# Taxonomy of Digital Creatures: Defining Character Development Techniques Based Upon Scope of Use

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## 1 Course Description

Using computer graphics to develop digital creatures from concept to realization requires a series of decisions based on how the character is expected to be seen. This course focuses on how to use a creature's scope of apearance to effectively define the best use of modeing, rigging, look development, and animation techniques.

This course presents a process for dissecting reference material, a language for communicating informaion specific to digital creatures, and a method for making a relationship between pre-production development and shot production. Technical information is divorced, as much as possible, from this material. In fact, one of the primary goals of the course is that the information presented be undiminished by changes in technology.

The concept art, storyboards, and animatic frames are drawn from feature film work. The projects from which examples are taken include **War of the Worlds**, the Star Wars films, the Harry Potter films and others. Though these examples come from the use of digital creatures in live action films, many of the processes discussed and the questions posed are relevant to the construction of digital creatures for all media.

## 2 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 methodology and language for the craft. Basic comprehension of modeling, animation, and texturing issues is required.

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## 4 Introduction

This course expands upon the ideas presented during the Taxonomy of Digital Creatures course at SIGGRAPH 2005 in Los Angeles. That session introduced the concept of breaking down creature affects work by systematic review of reference artwork and categorization of the results. This course builds upon that methodology by delving deeper into the role that scope of use plays in the process of translating design elements into computer graphics techniques.

Digital creatures are prevalent in projects ranging in size from student shorts to the largest studio productions. Digital creatures may play the role of the star or be simply a background-filling extra. The camera may linger on each nuance of the creature's performance or only catch the most fleeting glimpse of the creature's form or action. This range of scope of performance has a large impact on the

decisions made regarding the techniques and technology used to create the creature. The techniques for modeling, rigging, rendering, and motion generation employed are technological answers to the questions posed by the creature's design and the scope of its use.

This course is about the questions raised when embarking on the task of digital creature development rather than answers. It is about the processes for deducing the most effective solutions, and the most effective process for testing those solutions. The specific technological answers to problems change over time with software and hardware advancements. The questions that precipitate those solutions do not change.

This course breaks down the process of bringing digital creatures from concept to the screen into a series of questions, or decision points. Emphasis is placed on the craft of dissecting reference artwork, storyboards, and animatics so that development techniques can be aligned with what is known, or inferred, about the expected visual end product.

Two principal questions: "how much of the digital creature do we see, and for how long do we see it¿', are broken down into issues of design style, performance generation, environment variation, and interaction with the environment. The goal of this process is to allow the performance requirements for the digital creature to drive the techniques employed in its construction and look development.

## 5    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 size, 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 an experienced commuter knows the best path to take during rush-hour, an experienced digital creature developer understands how to make efficient connections between reference material and computer graphics techniques.

A secondary goal of this course, and its predecessor at SIGGRAPH 2005, is to promote design oriented achievement in the development 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 affect vendor, the dual goals of creating fresh imagery and achieving economy are constantly in conflict. As a tool the computer encourages iterative behavior. Non-destructive adaptation and re-use of existing assets is one of the primary benefits of working digitally. Efficiency, therefore, becomes a partner to the creative process. Sometimes this partnership frees creativity and sometimes it restrains it.

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. Unsatisfactory results occur when the visuals are derivative of the tool or process rather than the creative reason behind their use.

Assuming that the original conceptual creature designs and camera work are provocative, derivative execution of the computer graphics work is often the result of using the tools at hand rather than al-

lowing the creature and shot 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 concepts without respect to the 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 or technique 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 was created. Making an assumption that the standard set of tools and techniques is appropriate for a task is unwise economically, and detrimental to creativity.

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, computer graphics, and film production. Some of the terms, such as rigging, skinning, and motion capture are expected to be readily understood by the reader. Other words, or the way in which a word is used, may be more obtuse. 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 with respect to digital creatures.

## 6    Meaning

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, methods used to generate their on-screen performances, and the manner in which the creatures are seen on screen.

The overall aesthetic and economic success of a digital creature oriented project can be greatly affected by the timing of decision making. During analysis of creature designs and performance requirements questions should arise about how the affects will most effectively be handled. Thoroughly addressing these decision points is key to the success of a project. The first goal in addressing 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 could not be animated as an expres-

sive character, but 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 those terms apply to digital models. The only difference between a creature and a character is in the performance, not the construction. There is no difference between the two when the subject at hand is design and technique. A creature and a character can share exactly the same set of techniques used in their construction and performance generation. The two terms are most usefully employed when discussing the role played on screen. A digital crocodile menacing a boat full of frightened tourists is more aptly described as a creature. A friendly ghost who befriends a lonely young girl is better described as a character. The term digital creature, rather than character, will be used predominantly in this text because the performances exhibited by the example models tend to inhabit the creature 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 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. The focus here is on analyzing designs and performance requirements. It is hoped that many of the ideas offered here will apply to all digital creature creation efforts.

Because this course deals primarily with scope of appearance, which is defined by camera position and a creature's time on screen, portions of the decision making process described here will not be applicable to the development of creatures for interactive formats such as games. In those formats, the user is provided control over the camera. For user controlled formats the way the camera captures the world is unknown during development, thus performance driven development is determined by the capacity of the game engine. In director controlled formats, such as feature films, what the camera sees is determined prior to image generation. Thus, the way the camera captures the world becomes the basis for performance driven development.

This course deals with the construction of digital creatures so that they can fulfill on-screen performance requirements. Though this course will discuss modeling, rigging, deformations, and dynamics issues as they relate to scope of use, those topics are more heavily influenced by design elements and were more fully developed in the previous course presented at SIGGRAPH 2005. This course will focus more directly on look development -texture and material, as well as performance generation. These issues are more directly affected by the creature's scope of appearance.

The term "shot" will be used repeatedly throughout this text. A shot is the imagery seen on screen between edit points, or cuts. A project will typically be composed of multiple sequences, or scenes, and each sequence will be composed of multiple shots. A shot, or number of shots, is a common unit of measure when the scope of visual effects and animation work is being evaluated.

# 7  Define Scope of Appearance

The previous course introduced the concept of the two fundamental questions that must be considered for each creature development project: "what does the creature look like, and what does the creature do?" All other questions fall under the these two umbrella questions. The process of analyzing creature designs and performance requirements is undertaken in order to answer these questions. In turn, answering these questions leads to good decision making regarding the use of computer graphics techniques.

One particular question, however, acts like a modifier for other questions: scope of appearance. *Scope* refers to the range of use of the digital character throughout the project. Is the creature seen in only a few frames of one shot, or is it among the lead characters driving the story? A digital stunt double often fits the former description, while characters such as Draco, in 1996's **Dragonheart**, and Kong in 2005's **King Kong** fit the latter description.

Scope of appearance is determined by time and size. How much time is the creature on screen and how much of it do we see when it is on screen? Choosing the best dynamics method for clothing on a character, for example, isn't determined simply by knowing that the cloth looks like silk or leather. Knowing that the clothing will fill the screen space or be on screen a great deal of time also influences the technical decisions.

# 8  Reference Material

Answers to the fundamental questions about what a digital creature looks like and what it is required to do come from a variety of sources. Still artwork, reference photography, and sculpted maquettes are static imagery and are most often useful for answering the questions around what a creature looks like. For answering questions of scope animatics, storyboards, and video or film reference are more helpful. Storyboards are static imagery, yet are created specifically to communicate action. Storyboards are often edited in to story reels and animatics. To some readers story reels and animatics are synonymous. For this discussion a distinction will be made between the two.

Verbal and written descriptions are often valuable and loaded with key pieces of information, but the validity of these sources is variable -particularly in reference to questions of scope. A script can be broken down into a rough estimate of shot count and time on screen. Occasionally a script will include key words about a characters relationship to the camera, such as "extreme closeup on ALIEN HAND reaching through curtain.", but words, verbal or written descriptions can be interpreted many ways. Images, particularly those that convey the action of the camera are less prone to vaguarity.

## 8.1  Still or Flat Art

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 drawings are particularly useful for determining proportion and mass.

## 8.2  Maquettes

Maquettes are three dimensional sculptures. They're often made originally of clay then cast in plaster. Most maquettes are around eighteen inches (45 cm) tall. The benefit of having a maquette 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 maquettes.

Figure 1: Concept art of the horntail dragon from **Harry Potter and the Goblet of Fire**.



Figure 2: Photo of a horntail dragon painted maquette from **Harry Potter and the Goblet of Fire**.

## 8.3  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 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 seen in the environment of the set.

For issues of scope, reference photography is a great source for determining the level of detail required. Photographs of real objects in real-world lighting environments reveal the form, color, and texture detail that our eyes comprehend given a set distance from camera and/or movement relative to the camera and set a visual target which the digital work must attempt to match.

## 8.4  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 often not useful, and in fact can be misleading, for determining what a creature looks like.
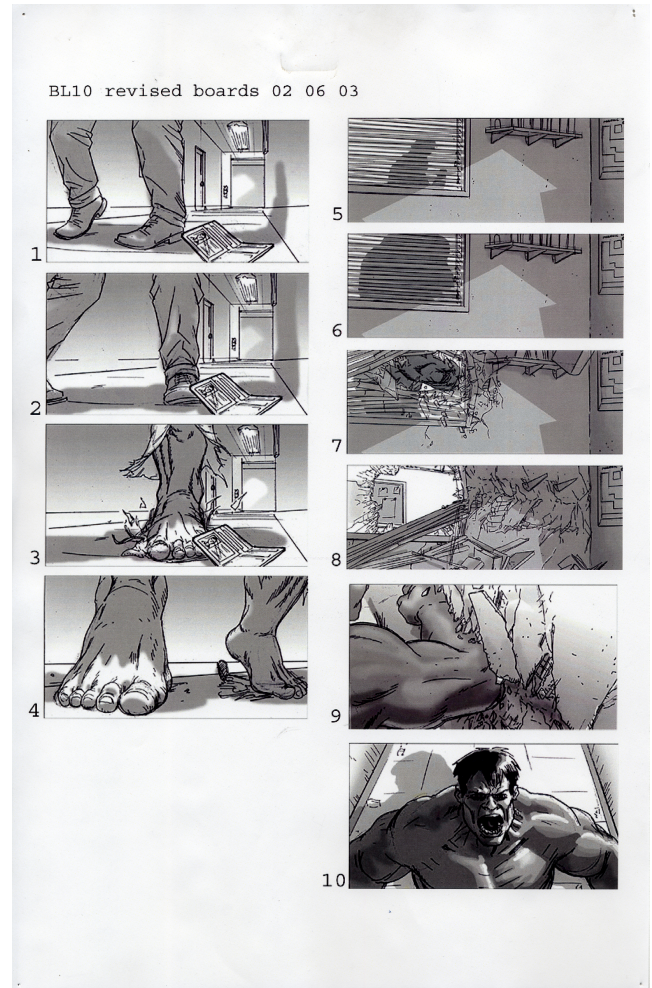


Figure 3: Story board of Hulk transformation sequence featuring an extreme close-up shot of Hulk's foot.

## 8.5  Story Reels

A story reel is a filmed version of a series of storyboards, created to test dramatic timing. At its simplest, a story reel consists of a series of storyboards edited together, each board held on screen for the amount of time that the shot is expected to last, and displayed in sequence. In more complex forms, running footage from other projects showing similar action or environments may be used to show what is intended for the final shot or sequence. A sound track containing rough dialogue, sound effects, and a representative musical score is typical. The purpose of most story reels is to convey the intended feel and pacing of the finished product.

## 8.6 Animatics

Animatics, like storyboards and story reels, are created to communicate the director's intentions with the camera. It is common to consider animatics and story reels to be two different terms for the same concept. However, a distinction is drawn here for purposes of computer graphics pre-production. Unlike story reels, animatics rely more heavily on animated images rather than still art. High quality animatics feature articulated creatures, detailed settings, rough lighting cues, and even effects animation. The primary purpose of animatics is to understand complex action and the way the camera will capture that action. The communication of the project's tone and dramatic timing is of lesser importance. As such, animatics are typically more informative than storyboards and story reels in terms of communicating how a creature is seen relative to the camera.

Director approved animatics, if available before full production models are built, rigged, and textured, remove the majority of guess-work about what parts of the creature will be seen and at what level of detail. Animatics can be expensive to produce. Where there may be a story reel or collection of story reels representing an entire project, animatics for live action projects are typically only created for specific sequences.



Figure 4: Still frame from the stop motion animatics created by Tippett Studio for the raptors in the kitchen sequence in **Jurrassic Park**.

## 8.7 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 around the color and texture 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.

## 8.8 Importance of Reference Material

In the practice of buying and selling real estate the age-old axiom for what is important is "location, location, location". For the craft of building digital creatures this axiom can be expressed as "reference, reference, reference." Whether an artist is creating a digital double for a live action actor or creating a creature drawn purely from imagination the two fundamental questions remain the same: what does it look like and what does it do? The best way to answer those questions is to rely on images and elements taken from the real world.

# 9 Design Style

Design style is the visual context for the creature. Sometimes the design style of the project is called the visual 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. The design style can sometimes be different for the creature than for the work of which it is a part. 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.

## 9.1 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. It 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 visually rooted in their environments.

As a creature developer it's 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. Material properties, however, may require shading and texturing complexities associated with photo-real rendering. From an early age we, as viewers, are willing to engage with characters that have simplified forms or move in ways that are less than physically accurate. We don't, however, encounter the same exposure to objects that don't appear to exist in the same environment as we do. The exception to this phenomena is when the materials evoke the look of a world that is not real, but with which we have visual experience, such as the use of cartoon shading.

Primitive creatures are dependent 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 elements, unless duly recognized and faithfully looked after, can become lost during the development process when attention is turned to technical issues.

## 9.2 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 unnatural ways.

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 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 real. 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.

## 9.3 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 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 dependent 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 the few visual cues define a creature can be a saving grace when trying to determine what precisely is incorrect 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 just the right amount of light refraction 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 implausible.

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 when

attempting generate 3D geometry based upon 2D artwork it is often very helpful for creature developers when trying to determine the overall aesthetic required. Recognizing the style is an important part of staying in sync with the director's vision.

## 10 Look Development and Motion Development Questions

Before being used in the production of specific shots digital creatures go through a development phase known as pre-production. During pre-production the form, color, texture, and action of the creature is investigated. The purpose of pre-production development is to enable an efficient and consistent workflow during the production of shots. The higher the number of shots, the longer the screen time for the creature, the greater the need for robust pre-production development. Creatures appearing in a single shot or receiving a limited amount of screen time during a small number of shots may go through no pre-production process at all. Their development may occur only during the production of the shot or sequence of shots in which they appear. For the majority of creatures, however, turntables and motion tests are the two most common forms of pre-production testing.

Turntables are the most common form of pre-production look development testing. A **turntable** is the process of viewing a model from a variety of angles by either rotating the creature in front of a camera or rotating cameras around the creature. Turntables are useful for judging form, color, and texture.

Motion tests are used to judge movement. **Motion tests** involve animating a creature or parts of a creature and placing the camera so that the motion can be seen clearly. Motion tests may be animation cycles such as a walk, run, or wing flap. Motion tests are often used to judge action relative to primary animation such as skin deformations or clothing dynamics. Motion tests may focus on a single part of a creature such as tests for facial expressions or focus on the entire form such as movement into and out of key poses.

There is no single set of best practices for the use of turntables and motion tests. The techniques and procedures employed should be defined by the expected scope of use of the creature during production. The answers to each question raised when attempting to determine scope of use can be used to define the best use of turntables and motion testing.

Artists experienced in the use of turntables and motion tests develop standardized setups so that cameras, materials, lighting, and environments are common from turntable to turntable and motion test to motion test. By neutralizing variation among the common ingredients of turntables and motion tests it becomes easier to focus on the elements in the imagery that truly require attention. For example, if a modeler's turntable for a creature is rendered with long lens and the texture painter's turntable is rendered with a short lens the visual difference in depth within the model due the lens difference may make it difficult to determine the degree by which the form is enhanced by texture.

The creation of a single set of robust development tests is not always preferable. When shot performance requirements are known during pre-production gearing pre-production testing toward the shot production environment makes economical sense. Altering development standards based upon incomplete and possibly false assumptions about scope of use can scary. The goal in pre-production is to put effort into things that will show up on the screen. The correct balance is struck when the number of corrections required during shot production to recover from pre-production mis-steps adds up

to a savings over time and resources spent over-building in pre-production.

## 10.1 Relationship to Screen and Camera

Imagine a conference room at a visual effects company. The chairs around the table are filled with artists who have gathered to review art work and plan the development process for a digital creature. Leading the discussion is the Visual Effects Supervisor for the project, just returned from discussions with the director. As soon as the art work is spread across the table one of the first questions is bound to be, "how hero¿'. This is not a question with an object, such as "Et tu, Brute?" It's a question with an adjective. "Hero" is a qualifier. The answer to the question communicates the degree of fidelity required for the look and performance of the creature.

### 10.1.1 Level of Detail

For the sake of efficiency creatures are developed to look good and perform well only as required by the scope of their use. The categories describing breadth of the creature's performance requirements are called **levels of detail**. These level of detail categories are sometimes given the names "high", "medium", and "low" in reference to the resolution of the geometry, texturing, and/or rigging level required. I prefer the terms "hero", "mid-ground", and "background", respectively, because these terms imply a relationship to the camera. It is the creature's relationship to the camera that determines the level of detail required.

Some creatures may only exist as hero models. Some are only built to background or mid-ground levels. A creature that is seen in many shots and at a variety of relationships to the camera will often be built as hero, mid-ground, and background versions. There may also be a "hero-hero" versions for extreme close-up shots or highly specific performance requirements. The goal when producing creatures at multiple levels of detail is to achieve the same visual result with the lower detail creature as would be achieved with the higher detail creature in the same viewing environment. For example, a background creature developed to be visually effective at 1/8 screen height should appear insignificantly different from the hero version of the creature when seen at 1/8 screen height.

The two biggest determining factors for whether or not a character is hero, mid-ground, or background are size on screen and time on screen. Usually a creature that receives a lot of screen time will need to be built to hero quality as it's likely that if the creature is in a large number of shots sooner or later it will be close to camera. However, the reverse is not commonly true: minimal screen time does not mean that the creature will only be mid-ground or background. It is possible that a creature can be seen only briefly, but for that brief period of time be seen in great detail due to its size on the screen.

#### Background

A background creature is seen minimally relative to the size of the screen. A background creature will be far from camera. If a background creature has a small amount of screen time it's desirable to spend minimal effort upfront in preparing the creature. Visual problems that arise when the creature is on screen can typically be handled via "fix-it" solutions such as shape animation or digital paint within the context of shot production except for situations involving multiple instances of the background creature.

If a background creature will receive a large amount of screen time either due to many appearances or muliple instances in the same
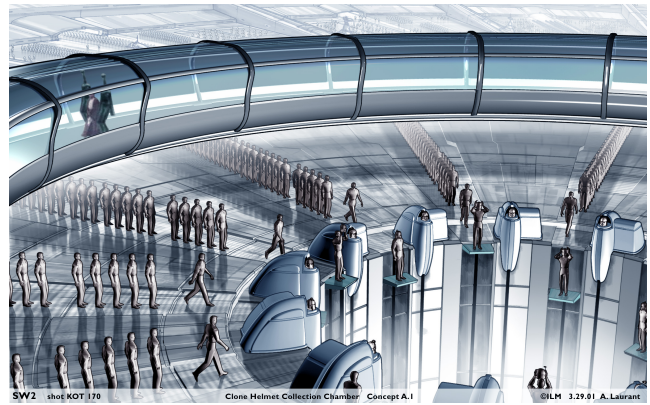


Figure 5: Concept art of the helmet room in **Star Wars: Episode II "Attack of the Clones"**. The figures would be considered background level creatures for this shot.

shot care must be taken to make the background creature efficient. Efficiency for background creatures is defined by the computational expense of generating the creature's image and performance per frame. Geometry, rigging, deformation systems, and texturing and shading methods each contribute to making a creature more or less efficient.

Two common practices for making a creature more efficient are "de-res-ing" and "baking". The process of de-res-ing is accomplished by making file sizes smaller -for example, by removing vertices from geometry, or reducing the size of a texture. Baking attacks efficiency by minimizing processing time rather than file reading time.

**Baking** implies that an effect is pre-determined, or pre-calculated. For example, self shadowing for furry creatures is computationally expensive to calculate. If a large number of shots feature furry creatures in the background it's possible that shadow passes from a variety of light directions can be pre-rendered and accessed according to look-up conditions as needed per shot. If seen in detail it will likely be obvious the the shadowing is incorrect relative to the lighting direction, but when seen at a reasonable distance from camera the effect should appear visually plausible.

Baking can be employed for motion as well as rendering. Pre-developed animation cycles and motion capture segments can be reduced to transforms per frame and placed in a motion library. Then, background creature animation can be produced by accessing the motion library according to either directed or pre-determined rules. With baked transforms solving for inverse-kinematics and other computational processing within rigging is not required. The same principle applies to deformations on surface geometry.



Figure 6: Shadow passes for a wookie in **Star Wars: Episode III "Revenge of the Sith"**. These types of images were precomputed and assembled into a library where they were referenced per frame rather than rendered per frame. This library provided imperfect, but passable fur shadowing and occlusion for background and midground wookies.

When reviewing storyboards and animatics it is important to recognize opportunities for efficiency savings such as de-res-ing and baking for background creatures. The pre-production motion and look development exercises can be developed to focus specifically on ensuring that the creature works within its scope of appearance. Baking and de-res-ing are not mutually exclusive.

### Midground

Mid-ground creatures are probably less common than either background of hero. There is a tendency during the dissection process of storyboards and animatics to err on the side of conservatism -that is to say that it is safer to over-build a creature and pay the price of inefficiency than it is to under-build and pay the price of a visually flawed effect. Thus, a mid-ground creature is the most difficult to define based upon storyboards and animatics. A relatively minor change in camera position or edit point can mean the difference between a creature being large on screen or not.

However, there are some visual rules of thumb that help determine if a creature should be developed to mid-ground quality and these in turn drive the pre-production decision making. If the creature's whole body fills less than 1/3 of the height of the screen it can likely be built as mid-ground. At this level individual hairs on a furry creature, and muscle definition on a bare-skinned creature are not likely to show up except along the silhouette. Eye direction and movement will not be discernible for creatures with standard proportioned eyes. Subtle surface material changes such as from skin to fingernail, and the difference between individual teeth with not be visually apparent. Articulation of minor digits such as fingers and toes can likely be accomplished via a single set of transforms.

Effects which alter the silhouette, however, must be dealt with effectively for mid-ground creatures. Long hair, loose clothing, and dangly bits such as chains, will catch the viewer's eye if they have no motion relative to the creature's primary actions.

De-res-ing is the most common practice employed for creation of a mid-ground creature's assets if hero level assets already exist. When both a hero and a mid-ground version of a creature is required it is usually most efficient to develop the hero creature first. Most artists feel that it is easier to achieve satisfactory results by reduction rather than by addition. Baking is possible with mid-ground creatures, but more constrained by surface types. For example, baked lighting and occlusions will display visually obvious artifacts more easily on deforming surfacing versus surfaces that deform little or not at all.

### Hero

A hero creature is built to hold-up for any kind of performance required. It's expected that a hero creature may be seen from any angle, be any size relative to the screen, and need to hit any anatomically possible pose. The term "robust" describes the techniques that should be employed when constructing a hero character.

The number of animation controls and the flexibility of those controls must be broad for hero characters. Likewise, skin deformations, cloth and hair animation must be setup to achieve an effect at least roughly believable with minimal effort. Materials for surfaces on hero creatures will require extensive look development. Care must be taken to achieve granularity within texture coloration and variation across a surface in the way that the material responds to light. The goal for developing hero creatures is to create a base model that works for the majority of the required performance and environments, while making allowances for adjustments to the creature's appearance in individual shots.

Many renderers include functions for up-res-ing and down-res-ing objects based upon the object's size in screen space. The factor by which the model is altered is dependent upon the range of material provided to the renderer. Procedurally determined resolution changes based upon screen space can be applied to geometry, textures, and the number and size of instanced objects such hair.

### 10.1.2 Hero-Hero

The term hero-hero is typically used to describe a part of a creature rather than the whole. Hero-hero means that some part of the creature will be seen in an extreme close-up shot. It will fill the screen, and the camera will linger long enough for the viewer to get a good look. These types of shots are used in action and science fiction projects to tease the audience about what the entire creature must look like. Hands, feet, claws, and eyes are common parts of creatures that must be built as hero-hero.



Figure 7: Still frame from **War of the Worlds** animatics featuring the tripod filling the screen as it rises from the ground.



Figure 8: Still frame from the completed shot of the tripod rising from the ground. Note how close tripod is to camera, but also how much the atmospheric effects soften the visible details.

Sometimes a hero-hero model requires modeling, animation, rigging, texturing and shading detail far beyond what a hero model requires. When the camera is very close to skin, for example, veins, pores, and perspiration are apparent. From a few feet away these details are not typically apparent as individual elements. Skin also changes color under tension and compression. This effect may be visible in an extreme close-up shot though it likely would not be in a standard close-up.

Completing a model that will hold up visually on the screen in an extreme closeup requires that attention be focused on the areas of the model that will receive the audience's attention. Careful attention should be paid to storyboards and animatic material and questions answered regarding the veracity of the camera framing. The goal is to build only what is required.

### 10.1.3   Questions About the Screen

What is the creature's relationship the the screen? The priority is to determine how much of the screen the creature will fill. 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.

Screen size is modified by the aspect ratio of the image. Aspect ratio is the dimension of the height of a viewing screen relative to its width. Most feature films are released at aspect ratios of 1.67, 1.85, or 2.35. Theater screens are much wider than they are tall. Standard broadcast television is 1.33, also known as 4:3. HD is 1.78, also known as 16:9.

How does aspect ration affect creature development? Aspect ratio directly affects how much of a creature can be seen on screen at once. For example, framing on a standard "two-shot" of characters in conversation or facing off for confrontation places the mouth and eyes of the primary character at around 2/3 the height of the frame. A wide aspect ratio, as is used for theatrical releases, means that less of the character will be on screen given this framing. In a narrow aspect ration, such as for television, a two-shot will typically show more of the character.
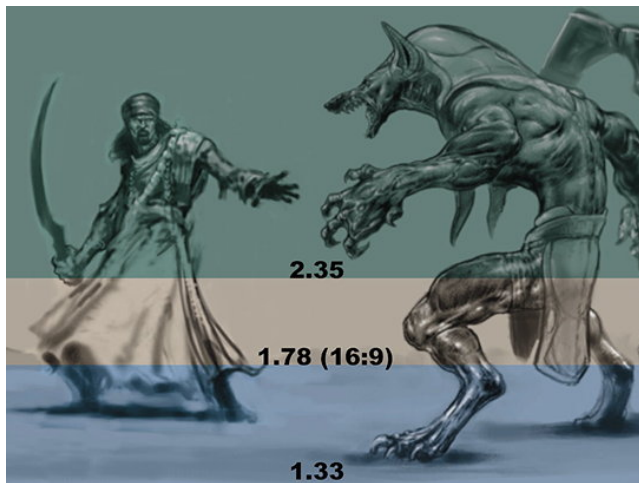


Figure 9: Concept art of an Anubis warrior from **The Mummy Returns**. The full image has an aspect ratio of 1.33. The horizontal line around the warrior's ankles represents an aspect ratio of 1.78, or 16x9. The horizontal line about waist high on the warriro represents an aspect ratio of 2.35.

Creatures developed for theatrical release projects typically have to be built with more detail than would be required for video release due to the larger size of the projected image. However, it should be understood that in theatrical presentations the viewer is unable to scan the entire image during the course of an average single shot -this is particularly true for wide aspect ratio images such as 2.35. Through the use of shot to shot edits, lighting, motion, and placement in frame the director will be guiding the audience to look at

a particular spot for each shot. Creatures developed to be the focal point will need more care than creatures that are not, even though their size on screen may be relatively equal. Small aspect ratios, such as 1.33, narrow the field of view even when projected on big screens. Thus any object in the foreground is likely to receive a great deal of the viewer's attention.

Screen size and aspect ratio have an effect on how action shots are handled, too. Wider formats provide horizontal room for action to take place, thus the camera does not have to move as much to track the action. Narrow formats require that the camera move more to keep up with action. Given a shot, for example, that is 2 seconds long and features a creature flying from left to right, a wide aspect image will require less camera motion to keep the creature in frame, therefore, the creature's motion relative to the camera will be high. To capture the same shot for the same duration and path of action with a narrow aspect ratio format the camera will need to move more, thereby causing the creature's motion relative the camera to be less than in the wide aspect ratio image.

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 measure 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.

The key issue is recognition of two factors. First, most professionals in craft of producing imagery have more finely tuned sensitivity to moving imagery than the general audience. Plainly put, your peers are going to be tougher critics than the average person. 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.

### 10.1.4   Questions About the Camera

#### Viewer Controlled Camera

Interactive formats, such as games, provide the viewer with control over the camera position and direction. While there are often environmental limitations over where the viewer can travel, there are rarely limits on how the digital characters in the environment are seen. The viewer can choose to see the character from any angle and for any length of time.

Decisions regarding the construction of digital characters for interactive environments are determined more by the capacity of the game engine rather than the camera through which the characters will be seen.

#### Director Controlled

Director controlled formats are non-interactive. The creator of the project has determined what the viewer will see. The camera position is not in the viewer's control, nor is the length of time that creatures are seen on screen.

A creature's orientation to camera is pre-determined with director controlled projects just as a stage play is formally presented to a seated audience. If it is known that only one side of a creature model will be seen then only that portion of the model should be developed.

**Lens(horizontal field of view)**

During pre-production the lens chosen for any particular shot can often only be guessed at. Wide-angle lenses are often used to capture action. Long lenses are typically used for medium and close-up shots on characters. Lens focal length does play a role, though minor, in how a creature is seen. The standard question, concerning lenses in pre-production, is determining what lens to use for look development.

If a creature will be seen in a wide range of situations then a relatively flat lens should be used for pre-production look development tests. Flat lenses will produce less distortion between part of a model close to camera relative to parts further from camera.

However, orthographic lenses flatten the subject too much. With orthographic lenses there is no perspective due to depth from the camera. For this reason orthographic cameras should not be used to make aesthetic judgments about how the character will look in shots.

If a creature will only be seen in a single kind of situation -only in action scenes, for example, then it makes sense in terms of efficiency to perform pre-production development tests with a lens that would likely be used for those kinds of scenes.

**Stereo**

Stereo viewing, also known as '3D' is the capture of imagery with two cameras and projection as a single image. Viewing in stereo requires special glasses so that the left and right eyes see slightly different images. The effect of stereo viewing is one of increased dimension within the imagery. Objects may appear to be at screen depth, deeper than the screen, or pop off the screen.

Full color stereo viewing is a higher fidelity experience than a comparable single image viewing. The typical interocular distance (distance between the cameras) is only around 2–1/2 inches (6.35cm) for character shots, which approximates the distance between human eyes. The degree to which the creature is seen in-the-round is not significantly amplified.

Stereo viewing enhances the perception of textural detail. There is a tipping point to this effect, however. During stereo viewing your brain tries to fuse the signals from left and right eyes together to create a single comprehensible image. Low level noise in one eye but not the other will be perceptually discarded. When texture (bump and displacement) levels are too low the effect is as if the detail is seen by neither eye. When texture detail is boosted to levels at which the visual signal from each eye can be fused together by the brain as a single element then the perception of detail is typically higher than that of a comparable mono-projection image.

## 10.2   Time On Screen

Time on screen is a measure of the duration of the total amount of time that a creature is visible to the viewer. Time on screen is determined by the number of shots and the length of those shots. In practice, most questions about screen time are simply answered by determining the number of shots. The average shot length for theatrical release action films is around 3–1/2 seconds -taking dialogue shots, establishing shots, and action shots into account. Working with an assumption of anywhere between 75 to 100 frames per shot at 24 frames per second is common.

Turntables and motion studies are often setup to run at 100 to 120 frames per cycle. The upside of this practice is that he length of the turntable or motion study corresponds roughly with an average shot length therefore the viewing experience of the creature in pre-production has a rough correspondence to the viewing experience of the creature in a shot. The downside of this practice is the common tendency to loop turntables and cycles so that the last frame leads to the first frame again and the action cycles over and over. This practice is admittedly an excellent way to study the creature's form, color, or action. However, it is a faulty practice in terms of providing a clear idea of what the creature will look like in a shot. Single viewings and looped viewings are both important. The best use of the two combined is when a single viewing is employed first in a review session and followed by time to recognize the key elements of this visual first impression. After the key points of the first impression are recognized then the review can move forward into looped review if required.

## 11   Interaction and Integration

The question of "what does it do" can 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. What effect does the creature have on its environment? What effect does the environment have on the creature? What about on other creatures, or actors, or props?

These questions can be answered, at least to the degree of getting development going in the right direction, by careful dissection of artwork, storyboards, and animatics. The goal of the investigation is to understand what should be developed as part of the creature and what should be developed within the environment to work with the creature.

### 11.1   The Environment's Effect on the Creature

#### 11.1.1   Lighting Setups

What kind of light falls on the creature? Is it daytime or night, indoors or out? For many situations, particularly for hero creatures, there will be multiple lighting environments. Other creatures may only be seen in a single environment.

The range of environments must be discovered and the look development processes constructed accordingly. Performing look development turntables in a daylight, or even neutral environment, is inefficient if the creature will only be seen at night or indoors.

A neutral environment can be the best place to start, however, if the creature will be seen in a variety of lighting environments or if the production lighting remains unknown. What is a neutral lighting environment? A true neutral environment would consist of white lights and a gray (Pantone 18%) background, with no reflected light. It must be recognized that the visual result is not likely to be indicative of the look of the creature in a real lighting environment. The goal with true neutral is establishing the baseline look, and the balance of the creature's native materials and colors. From this starting point it is easier distinguish an environment's effect on the creature's final look in a shot.

Daylight environments, with warm direct light and blue-green reflected light are often used in place of true neutral. The comforting factors of sterotypical daylight environments are that they provide an impression of what the creature will look like in a semblance of a real environment. Not to be overlooked, daylight also provides a good look at the model's form, color, and motion.

Figure 10: Still frame from a motion test for mid-ground ravens in **War of the Worlds** rendered over a neutral gray background.



Figure 11: Still frame from the look development turntable of a quidditch player from **Harry Potter and the Goblet of Fire**. The rendered image of the character is effected by the background environment.

Moonlight and indoor environments are more difficult to define as truly neutral. Night shots almost always feature strong contributions from artificial light sources. The art direction or cinematography for the shots can vary the color of moon light from blue to white to sometimes even green, yellow, or red. The same is true for indoor lighting—the environment may be cool like a laboratory lit with flourescent overheads, warm like a candle-lit cabin, or something else entirely.

Storyboards typically fail to offer much insight into lighting environment other than indoors or out, daytime or night. Occasionally a storyboard will feature an implied lighting direction, but this information is minimal and most-often highly subject to change. Animatics can be excellent sources for getting the first ideas about lighting environments. Animatics are often developed to communicate mood as much as action and therefore will often be lit in a way that communicates the director's intent.



Figure 12: Still frame from the look development turntable of the digital double of Christopher Lee as Count Dooku in **Star Wars: Episode III "Revenge of the Sith"**.

### 11.1.2  Light's Effect on Creature Color

Other than when seen in a truly neutral environment, a creature's perceived color is always the combination of the creature's native color plus the environment color. Brightly colored and reflective surfaces will more heavily display the environments contribution while dark and matte surfaces do not reflect as much of the environment. When the environment lighting is either strongly in line with or strongly opposing the creature's color the perceived shift in the creature's color will be dramatic.

For example, if a dinosaur is expected to appear reddish-orange in blue moonlight its native color will need to be close to neon orange. If that same dinosaur is expected to appear reddish-orange while prowling a cave dripping with molten lava its native color will need to be white-pink.



Figure 13: Concept art for the ceratosaurus in **Jurassic Park III**.

The key to efficient development of a creature's coloration in pre-production is determining what is expected to be seen in shots. Artwork can be misleading if the artist has implied a lighting environment's effect on the creature. It is also difficult to talk about "neutral" skin color in a meaningful way because we never encounter it in the real world.

Figure 14: Still frame from rendered shot featuring the ceratosaurus. The color of the skin texture was painted neon orange to achieve the the orange-red final color under blue moonlight.
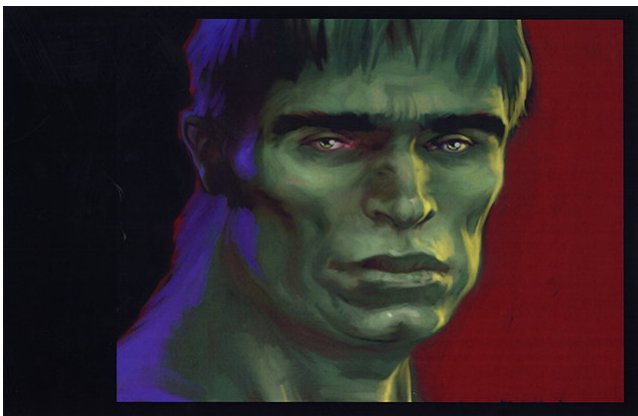


Figure 15: Concept art of the Hulk showing the effect of an implied lighting environment.

### 11.1.3  The Creature's Effect on the Environment

A creature's interactions with the environment can take many forms from simple to complicated. Shadow casting is the most basic form of a creature affecting its environment. Dust from footfalls, water splashes, and moving foliage, are more complicated. It is a mistake to classify those issues as effects related, and not specific to creature development when the scope of a creature's use is broad.

When an effect is commonplace for the creature then 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 and run time rules used to regulate the production of dust relative to height of the foot.

Creatures that are required to physically interact with objects in the environment may need to be built with special geometry that makes dynamic collisions easy to calculate. Creatures that cast light will need rigging points for the location and direction of the light. Some creatures may even be rigged with a floor or ground plane that tracks with the creature for shadow casting purposes.

There are a wide range of possibilities for how a creature can interact with its environment. For most occasions it will be sufficient to develop the effect in the context of a shot or sequence of shots

rather than in pre-production. It is wise, however, to be on the lookout for effects that are persistent across a wide range of shots and environments. These are the likely candidates for pre-production development as part of the creature.

### 11.1.4  Creature's Scale

A creature's size is relative. A viewer looking at a screen has no idea how big or small an object on the screen is except by comparing it to other objects on the screen. Certainly, a viewer will have preconceived notions of the size of familiar objects. A viewer will also try to fit new objects into the framework of what is known about objects of similar appearance.

Size comes into play for creature development when the relative size of features on a creature are visible—such as the scales on a dragon. Thus, this is not a big issue for background or even mid-ground creatures. It is an issue for hero creatures and can often become the issue that defines the visual plausibility of hero-hero creatures.

Imagine a human that is twice the size of a normal human. Are the hairs on its head twice the diameter of normal? What about the size of the veins visible in the sclera of the eye? Now, imagine the opposite scenario and picture an elephant reduced to the size of a house cat. It seems obvious that when a known object is made smaller everything about it must become smaller too, but going the other way is more tricky. When an object is supposed to be perceived as very large the effect is more pronounced when it not only appears large relative to its environment but also appears large relative to things within it that have a recognized size.

The question of size in pre-production can not be fully answered by knowing only the overall size of the creature. If the creature is either significantly smaller or larger than objects with which it will be compared then more detailed information is needed regarding the scale of the elements within the creature.

## 11.2  Interaction with Other Characters

### 11.2.1  Live Actors

Interaction 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 composed of the same materials, and have generally the same level of complexity in visual makeup and action. This problem is affected by the design style of the creature. A primitive creature will only integrate well with a live action actor if the visual style of the project facilitates out-of-place pairings. Abstract and naturalistic creatures have better luck integrating with live actors with, perhaps, abstracted creatures faring better because of the latitude they provide for believability.

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.

The most difficult shots are close-ups in which a live actor and the digital creature are in the same plane relative to the camera and affected by the same lighting environment. This situation provides the viewer with a framed point of comparison. When seen alone a digital creature only has to be plausible according to the viewer's

mental concept of whatever it is supposed to be. When seen together with a live actor the creature has to be plausible relative to everything that the actor is plus what's in the viewer's mind.

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. Perhaps the most common pre-production question after "how hero?" is if the creature is seen next to a live version of itself or something similar. If the creature is a digital double of a live actor or animal the question will be, "do we cut from the real one to this one?" The context in which the creature will be seen has an enormous impact on the work required to make it believable.

### 11.2.2 Computer Generated Characters

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. It is advisable to use the same standards for development for two digital creatures that will be occupying similar screen space in the same shot. For example, if one creature is built to hero standards for a large number of shots and thus includes flesh and muscle dynamics it will be recognized as visually apart from a similar creature that was not developed with muscle and flesh if both are seen together. This effect is particularly apparent when key-framed and motion capture animation are used in the same shot on different creatures, and when shading techniques such as subsurface scattering are used on one creature but not on another.

## 12 Conclusion

The craft of digital creature development combines both the art of image creation and the science of computer graphics.The ability to frame technology's use within the requirements of the imagery distinguishes efficient creature development work from work that is overbuilt, or worse, fails to impress the audience. This course emphasizes that the pre-production process can be geared to effectively suit the production performance needs when the right questions are resolved through the dissection of artwork, storyboard, and animatics.

With reference material in hand the future audience's ability to scrutinize the creature can be understood. Knowing the creature's relationship to the camera and how long the creature will be in front of the camera drive the decisions about how to build, animate, and texture the creature. These questions about camera and screen time are independent of technology changes. Whenever director-driven media is created the camera and the screen dictate the scope of visual effects work, including creature development.

It is hoped that, rather than describing a specific technique, this course offers a philosophy of investigation and problem solving. The specific terms and categories offered within the course are not implied to be canon, or in some cases even widespread. They represent an attempt to describe, label, and categorize processes and ideas that are common within the creature development community, but are rarely structured together as elements of the same practice.

It is hoped that this course, and its predecessor from SIGGRAPH 2005, will encourage other practicioners in the field of creature development to present their own ideas. For students and artists new to the craft it is hoped that this course will encourage problem solving that is not determined by the tools at hand, but rather by the visual goals in mind.

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Figure 12. Look development test of digital double for Christopher Lee. **Star Wars: Episode III Revenge of the Sith**. 2005. Lucasfilm Ltd. & TM. All rights reserved.

Figure 13. Concept art of ceratosaurus. Artist: Erich Rigling. **Jurassic Park III**. 2001. Universal Studios. All rights reserved.

Figure 14. Still from final shot featuring ceratosaurus. Jurassic Park III. Universal Studios. All rights reserved.

Figure 15. Concept art of Hulk. **Hulk**. 2003. Universal Studios. All rights reserved.

## 14 Notes About the Author

Tim McLaughlin's work at Industrial Light & Magic has been focused on constructing photo-real organic creatures for feature films since he joined the company in 1994.

His education background includes both a Master of Science in Visualization Sciences and a Bachelor of Environment Design degree from Texas A&M University. He also holds an Associate of Arts degree from Kilgore College. Tim is a Visiting Professor at Bournemouth University's Media School, Poole, England, and serves on the Dean's External Advisory Board for the Texas A&M University's College of Architecture.

Tim is a member of the Visual Effects Society and ACM Siggraph.

## 15    Acknowledgments