpenEXR’s “userData” class. In this example, the information of the shot follows the image which makes it easily accessible to the artist viewing the images. No longer do artists need to open multiple files to discover properties of a shot or its current state. Artists can simply access the image which contains all of the important shot data. OpenEXR's provide another means to storing information within an image to help AIM be a more robust system.

6. ANALYSIS

6.1 Expected Impact and Issues Related to Implementing a Story Modeler

6.1.1 Economics of Animation Production

With a Story Modeler I expect increased collaboration between the front end and back end of production. The greater communication between the artist creating the story and the artists making the 3D images decreases miscommunication and the amount of time this information takes to pass between departments. I expect time savings for asset creation based on the how long it takes to deliver the documents and give updates to the artists. Saving time and decreasing miscommunication errors helps keeps production costs down.

6.1.2 Preservation of Artistic Intent

The story modeler saves producers time allowing them to keep track of all documents needed for asset creation. Creating a container for all of this information allows the parametric change engine a way to monitor story and artistic changes. Monitoring these changes and new updates ensures that changes to the artistic direction of the film is given to all who need access. The artists downstream of the story department also benefit from a more transparent process allowing them access to original documents which define assets they construct.

6.2 Expected Impact and Issues Related to Implementing a Parametric Change Engine

Developing a large system, such as AIM, and its supporting tools contains inherent problems such as the system's requirement to access data from many different programs across a large network of computers. The parametric change engine must track all of the changed data among thousands of shots. Computationally tracking so many changes across the system may over burden a network. It also requires more storage space. Each area of the pipeline uses various tools because some individual digital tools perform specific tasks better than others. Many studios simply prefer one tool over another. Since the artist uses multiple tools, developing the parametric change engine becomes more difficult to implement as it needs to track more information with each added tool.

6.2.1 Economics of Animation Production

Some of the benefits provided by the AIM system, I am proposing, only appear after use on multiple shows. As previously stated, one advantage of using a system with strictly digital data includes the ability to track statistics and store them for future use. After a few shows run on this system – which tracks and reports statistics such as render time, real time, and labor costs – I expect patterns to emerge. Patterns provide producers and technical supervisors with information to make clearer decisions for future projects. Maybe we learn from this data that shadow maps provide cheaper render times, but ray-traced shadows cut an artists time by fifty percent which offsets the computational cost of using ray-traced shadows. The parametric change engine's ability to save money comes from its ability to report to a user why the cost of a shot changes. It enables the supervisor and producer with the information to make more informed decisions for how to manage the production.

6.2.2 Preservation of Artistic Intent

The parametric change engine requires a robust back-end development to ensure its stability in the system. The parametric change engine helps preserve artistic intent by tracking changes while the show is in production. The tracking provides information to supervisors if artists deviate from the director's vision. The parametric change engine aids preservation of artistic intent by keeping all defining documents up to date by propagating that information to departments downstream. Keeping downstream departments up to date preserves the director's vision by keeping the artists informed of changes made to any of a productions defining documents. Then artists make necessary changes as they receive updates.

6.3 Expected Impact and Issues Related to Implementing an Intelligent Shotfile

6.3.1 Economics of Animation Production

The intelligent shotfile contains the ability to save a production money and time by storing information about a shot, including statistics and bidding information. Gathering statistics and bidding information makes the ISF a simple tool for monitoring the cost of a shot. The ISF provides information about how artist's changes affect the cost of the shot. Receiving these updates allows supervisors and producers to correct artists or update predictions for expected costs.

6.3.2 Preservation of Artistic Intent

The intelligent shotfile works with the parametric change engine to store the changes being made within shots. The data gathered by the parametric change engine and stored in the ISF provides the same advantages to artist preservation as those mentioned above in the parametric change engine section. The only difference only is that the ISF acts as the container for this information storing it for use by producers, supervisors and artists. It allows each group to view information about changes occurring with-in a shot and keeps all parties informed if those changes affect the artistic vision of the production.

6.4 Expected Impact and Issues Related to Implementing an ARSC

6.4.1 Economics of Animation Production

The ARSC is expected to aid a production by saving money and possible time by reporting the current rendering statistics for a shot. This information provides users with information about items causing long render times. A supervisor or artist's review of this data allows them to apply their knowledge of how making changes in a shot saves the production time and money. It also provides a means of debugging errors in a shot. If one render takes longer then another with only minor changes the ARSC provides a better data to explain why this might happen. The artist may learn the problem is not her own changes but changes made by someone inadvertently upstream. This feature saves the artist time and the production money.

6.4.2 Preservation of Artistic Intent

Most companies using BIM noticed savings by eliminating rework. Rework is viewed as one of the top methods of wasting time and money[Autodesk 2009a]. Much rework is done because of mishandling information leading to the loss of artistic vision. The ARSC contributes to maintaining the directors vision by monitoring how the final images compute.

6.5 Expected Impact and Issues Related to Implementing a Visual Notes Dope Sheet

6.5.1 Economics of Animation Production

The visual notes dope sheet helps a production keep communications between artist and supervisors clear and concise. The dope sheet provides a means for the artist to easily access the notes received by the supervisor. Facilitating better communication, increased collaboration and easy retrieval of information the visual notes dope sheet speeds up the process for creating imagery and saves the production time and money.

6.5.2 Preservation of Artistic Intent

The entire purpose of the draw-over tools and visual notes dope sheet is to provide better communication to accomplish the vision of the director. Clear notes with illustrations allow supervisor to communicate precisely what artists need to do to complete the director's vision.

6.6 Why BIM is Not a Perfect Fit with Animation Production

Although BIM is a wonderful tool and great system for managing the construction process, it is not a perfect fit with animation production. The production of animation differs from construction because no real world items are manufactured. The end product for an animation is a series of images stored digitally.

The great advantage of BIM over previous practices is automated drafting with smart models. Automated drafting saves the architectural firms time and money by facilitating collaboration between different groups of skilled workers and decreasing the turn around time of creating the working documents. However, no application for this automation exists in the animation system I propose. The automated drafting is powerful because all objects in the 3d model receive class and object information making the entire model hierarchal in nature. Each class and object definition includes information imbedded about how to create the object. A door or window is defined at being in a wall and made from glass. The imbedded information helps to define the 3D model into schedules and materials lists needed by the construction crews.

Unfortunately the animation industry cannot automate the design process to also create the working documents of the production. Creating the 3D items for construction is not similar to creating the 3D assets for animation. While the architectural BIM model, and Revit®, allow for the direct translation of a 3D models into 2D construction plans; animation works in reverse order. Two-dimensional documents define the 3D assets in animation production. The 3D assets for animation require definition by concept art while 3D models for BIM define construction. Creating the 3D assets for animation similar to creating the construction documents of the construction process.

6.7 Impact of Use of the Proposed System Over Multiple Productions

As stated earlier the AIM system needs to run over multiple productions before its benefits completely materialize. After multiple shows I expect patterns to emerge. Based on project savings within construction, a project like Pixar's *Wall•E* might realize

Table 2 Potential saving for films using AIM

	Nemo 90M	WallE 120M
30%	27M	36M
2%	1.8M	2.4M

a savings of 2.4 million USD, substantial to say the least. This is a conservative estimate of only 2 percent savings. Some firms using BIM experienced as much as 30% savings which would equate to 36 million USD in savings for a production like *Wall•E*[Autodesk 2009b].

Although using the AIM system over one show is expected to provide a studio savings I expect more benefits by using the system over multiple productions. Using AIM over multiple productions provides a studio with multiple data sets to compare and learn how to better leverage the system for future productions.

7. FUTURE WORK

7.1 Future Possibilities

More research needs to occur in order to implement AIM. The fields of project management, organizational behavior and user interface design give more insights into creating a truly effective system. Project management, in particular, provides insights into better practices for managing a project through to completion. Organizational behavior, an area of study within many business schools, helps find optimal ways for an organization to reach stated goals. The study of interface design helps software companies produce more effective user interfaces. Studying these areas potential contributions may provide development of a refined and robust AIM system yielding greater gains for the animation industry.

7.2 Visual Effects Houses

The visual effects industry includes elements very similar to the animation industry. IBISWorld Report lists both animation and visual effects in the same post-production industry as seen below in Fig.19[IBIS World 2009]. The post-production industry includes the sub-industry of visual compositing and effects which make up 17.8% of the entire industry [IBIS World 2009]. Graphics and animation comprise only 7.3% of the industry [IBIS World 2009]. Both of these areas produce expensive projects. Many effects houses use the same software tools as full-length animation studios. Transitioning the AIM system to VFX should not involve the same overhead as its initial

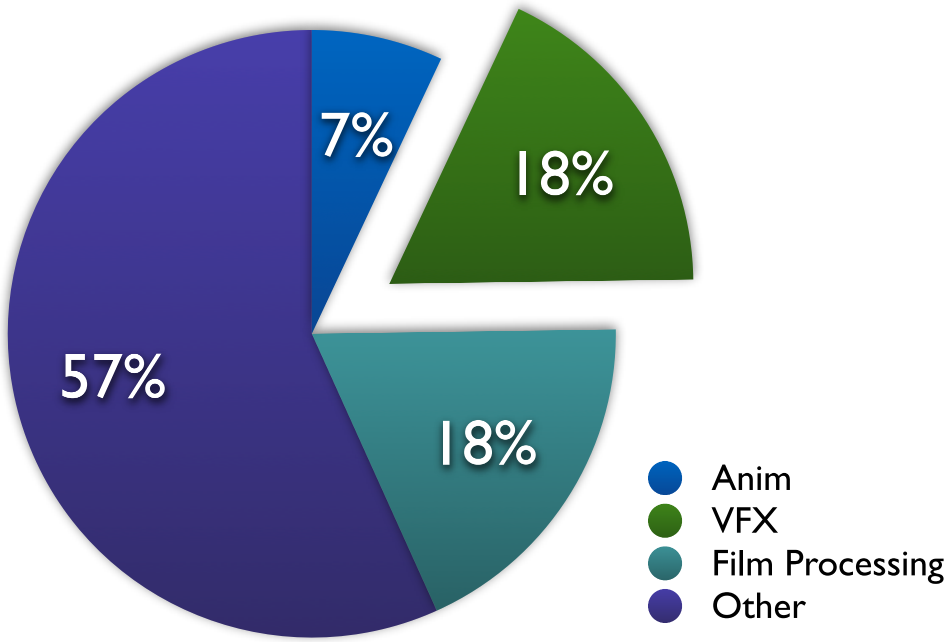

Fig.19. Distribution of the post-production industry.

startup with animation. The AIM system appears very attractive to the visual effects industry because of potential cost benefits. Visual effects studios run tighter budgets, as competition between studios remains high. When a movie contains a large amount of effects shots producers spread the workload over multiple studios. Coordinating information between studios proves difficult when individual studios employ different techniques for producing images. For example, they often create models at one studio and share the models with another studio for use in a shot. Users find the need to convert files or recreate assets because they fail to translate properly across different pipelines. When conversions of digital data occurs studios run into data integrity issues, a phenomenon called bit rot [Wikipedia 2010b]. The AIM system saves time and money in such cases. One of the main tenants of the system, interoperability, insures studios using AIM benefit from better collaboration of data and information between multiple users. Large data transfers between studios become unnecessary when all the assets reside on a server for all involved companies to source data. Maintaining asset integrity increases with a central repository of information and limits communication errors between studios.

7.3 Back-end

The AIM system depends on the development of a robust parametric change engine. The first step in implementing the proposed system means developing this change engine. Then the system's development moves into implementing intelligent shot files(ISF), necessary for testing the change engine. Feasibility tests need to track how large amounts of data move through the system. The tool used for writing changes between files also needs testing. In addition, the system needs the development of a monitoring tool. Such monitoring tools watch the system, and prevent overwriting important data if the parametric change engine fails. The development of the parametric change engine and ISF components of the AIM system create the building blocks of the system. The automated render statistics compiler (ARSC) also needs development. It contains a similar structure to the ISF. They require their own file designation to prevent confusion with the ISF. Already an industry standard, OpenEXRs do not need development because they already contain the needed functionality for the AIM system. The classes which store information from the ISF do require development. The visual drawing tools currently used in other software packages need less development. Other software using these tools show that draw-overs prove feasible. However, these tools need integration into the AIM system. Tracking these draw-over notes remains important to facilitating greater communication. The visual notes dope sheet also needs development. The dope sheet is a a tool already used by animators. So developing a dope sheet with references to images and notes should not require as much work as other areas of the AIM system. Finally, a program to interact with all of the data needs development so artists and producers access the same data. This interface needs to present the information in the ISF in a user friendly window. All of the elements of the AIM system require an orderly approach in their development to ensure each piece of the system works together.

7.4 Live Action Filmmaking

A system of information modeling tools easily transfers to the movie industry. The movie industry works similarly to the construction industry. Movies require coordination of large amounts of materials, talent and equipment. Producers bear the responsibility for getting everyone on board to deliver a product on time and within budget. An integrated system of tools based on the elements of BIM and AIM holds the potential to save money in the movie making process by streamlining communication with contractors. The number of contractors increases substantially for a full-length movie when compared to an in-house animation production. Areas in the live action field which require special attention include: set building, prop production, lighting contractors, makeup, location management, and visual effects. Managing these additional assets and departments with a standard set of tools across the production provides a common starting point for producers to track their show's health. As the cost to enter the movie industry decreases, competition increases. It creates an environment with more players in the industry. Those wanting to survive in the industry need to look for ways to keep costs low and quality high. Having access to a system such as AIM, enables greater collaboration between departments which brings efficiency and cost savings to a production.

8. CONCLUSION

Clearly, animation production contains areas that need improvement. Budgets need cutting, and time needs saving. Simply adding new tools to a pipeline hurts the process of film making if collaboration decreases. Large areas within the current production pipeline need increased monitoring. Supervisors and producers need critical information to help them produce animation more efficiently. Instead of creating only new tools to manage these problems, a new system leveraging tools already in use by artists contains the potential to increase the efficiency of animation production.

The thesis describes the workflow of the animation industry and what areas of the full-length film making process stand to benefit most from advancements to save productions time and money. The similarities described here between animation and the construction industry's workflow leads me to believe that modeling a new system after BIM, could prove to benefit the animation industry as the construction industry benefits from BIM. The proposed new work management system for animation productions is based on principles learned from Building Information Modeling. Animation Information Modeling is the proposed system to manage the work within an animation production. It leverages the same principles BIM uses to create a more efficient workflow and coordinate data between skilled workers with greater efficiency .

I choose this topic because I see room for improvement and a need to overcome inadequacies within the production cycle of full-length animated feature films. The animation industry is becoming more competitive. With the trending declining number of movie productions there is a need to make animation production more cost effective. The industry chronically throws away valuable information that, if leveraged properly, potentially increases the efficiency of production and decreases the time and budget of the production. I see the animation industry as having the unique ability to track all the information and data it consumes and produces because most of the production occurs within the computer. If the industry tracked statistics related to the digital processes used to create animation certainly the industry will learn were to save time and money over multiple areas of a production.

AIM helps to relieve the stresses put on productions by increasing their efficiency. It provides a clear accounting of the current state of a show. The automated elements of the system provide new tools for the animation industry. AIM gives immediate feedback to supervisors, showing shots which require additional work. Making tools interoperable means information moves with greater ease between artists and departments, facilitating greater collaboration. Better collaborative tools help communicate information accurately to artists, supervisors, and producers. Reports and updates provide current information which enables producers and supervisors to make quick management decisions. Information from accurate reports means increased transparency of the current status of a production. Understanding the current needs of a production leads to informed decision making and more efficient management practices. New information gathered from the AIM system, contains the potential to educate the industry with new insights about how the industry works and how to increase efficiency in animation productions.

The strengths of the AIM system include the valuable information garnered from leveraging computer resources. The reported information provides more knowledge about managing current and future projects. It also provides insights for producers to identify opportunities for savings in their productions with insights to seeing how small decisions affect the production on a macro level. The AIM system provides the animation industry with a new approach to solving the problems of creating full-length animations by keeping them on time and on budget.

Implementing Animation Information Modeling potentially changes the industry by making animation production faster, more accurate, more transparent, and cheaper. The expectation for animation production is to eventually establish true savings after implementation of the AIM system. The research done for this paper is only the starting point of creating a working prototype to address the shortfalls of current animation productions. The theories developed here now need proving by creating an implemented AIM system running in an animation production's pipeline.

REFERENCES

AUTODESK, 2007a. BIM Concept to Completion. From www.autodesk.com/revit, Hampshire, UK, 3.

AUTODESK, 2007b. Bim and Project Planning. From www.autodesk.com/revit, Hampshire, UK, 6.

AUTODESK, 2007c. Buzzsaw Overview. From http://pdf.directindustry.com/pdf/autodesk/autodesk-buzzsaw/14521-91361-_2.html, Hampshire, UK, 1-3.

AUTODESK, 2007d. Parametric Building Modeling: BIM's Foundation. In www.autodesk.com/revit, Hampshire, UK, 6.

AUTODESK, 2008. BIM and Visualization. From www.autodesk.com/revit, Hampshire, UK, 8.

AUTODESK, 2009a. BIM - Simply a Better Way of Working. From http://www.paradigm.ie/pdf_2012/revit_architecture_overview_brochure_a4_en-gb.indd.pdf Hampshire, UK, 6.

AUTODESK, 2009b. Business Value of BIM. In *SmartMarket Report.* McGraw-Hill Construction, New York, NY. From August 12 2009.

BLENDER, 2009. Grease Pencil. From http://www.blender.org/development/release-logs/blender-248/grease-pencil, Nov 10 2009.

BOX OFFICE MOJO. 2011a. *Finding Nemo (2003) - Box Office Mojo*. From http://boxofficemojo.com/movies/?id=findingnemo.htm, September 21 2009.

BOX OFFICE MOJO. 2011b. *Fly Me to the Moon (2008)* - Box Office Mojo. From http://boxofficemojo.com/movies/?id=flymetothemoon3d.htm, September 21 2009.

BOX OFFICE MOJO. 2011c. *Toy Story 3 (2010) - Box Office Mojo*. From http://boxofficemojo.com/movies/?id=toystory3.htm, September 21 2009.

BOX OFFICE MOJO. 2011d. *WALL-E (2008) - Box Office Mojo*. From http://boxofficemojo.com/movies/?id=wall-e.htm, September 21 2009.

DUNCAN, W.R. 1996. *A Guide to the Project Management Body of Knowledge*, Project Management Institute, Newton Square, PA.

DZAMBAZOVA, T., KRYGIEL, E. and DEMCHAK, G. 2009. *Introducing Revit Architecture 2010: BIM for Beginners.* Wiley Pub, Hoboken, NJ.

EASTMAN, C., TEICHOLZ, P., SACKS, R. and LISTON, K. 2008. *BIM Handbook*. John Wiley & Sons, Hoboken, NJ.

HARDIN, B. 2009. *BIM and Construction Management: Proven Tools, Methods, and Workflows*. Wiley Pub, Hoboken, NJ.

IBIS WORLD, 2009. *Video Postproduction Services in the US*. In IBISWorld Industry Report, IBIS World.

KOPCZYNSKI, C. 2007. *Buildable design with BIM*. Autodesk, Hampshire, UK.

LOVEDAY, S. 2010. *Licensing Industry News and Analysis.* From http://www.licensing.biz/brand-profiles/196/Shrek, Feb 22 2011. Licensing.biz.

NISSEN, M. and LEVITT, R. 2002. *Toward Simulation Models of Knowledge-Intensive*

Work Processes. Center for Integrated Facility Engineering.

SEYMOUR, M. *The Technical Oscars: ILM and the Foundry*, From http://www.fxguide.com/article404.html, Feb 19, 2007.

SHOTGUN SOFTWARE INC., 2010. *Shotgun: Web-based, Cross Platform*. From http://www.shotgunsoftware.com/features. February 23 2009.

SMITH, D.K. and TARDIF, M. 2009. *Building Information Modeling: A Strategic Implementation Guide*. John Wiley & Sons, Hoboken, NJ.

TWEAK SOFTWARE, 2009. RV. From www.tweaksoftware.com, June 9 2010.

U.S. GENERAL SERVICES ADMINISTRATION, 2009. 3D-4D BIM. From http://www.gsa.gov/portal/content/105075, July 15 2009.

WIKIPEDIA, 2009a. Gantt Chart. From http://en.wikipedia.org/wiki/Gantt_chart, July 27, 2009.

WIKIPEDIA, 2009b. Java(programming language). From http://en.wikipedia.org/wiki/Java_computer_language, July 2010.

WIKIPEDIA, 2009c. Python(programming language). From http://en.wikipedia.org/wiki/Python_programming. Nov 23 2009.

WIKIPEDIA, 2010a. *Auguste and Louis Lumière*. From http://en.wikipedia.org/wiki/Lumière_brothers, Sept 28 2010.

WIKIPEDIA, 2010b. Bit Rot. From http://en.wikipedia.org/wiki/Bit_rot. June 23 2010.

VITA

Name: Nicholas D. Naugle

Address: Visualization Sciences

3137 TAMU

Texas A&M University

College Station, Texas 77843-3137

Email Address: nick.naugle@gmail.com

Education: BFA Animation - Brigham Young University 1999-2005

M.S. Visualization Sciences - Texas A&M University 2006-2011