Taxonomy of Digital Creatures: Interpreting Character Designs as Computer Graphics Techniques

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Course Description

Digital Creatures are a staple of big-budget live action films and student projects alike. These creatures range from fantastic monsters, to digital stunt performers, to fully emotive and articulated synthetic actors. The creation of these characters most often begins with an artist using pencil and paper and results with an artist using keystrokes and pull-down menus.

Along the way the artists involved, to varying degrees of formality, employ analytic techniques to determine how conceptual design elements will be executed as computer graphics techniques. It is most often in the best interest of storytelling to hide the artifice behind the product in the image. Thus it is in the artist's best interest to avoid situations in which the design is a derivative of the technique.

This course presents a system, and a language, for dissecting artwork, reference material, and storyboards with the goal of allowing the performance requirements to drive the technical decision making process. Encompassing questions such as what does it look like and how does it move are broken down into issues of design style, body type, integration into the scene, and relationship to the camera.

This course is illustrated with concept art, images of sculpted macquettes, storyboards, and shot breakdowns from feature film work. The projects from which examples are drawn include seminal computer graphics creature work such as **The Abyss** and **Terminator 2** as well as more recent work from the new **Star Wars** trilogy, and **Van Helsing**.

Prerequisites

This course is designed for students and professionals who are interested in or who work in the area of digital creature design and development. For students the course will be an exposure to the factors that are considered when approaching digital creature development projects. For professionals the course will offer a methodolgy and language for the craft. Basic comprehension of modeling and animation issues is required.

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1 Introduction

The evolution of digital creatures is one of the most intriguing histories in computer graphics. Digital creatures populate productions from student projects to summer blockbuster movies. The techniques used to create digital creatures range from the fundamental building blocks of computer graphics to the cutting edge of modeling, rendering, and motion generation research. One thing that all the techniques have in common is that they are technological answers to visual design problems.

This course is about the questions raised when embarking on the task of digital creature development rather than about the answers. Specific solutions to a problem is solved changes with technology. Creature designs, however, since they are based upon biological forms, more static in comparison.

This course breaks down the process of bringing digital creatures from concept to the screen into a series of questions based upon form and action. Emphasis is placed on the craft of dissecting design elements in concept artwork and classifying those elements such that they loosely align with types of computer graphics techniques.

The two overriding questions -what a digital creature looks like and how does it move, are broken down into issues of design style, body type, surface type, performance generation, integration, interaction, relationship to the camera, and scope of use. The goal of this process is to allow the performance requirements for the digital creature to drive the techniques employed in its construction.

Examples provided are derived from the use of computer graphics creatures in live action films. Though the examples used come from the same family of projects the majority of processes discussed and the questions posed are relevant to the construction of digital creatures for all media.

2 Objectives

The principal goal of this course is to contribute to the body of knowledge in the area of digital creature development. The approach taken is to define a process that can applied by students and professionals alike -a process that is independent of project scope, budget, and technology.

It is likely that experienced artists in the field of digital creature development perform as a matter of habit many of the processes described in this course. Most of these artists likely do so without the need for conscious thought of the process itself. Just as a fisherman knows that weather, tides, and season dictate where to fish and what kind of bait to use, an experienced digital creature developer understands how to use artwork and reference material to drive decisions about the application of computer graphics techniques.

A secondary goal of this course is to promote design oriented achievement in the creation of digital creatures. Whatever the size of a production may be, from the work of a single student to a project at the largest visual effect shop, the dual goals of creating fresh imagery and achieving economy are constantly in conflict. The computer, by its non-destructive nature and interface geared toward economizing iterative tasks, encourages artists to recycle past work and re-use techniques. Efficiency, therefore, becomes a partner to creativity -sometimes faithfully, sometimes destructively.

There is constant conflict between the desire to create something visually unique and the requirement that the project be responsible to the restrictions of budget and time. Success is achieved when high performance and great economy coincide. Less than satisfactory results occur when the visuals are uninspired -a derivative of the tool.

Assuming that the original conceptual designs are provocative, derivative execution of the computer graphics work is often the result of using the tools at hand rather than allowing the design to determine the tools. Though there is no failsafe way to avoid creating derivative work, a way to safeguard against it is by first dissecting the design without respect to technology. Adherence to this process of analysis will create an environment in which the performance requirements drive the application of technology rather than the other way around.

This may appear on the surface like a sure way to open the door to endless exploration of the unknown. On the contrary, the process of systematically asking questions then categorizing the answers performs two beneficial functions: issues are eliminated, and issues are recognized.

Issues are eliminated when analysis determines that the visual goal does not require a particular technique. This is most often the case when a widely used tool in digital creature development is found to be unnecessary for a specific creature.

Recognition of issues means that problems can be anticipated. Unexpected problems are destructive both to the quality of visual imagery and the efficiency by which it is created. Making unconsidered assumptions that the standard set of tools and techniques is appropriate for a task is unwise economically, and detrimental to creativity.

Of lesser importance, a final goal of this course is to provide a vocabulary for the purpose of clearly communicating ideas about creature development. The terms used here are pulled from the science of comparative anatomy, visual design, and computer graphics, and film production. Some of the terms, such as modeling, rigging, and skinning are expected to be readily understood by the reader. Other words, or the way in which a word is used, may be more obscure. Effort has been made to define the meaning of the word or term in these situations. The definitions are typically specific to the use of the word or term in respect to digital creatures.

3 Meaning and Scope

In the science of biology, taxonomy is the categorization of a creature and its parts relative to other species. Digital creatures have their own form of taxonomy. Digital creatures can be separated into categories determined by the computer graphics techniques used in their construction and to generate their on-screen performances. Those techniques range from methods nearly universally applied, such as the use of inverse kinematics in animation rigging, to techniques which are specific to a unique creatures employed on a single project.

Regardless of whether a technique is commonplace or unique a decision was made to use it. The timing of the decision and the manner in which it was made have an impact on the overall aesthetic and economic success of the project. Effectively handling these decision points is key to the success of a project. The first goal in handling them is to recognize what the decisions mean visually and what they mean in terms of resources. Each general topic covered by this course is a decision point.

Digital Creatures range from fantastic monsters, to digital stunt performers, to fully emotive and articulated synthetic actors. This course is geared specifically toward making good decisions when building digital creatures. It is therefore necessary to define the term digital creature. For the purposes of this course a digital creature is defined as an articulated surface or set of articulated surfaces constructed, animated, and rendered on a computer.

The key term in this definition is **articulated**. Without articulated motion: movement of one part of a model relative to another part, the model is locally inanimate and therefore not a creature. That's not to say that a simple cube can not be animated as an expres-

sive character, only that a non-articulated model is not in the family digital creatures.

This course makes a distinction between the craft of building a creature and the art of creating a performance. The topics dealt with here are solely concentrated on the former, not the latter. This course does not attempt to make a distinction between the terms **creature** and **character** as they apply to digital models. The meaningful difference between those two terms is applicable to performance on screen rather, and is not applicable to differences in the techniques used in the construction of the models. For examples, a digital crocodile menacing a boat full of frightened tourists is most aptly described as a creature. A child-like alien who befriends a lyoung boy is best described as a character. Yet, those two models could share similar modeling, rigging, and deformation techniques. The term digital creature is used predominantly in this text because the performances exhibited by the example models fall primarily in the creature rather than character realm.

Visual effects for live action films, by and large, tend to employ more digital creatures than digital characters. This course is, in fact, specifically dealing with issues related to the use of digital creatures in live action films. All of the examples provided are pulled from live action films. However, there is no intent made to separate digital creatures used in live action films from digital creatures used in other formats. On the contrary, the focus here is on the process of analyzing design. It is hoped that many if not most of the ideas offered here will be applicable to the designs of digital creatures for any media.

The processes described here are relevant to building digital creatures so that they'll look and move according to what is required by the script and the key creative responsible for bringing that script to the screen. This course, however does not encompass all of the aspects required for developing digital creatures. Texturing, lighting, rendering, and integration are dealt with only superficially. Those elements play as big a role as geometry and motion issues in creation believable digital creatures.

4 Two Fundamental Questions

There are two basic questions to be asked each time the development of a digital creature is considered: "what does it look like", and "what does it do?" All other questions fall under these two umbrellas. All analysis of of reference material and artwork is performed in order to answer those two questions.

5 Sources of Information

Most projects begin as words on a page -a script, or as verbal descriptions. The words, whether spoken or written, are intended to create images in the listener's imagination. For example, here's a written description of the spinosaurus from the working script of the film **Jurassic Park 3**:

> We're looking down on Cooper from behind. As the plane approaches, A SHADOW falls over the injured mercenary. Then, with brutal speed an ENORMOUS BEAST seizes him in its massive jaws and lifts him into the air.
>
> From this angle we get only a glimpse of a long crocodilian snout, powerful clawed forearms and spiny sail rising from the creature's back.

Each reader of the script is likely to form his or her own mental images of a spinosaurus. In order to bring to the screen an image of a spinosaurus investigation must be done to define what the words in the script mean visually. The most efficient way to perform the investigation is through concept artwork. Concept artwork is generated to define not only the look of creatures, but also the manner in which they perform relative to the other elements in the story.

Still artwork, reference photography, and sculpted macquettes are static imagery and are most often useful for answering the questions about what a creature looks like. Animatics, and video or film reference are motion imagery and are typically most helpful for answering the questions about what a creature does, or how it performs. Storyboards are static imagery, yet are created specifically to communicate action.

5.1 Still or Flat Artwork

Still, or flat art is the most common source of information about what a digital creature looks like. Line drawings convey form. Color and texture information can be gleaned from paintings. Orthographic drawing are particularly useful for determining proportion and mass.

Figure 1: Concept art depicting the T1000 from **Terminator 2: Judgment Day**.

5.2 Macquettes

Macquettes are three dimensional sculptures. They?re often made originally of clay then cast in plaster. Most macquettes are around eighteen inches (45 cm) tall. The benefit of having a macquette is that the creature can be seen in the round. Issues about proportion, which can often be confused by the use of perspective in two dimensional artwork are clarified in macquettes.

Figure 2: Clay sculpted macquette of Mr. Hyde from **Van Helsing**

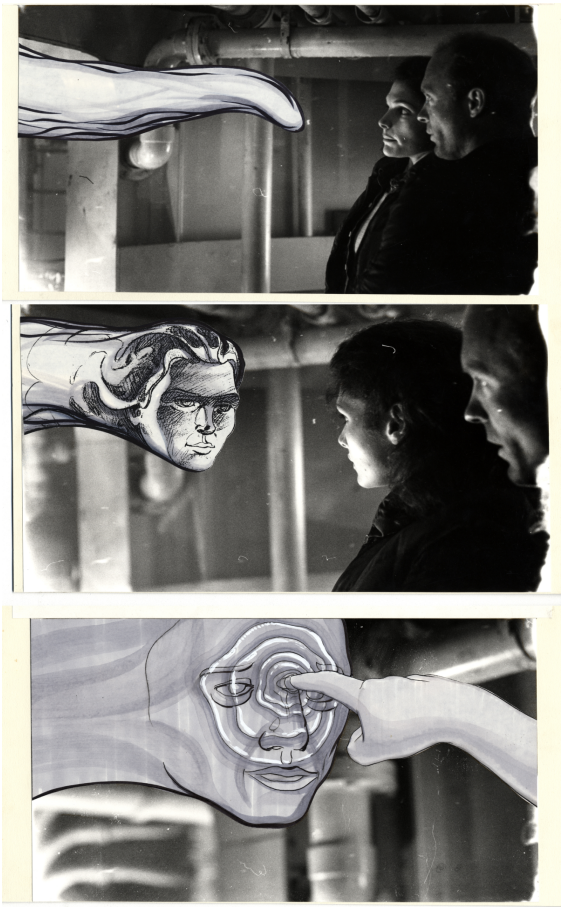

Figure 3: Performance of the pseudopod in **The Abyss** as depicted through storyboards. These drawings clearly illustrate the psuedopod's form, it's proximity to camera, and that is must assume the shape of the actor's face.

5.3 Reference Photography

Reference photography is of particular importance when the digital creature has a live action counterpart. This is almost always the case in the use of digital doubles as a replacement for live action stunt work. Digital creatures in live action projects will also often have live action counterparts in the form of animatronic puppets used for on set photography.

Both in the case of digital doubles and when animatronic creatures are used it is essential that reference photographs be taken of the characters. Photographic reference should include both neutral and stage shots. Neutral photography captures the subject so that size, proportion, color and texture information is easily determined from the images. Stage shots capture the character as seen in the environment of the set.

5.4 Storyboards

Storyboards are line art created sequentially for the purpose of describing action. Storyboards are drawn from the camera's point of view. The primary purpose of storyboards is to show how a scene described with words in a script will be captured by the director?s camera. Therefore, storyboards are very useful for determining how a creature will be seen on screen. Storyboards are typically drawn very quickly, thus they are most often not useful, and in fact can be misleading, for determining what a creature looks like.

5.5 Animatics

Animatics, like storyboards, are created to convey action. Unlike storyboards, animatics are animated images rather than still art. High quality animatics feature articulated creatures, detailed settings, and even effects animation. As with storyboards animatics are very useful for determining how a creature is expected to perform, but they are not typically reliable for determining what a creature looks like.

5.6 Real-World Reference

There are many other sources of information for what a digital creature looks like and a digital creature is expected to do. Real-world materials, in particular, can move the discussion about an issue from the point of being partially understood to having a locked down answer. For example, an animal pelt can directly address questions about the length and density of a digital creature's fur. Live action footage of a cheetah running can determine the range of motion for a digital creature?s run. The important point is to keep searching for sources of information when questions remain.

Figure 4: A still frame from the animatics of **Star Wars: Episode III "Revenge of the Sith"**.

5.7 Importance of Real-World Reference Material

In the real estate market "location, location, location" is the primary determing factor for the value of a piece of property. In computer graphics the primary factor that leads to being able to efficiently and successfully build a digital creature is "reference, reference, reference." Whether an artist is creating a digital double for a live action actor or creating a creature drawn purely from imagination real-world reference provides a firm basis for beginning development and a touchstone for continuing work. A photograph of a rhinoceros' ears, for instance, may lead to the realizaton that fine tufts of stiff hair on an otherwise hairless creature is an important contrasting design element. The photograph may also lead to the realizaton that the effect can be executed as painted geometry with opactity rather than as actual hairs curves. We experience most of our world through our vision and mental images of what we have seen. Therefore, even the most abstract representations of a creature will have some basis in real world forms and actions.

6 Questions Regarding Look

"What does it look like"? When asked to build a digital creature this should be the first question that pops into the mind of an artist. There are many factors involved in answering this question, but they primarily break down into three categories: style, anatomy, and surface material. When considering each of these three major questions many other sub-issues arise. The answers to these questions begin to categorize themselves into the digital creature taxonomy.

6.1 Design Style

Design style is a factor both for the creature itself and for the work of which it is a part. Sometimes the design style of the project is called the "tone" of the work. Projects have a thematic tone and a visual tone. It?s the visual tone that is most important in relation to the design of digital creatures. On a motion picture project the visual tone of the film is determined principally by the director, art director, and cinematographer.

There are many ways to describe the visual tone of a film. For digital creatures three categories will suffice. These are primitive, abstract, and naturalistic. It?s important to recognize when the design style of a creature conflicts with the visual style of the overall project. The two styles do not have to coincide, but they should be complementary.

6.1.1 Primitive

The term primitive, as it relates to creature design style, describes the form of the creature. It is not intended to describe the techniques used to develop the creature, which may in fact be very complex. Primitive style is most often associated with a cartoon aesthetic.

For live action projects primitive digital creatures typically contrast simplified forms in modeling with photo-real texturing and rendering. From the point of view of the tone of the project the simplified ?cartoon? forms disassociate the character from the behavioral rules of the real world but the photo-real rendering and integration keep the characters believably physically rooted into their environments.

As a creature developer it is important to note that for modeling, rigging, and skinning, primitive digital creatures typically require less rigid adherence to physical properties. For instance, it will likely not be important to model a caruncula in the eye, or create deformations representing muscle flexion.

Primitive creatures, however, are dependant upon significant identifying features for visual success. When dissecting creature design artwork featuring a primitive creature it is important to note the two or three features that are most prominent in the design artwork. For example, bulging eyes, or fingernails that are bright red no matter the lighting environment, are significant design elements. The caricatured element can prove difficult to maintain throughout the development process but must be present in order for a primitive creature design to visually succeed.

6.1.2 Abstract

Abstraction, in artistic terms, is the process of taking known elements and turning them into new forms. Abstract art can also sometimes be described as non-representational. That is not how the term is used here. Abstract design, as it relates to creature design style, describes digital creatures whose forms are composed of physically plausible elements, but in which those elements have been proportioned or combined in not found in nature.

Abstract digital creatures are heavily represented in feature film production. Most often the reason for creating a creature effect in computer graphics is because the forms are physically implausible to model or animate practically. It is not uncommon to hear that the idea of using an actor in makeup and a prosthetic suit was considered for a project but the limb proportions or mass prevented the idea from proving sensible for the performance required.

When considering abstract designs in term of computer graphics techniques it is important to stay rooted in the real world. Abstract creatures should create the visual impression that they are believably organic. Texturing and shading, in particular, should have the material quality (reflectance, refraction, displacement and color detail) that real world creatures of that size possess. Similarly, forms and deformations should bring to the viewer?s mind the same degree of physical believability that a real world creature would present.

6.1.3 Naturalistic

Naturalistic digital creatures are typically the most difficult to successfully accomplish. A naturalistic design style is one in which the creature must look and behave exactly like a creature or person from the real world. The modeled form must be proportionally correct. The range of motion and pivot positions allowed by the rigging

Figure 5: While the final creature design in the film is not primitive this concept art of the Van Helsing wolf shows elements that the director wanted featured on the creature no matter the pose, lighting, or action: attention grabbing eyes and sharply angled musculature.

must be on target. Deformations must smoothly transform the geometry from one pose to the next, and texturing and shading must incorporate photo-real material reactions to light and shadow.

Naturalistic designs are typically employed for digital doubles of live actors. They are also sometimes used for featured animal performances, sometimes as digital doubles for live on set animals, and sometimes on their own. Of all three design styles naturalistic creatures are the most dependant upon reference materials. In fact, it's safe to say that unless the model is used in only the most forgiving of circumstances it is impossible to successfully accomplish the development of a naturalistic digital creature without detailed reference material.

Perhaps surprisingly there is a similarity between naturalistic designs and primitive designs. That similarity is the importance of the two or three defining features of the creature. As with primitive designs, when dissecting artwork and reference material it is important to identify the visual elements that characterize the creature. Knowledge of what few visual cues define a creature can be a saving grace when trying to determine what precisely is not correct about the image of that creature in shot production. For example, an actor may have a specific hunch to his shoulders that is uniquely characteristic. Or, achieving the appropriate refraction of light through an elephant's tusk could mean the difference between creating a photo-real elephant and one that strikes the audience as being a bit unreal.

Figure 6: Concept art depicting the Hulk as an abstracted form of Bruce Banner.

Determining the visual style of a project and design style of a creature is not always easy. Artwork is generally the first source for determining style. It is helpful that when concept artists are working closely with a director they are often more focused on capturing mood than defining form. While this can be frustrating for a creature developer attempting generate 3D geometry based upon 2D artwork it is often very helpful for creature developers trying to determine the overall aesthetic required. Recognizing the style is an important part of staying in sync with the visual goals of the production.

6.2 Anatomy and Geometry

Design style precedes the discussion on anatomy and geometry because the answer to the question of, "what does it look like," is narrowed by determining style first. However, form is typically first in the mind of those who ask the question, ?what does it look like,? and for good reason. For most digital creature work, form, or questions of anatomy and geometry, determine the complexity of the job at hand more than any other issues.

There are four main categories of questions about anatomy and geometry. They are symmetry, body type, skin type, and accoutrements. Within those four main categories are many subcategories therefore the discussion of form gets quite complex.

It is while working on technical issues related to these subcategories that many creature development efforts become bogged down. Thus, it is also true that by identifying design elements within these issues accurately and relating them correctly to technical solutions great savings in efficiency can be made.

6.2.1 Symmetry

The geometric issue that has the greatest impact on production efficiency is symmetry. A creature that is radially or bilaterally symmetrical, or segmented requires less work than a creature of similar scope that is asymmetrical. For bilaterally symmetrical creatures (creatures that can be divided into mirror images), the work required to model, rig, skin, and texture the model is generally half the amount of work required to do the same tasks for an asymmetrical model. Segmented creatures feature parts that can be re-used, in whole or in part, for other body parts. For example, fingers can usally be sculpted from the same base piece of geometry.

When dissecting design artwork it is important not to take symmetry for granted. It is easy for a concept artist to use a line drawing to communicate asymmetry but for a viewer of the artwork to misinterpret the asymmetry as a factor of foreshortening, dramatic posing, or even poor rendering of perspective.

6.2.2 Body Type

Body type is an element of the design that is typically clearly defined by artwork (assuming that the artwork communicates what it should). Body type can be divided into four basic groups. These groups are: bipedal, quadrupedal, winged, and serpentine. From a technique perspective, the principal elements separating these groups are the animation control rigging styles used, and skin deformations.

Bipeds

Bipeds are two footed and primary animation is driven by the hips. Generally the most difficult geometry issues with bipeds involves creating accurate deformations around the shoulders. The legs of a biped are joined to the spine and thus have a limited range of motion. Arms, however, float over the upper torso, slung by muscle tissue from the spinal column to the shoulder girdle. This presents a particularly difficult rigging and deformation problem.

Quadrupeds

Quadrupeds are four footed. Their primary animation is driven through the front two legs. Like bipeds, the posterior appendages (the rear legs) are joined to the spine. The anterior appendages (front legs) are slung from the spinal column with muscle tissue and thus have a broader range of motion -typically not as broad as the range of motion for the arms of a biped, however. Generally, the most difficult geometry related issue for quadrupeds is the neck connection to the forequarters. Many quadrupeds have long necks making possible a wide range of motion. Rigging and skinning the neck and forequarters so that posing and volume preservation is natural can be difficult.

Winged Creatures

Winged creatures present relatively simple issues when only flight is concerned. Rigging and deformations issues become much more complex when the wings must fold. Winged creatures need to change the location of the principal driver of the rig from a center point between the wings when in flight, to the hips when on the ground. Wings that fold require special deformation techniques to draw the skin tight and fold it in the proper directions. Most wings are designed like a human arm in which the length of the index finger has been extended to a length that is equivalent to or longer than the length of the upper and lower arm combined. The skin connecting the distal tip of the finger back to the body forms the mass of the wing and is the are that requires the most attention for both flight and folding animation.

Serpentine

Serpentine body designs are snake-like. Some designs have legs, but the body type is serpentine if the principal motion is driven by an undulating motion down the length of the body. Fish are serpentine. A creature like a crocodile or salamander is considered quadrupedal if the leg motion swings under the body, but is serpentine if the leg swing is considerably outside the plane of the body during locomotion and the spine is undulating. In most cases the animation driver for a serpentine creature is the head. When dealing with serpentine body designs it is essential to understand the design style of the creature -whether it is primitive, abstract, or naturalistic, because deformation issues range from rudimentary smooth tube problems to highly complex radially contracting muscle and volume preservation problems.

Special and Transforming Creatures

There is a fifth category of body type that is not part of the four basic groups because it is simply a catch-all term for body types that do not fall into the other categories: special. Special body types include monopods, tripods, and creatures with greater than four legs, and creatures that transform from one body type to another.

A transforming body style is one in which both proportion and mass change. Transformations, particularly those that involve surface material changes as well as shape changes, create some of the most difficult creature development issues found. When dealing with transforming creatures the span of time over which the creature transforms is the most critical factor to determine. Sequential artwork depicting the key phases of transformation, with notations for timing of transition through each phase, is required. Careful dissection of this artwork will provide insight into whether to solve problems with rigging, special deformations, or the use of additional geometry, texturing, and compositing efforts.

6.2.3 Skin Type

About fifteen years ago the category of “skin type|” for digital creatures had a single entry: shiny, rigid metal. By the early to mid 1990s deforming skin became commonplace on digital creatures, followed by hair, then clothing. This was for good reason: skin deformation requires performing matrix algebra on each vertex or control vertice in the model; hair modeling and rendering require enormous memory and computational power, as does cloth dynamics. These are far more massive computational problem than simply defining the scale, rotation, and translation transformations for single nodes.

Despite the widespread use today, creating organic skin, clothing, hair, feathers, and scales remains at the forefront of creature development research efforts. Most the current effort is focused on the creation of physically based representations of skin, clothing, and hair (feathers and scales can be treated as hair in most systems in terms of setting up physically based rules). Therefore, the definition of each group and the questions posed by their use is composed physically based and non-physically based forms.

Figure 7: This sequence of images depicts the transformation of Velkan from man to wolf. While timing information is not noted here, this artwork defined the visual effects within the transformation: body proportion changes, skin ripping, and fur interaction with the ripped skin.

Flesh

Flesh is skin. Skin has the ability to stretch, compress, fold, and crease. Skin has thickness. It also has mass. When creating skin for a digital creature the problem is composed of both the skin and the impression of anatomy beneath the skin. On a real-world creature skin responds to the motion of the bones, muscles, and connective tissues. Believable CG skin not only has the surface properties of real skin, but its motion creates the visual impression that it is being driven by a complex system beneath the surface.

The simplest form of skin deformation requires only two transforms. Each vertex or control vertice on a surface is weighted to follow the scale, rotation, and translation of each of the two transforms by percentage values. Complex skin deformations are driven by systems representing the bone and muscle action beneath the skin. These systems typically perform dynamic simulations of objects representing the soft bodies beneath skin then solve for the way the skin reacts to those underlying actions.

When dissecting creature design artwork for flesh issues it?s important to note how much skin is actually seen and how quickly the creature will be moving relative to the camera. Flesh, except on very massive or loosely skinned creatures, has a very small range of motion relative to skeletal movement. Shape changes which maintain the physically correct form of a creature through a range of motion are typically much more successful at selling the believability of the creature than complex dynamics.

Clothing

For most digital doubles clothing is seen more than skin. In fact, it is more efficient to model only clothing, without skin underneath, for models which will always be seen wearing clothes.

In terms of complexity, digital creature clothing comes in two types, each with two possible modifiers. The two types are loose/flowing and tight fitting. The two modifiers are layered and tattered. It may sound surprising, but in terms of dynamics, loose, flowing clothing such as a long dress is an easier problem than tight fitting clothing such as a cotton t-shirt or leather pants. With loose clothing the material is free to move and resolve itself when dynamically simulated. Tight clothing is constrained by collision geometry.

The only benefit to tight clothing over loose clothing, from a level of difficulty standpoint, is that tight clothing may not always have to be solved procedurally in order to appear to be visually correct in a shot. Sometimes, simple deformations will work for tight clothing because the cameras relationship to the creature. Loose/flowing clothing, on the other hand, will need to be solved either procedurally or through the use of coordinated overlapping shape deformations in all but the most forgiving of shots in order to appear visually correct.

Layered clothing is two or more garments hanging from the same part of the body in way that makes one piece rest on top of another piece ?imagine a coat over a shirt. Layered clothing presents a difficult geometric and simulation/deformation problem. Sometimes the solution is to not simulate the lower garment because it?s hidden well enough by the top garment. If two or more pieces require simulation then ordering is necessary ?one piece must take priority over the other pieces or pieces when they?re both trying to occupy the same space.

Tattered clothing encompasses all garments that have holes or bits of cloth mostly separate from the remainder of the garment. Often, though a design includes clothing that has holes or is tattered, deformations can be handled as if the garment is whole. This is true if the holes and tatters are not large or long enough to move independently from the rest of the garment.

Collisions are an issues with most procedural animation systems, and are particularly important for clothing. From the perspective of dissecting the creature design, what?s important to note about collisions and clothing is whether or not additional modeling, rigging, and skinning is required. For example, a creature design featuring a loose robe or cape over highly ornate body armor will likely require the construction of a simplified version of the body armor in order to achieve efficient simulation times.

Material quality is also important to note when reviewing design artwork. In particular, how small are the wrinkles and folds relative to the size of the garment? Achieving very fine wrinkles requires either a great deal of geometry of a texture/shading solution. Achieving very fine folds is likely only solved with geometry and is not likely to have a texture/shading solution.

Are changes of costume required? If so, how different in term of shape and material quality are the costume pieces? The purpose of asking these questions is to determine what kind of efficiencies can

be gained by re-using geometry and/or simulation control settings from one piece on another, or on several.

Hair and Fur

When reviewing artwork for creatures that have hair or fur the first two observations should be about length and density ?in that order. Long hair is a fundamentally different problem than short hair. Long hair generally requires modeling, rigging, and simulation. Short hair often requires none.

Hair density makes a difference primarily for lighting and shading. Dense hair requires more computational power because of the number of hairs. Sparse hair tends to be more difficult to light, particularly in a back-lit scene, because the balance between seeing a dense block of hair and seeing no hair at all can be highly dependent upon the angle of light in relation to the camera. This problem has an effect on modeling because several modeling iterations may be required to determine the exact number of modeled hairs -assuming that geometry is required.

Accoutrements

Accoutrements are accessory items. They come in two forms: props, and dangly bits. Props are items not attached to the creature, but constantly seen being held or worn by the creature. Dangly bits are items physically attached to the creature but that are not part of the creature's anatomy.

Props

Props are most often a model on their own ?with their own rigging, perhaps deformations, and can even be an animated character. They become an issue connected to creature design when they are in constant close interaction with the creature. A good example of a prop fitting this description is the staff held by Yoda in the Star Wars films. The staff is geometrically separate from Yoda, yet it is seen so often with the character that rigging controls and special sculpting was done for Yoda to accommodate easy use of the staff.

Dangly Bits

Dangly bits are typically more difficult to deal with than props. This is because they are not self contained. Dangly bits are physically attached to the creature and react to its motion. A rigid buckle on a cloak is a good example of a dangly bit. Earrings are also dangly bits. A belt lies somewhere on the spectrum between clothing and a dangly bit.

The two most difficult problems to solve with dangly bits are how to attach them to deforming surfaces and how to provide for localized motion. Usually, the number of dangly bits and their size can be determining factors. Hundreds of teeth-like spikes lining the body of an eel-like sea monster will be best served by a procedural method for keeping them attached to the creatures skin. A handful of gadgets dangling from the belt of a digital character might be best dealt with by rigging and perhaps a bit of rigid body dynamics.

Special Attention for Accoutrements

The key issue with both props and dangly bits when analyzing creature design artwork is to account for them in relation to what the creature does. If the creature?s physique is fairly static in the area in which the prop or dangly bits are held or attached then perhaps very little needs to be done to accommodate them. On the other hand, if the props or dangly bits are featured prominently in areas of high action or deformation then special steps will need to be taken to deal with them.

Figure 8: Character design artwork for Watto from **Star Wars: Episode I "The Phantom Menace"**. This artwork was created to show the range of the character's facial performance. However, what it also shows is the character has a signifcant number of props and dangly bits.

The best thing about props and dangly bits is that they're often the feature of a creature that, when handled correctly, make the creature feel alive. They can be that little extra detail that pops the creature out of the screen as a character, or adds the extra needed dose of complexity to the image and motion.

7 Questions Regarding Performance

When beginning the task of developing a digital creature the first question is "what does it look like", but that question should always be followed by "what does it do." Answering the first question without seeking answers for the second is equivalent to building a race car without knowing whether the event is a drag race, road race, or off-road obstacle course.

Though only touched on briefly in the previous section about look, questions about performance impact every choice made about how to model, rig, and deform a digital creature. An artist must determine how the creature will be used relative to the camera (scope), and how the creature will be seen in relation to other creatures, performers, and the set (integration and interaction).

Answering the question, "what does it do" is often hard to determine from artwork alone. Sequential still art can be informative. Storyboards, animatics, and the script typically provide the most answers.

7.1 Scope

Scope refers to the range of use of the digital character throughout the project. The scope of a creature's use ranges from being seen only a few frames of one shot, to being among the lead characters driving the story. A digital stunt double often fits the former description, while characters such as Casper, in 1996's **Casper**, and Gollum in the Lord of the Rings trilogy fit the latter description.

A hero character is one that is built to perform adequately for any kind of performance required. It is expected that a hero character may be seen from any angle, be any size relative to the screen, and need to articulate and deform into any anatomically possible pose. The term "robust" describes the techniques that should be employed when constructing a hero character.

For hero creatures the number of animation controls and the flexibility of those controls must be elegantly designed. Likewise, skin deformations, cloth and hair animation must be setup to achieve at least roughly believable action with minimal effort. The goal for developing hero creatures is to create a base model that works for ninety percent of the required performances so that there is time to put additional effort into achieving the performances required by special shots during in shot production.

A background character is seen minimally. A background character will be a far distance from the camera, or seen only briefly on screen, or both. The term "minimal" describes a background character's pre-production development. It is desirable to spend minimal effort prior to shot production preparing a background character because the visual problems that arise when the character is on screen can typically be handled via "fix-it" solutions such as shape animation or digital paint.

The two biggest determining factors for whether or not a character is hero or background are shot count and size on screen. Shot count is the number of individual times, from edit cut to edit cut, that the creature is seen. Usually a high shot count dictates that the creature will need to be built to hero quality. It is likely that if the creature is in a large number of shots some of those shots will feature the creature will be close to camera.

However, it is unwise to assume the reverse -that a low shot count means the creature can be developed only as a background character. Only one close-up shot is required to necessitate the construction of a hero model, at least in terms of geometry, texturing and shading. For one hero shot deformations can often be handled via shape work.

A way of determining if a creature will need to be built to hero level is by finding out if the creature will ever fill 1/3 or more of the screen. At that size on screen and larger the creature is likely to become the visual focus of the shot. At 1/5 of the screen size and smaller creatures can fall into the background category.

Size on screen is modified by time on screen. Time on screen is not a factor of the number of shots but a factor of the length of each shot. Shot length is measured in frames per second (24 for film, 30 for video). There is a wide range of opinion, and some hard science, on the subject of how few frames are required for visual recognition of individual aspects of a form such as size, color, and shape. In practice, the key is recognizing two factors. First, most professionals of the craft of producing imagery have a more finely tuned sensitivity to moving imagery than the general audience. Plainly put: your peers are going to be tougher critics than the average member of the audience. Second, assuming image resolution is not a factor, the size of the screen has an inverse relationship to the fidelity required to achieve a believable image. A large screen requires a viewer's eyes to scan the image. On a small screen the entire image can be concentrated upon by the viewer.

Figure 9: Concept art from **Star Wars: Episode II "Attack of the Clones"** showing clone troopers with a variety of relationships to the camera. Those that are in the foreground would require hero level geometry and texturing. Those in the background would require much less detail.

Most creatures that are built to be used in a large number of shots and with variable relation to the camera are modeled, rigged, skinned, and textured at several different resolutions. These are typically called levels of detail. A widely used model may have a hero version, high-res version, medium, low, and pawn-res versions. A hero and a high-res version may be built so that the hero version can serve a particular shot or series of shots in which the camera gets very close to one particular part of the model, such as a close-up on a hand. The high-res version would then serve the majority of what would otherwise be considered hero shots.

A low-res version would typically serve for all background use. Medium-res would be somewhere between high and low, such as would be used for crowds on a sidewalk when the camera is moving down the street. Pawn versions are typically not rendered, but are used for animation choreography of large numbers of models such as for a stadium full of people, a battle between soldier armies, or a parade.

7.2 Interaction and Integration

The question of "what does it do" should not be limited to the creature itself. If the creature has interactions with other digital creatures, props, the environment, or live actors, it is important to define how those interactions take place.

Interactions with other digital creatures are typically the easiest to handle. Both models can be dealt with in the same space, within the same tool set. The physical proximity of two digital creatures is easily determined.

Interactions with the environment are more complicated, particularly for live action projects. Shadow casting is among the most basic forms of environmental interaction. Creating dust from footfalls, splashing in water, moving foliage, are much more complicated. It is convenient to classify those issues as effects related, and

not specific to creature development, but that approach can lead to less than efficient results. When the effect is commonplace for the creature an approach that allows the creature to drive the action is often most efficient. For example, the location of footfall is easily determined by tracking the position of objects on the creature's feet. These objects should be built into the animation rig or the geometry.

Like interactions with the environment, interactions with live actors is particularly difficult and a problem specific to live action projects. Unlike interactions with the environment, interactions with live actors is primarily a problem of integration. The digital creature must appear to exist in the same space as the live actor, often be made from the same material, and have generally the same level of complexity in visual makeup and action. This problem is closely related to the issue of design style. However, where design style is in regards to the overall look of the creature, integration with live action is specific to how the creature appears relative to live actors.

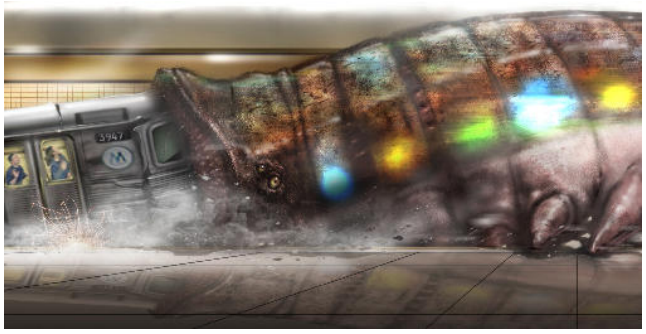

Figure 10: Concept art featuring Jeffworm from **Men In Black 2** devouring a subway train. This image shows Jeffworm interacting with the subway car, the subway platform, and people in the subway car -both the subway car and people inside the car were filmed as live action elements.

The term live actor is used in the above paragraph generically. The problem of integration with live animals is nearly as commonplace as is the problem with live human actors. The same factors apply with animals. For example, the quality of rendered fur on a digital creature will be held to a higher standard if the digital creature is seen in the same shot with a live action furry animal.

As with each of the other questions in this section, questions regarding integration with live actors are not usually apparent from still artwork, but instead from sources that visually describe motion such as storyboards and animatics.

8 Conclusion

The craft of digital creature development combines design and technology. It is the capacity of design to drive the application of technology that sets good creature development apart from work that visually fails to inspire the audience. This course emphasizes that the process of analyzing artwork and asking the appropriate questions about design elements within the artwok that are integral to the high quality and efficient production of digital creatures.

The first step toward being in a position to ask relevant questions is the acquisition of reference material. Once that material is in hand elements can be categorized in a form that relates to concepts from comparative anatomy and aligns with areas of technological solutions. This categorization, because it is only loosely associated with technology, can transcend changes in the computing environment.

Categorization begins by asking two primary questions: "what does the creature look like" and "what does it do". Through the process of asking these questions aspects about the design are refined from being simply forms on a page or actions in an animatic to being definable problems. Those problems, once generally defined, can begin to seek the application of specific technological solutions.

It is hoped that, rather than being a formula, this course offers a style of problem solving. The specific terms and categories offered within the course are not rigid, and are by no means put forward as some form of industry standard. They do represent a codification of terms and methods that have been employed, in one form or another, for over ten years by one digital artist. Putting this information forward in this form will perhaps encourage others to do the same. Just as an art instructor for a figure drawing class encourages students to "draw what they see, not what they know", this course encourages digital creature developers to solve the problems according to what they see in the creature design artwork rather than by doing what the tools offer.

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10 Notes About the Author

Tim McLaughlin is a senior member of Industrial Light & Magic's Creature Development group. His work revolves around constructing photo-real organic computer graphics characters and creatures

for use in live action films. Tim's primary focus is on rigging, skinning, and procedural animation for hair, clothing, muscle, and flesh.

Tim joined ILM in 1994. He holds a Masters degree in Visualization Sciences, and a Bachelor of Environmental Design degree from Texas A&M University, as well as an Associate of Arts degree from Kilgore College in Kigore, Texas. He is a Visiting Professor at Bournemouth University's Media School, Poole, England, and a member of the Visual Effects Society.

Author's Film Credits

2005	SON OF THE MASK	Creature Developer
2004	LEMONY SNICKET'S SERIES OF UNFORTUNATE EVENTS	Creature Developer
2004	VAN HELSING	Creature Supervisor
2003	DREAMCATCHER	Creature Supervisor
2002	MEN IN BLACK 2	Creature Supervisor
2001	JURASSIC PARK III	Creature Supervisor
2000	ROCKY AND BULLWINKLE	Creature Developer
1999	THE HAUNTING	Creature Developer
1999	STAR WARS: EPISODE I "THE PHANTOM MENACE"	Creature Developer Supervisor
1996	MARS ATTACKS!	Technical Director
1995	JUMANJI	Technical Director

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