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Optimal Proportions for the Facial Features of Cats

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Abstract

This research measures the optimal proportions for the facial features of five members of the cat family: lions, tigers, leopards, cheetahs, and domestic cats. Focusing on the eyes, nose, and mouth of each animal, the optimal proportions were examined to determine the optimal space between both eyes and the vertical and horizontal distances. First, actual images of cats (viz., lions, tigers, leopards, cheetahs, and domestic cats) were obtained from a Google Image search, with which the eyes, nose, and mouth of the cats were measured. Next, the optimal proportions were derived for the horizontal and vertical distances in each of the five mammals.

Keywords*: Cats, facial features, optimal proportions*

1. Introduction

In 2014, the global market for digital content increased by 4.8% over the previous year to $1.993 trillion. The animation industry witnessed significant growth, with a 14.4% increase over the previous year. In the future, animation is expected to lead the market, with over 5% annual growth [9]. In particular, the expansion of digital media has caused the amount of digital content to surpass that of printed media. An example of this is illustrated by the fact that, in 2012, Google's advertising sales surpassed the advertising sales from all printed media [12].

As digital media grows, the public demands more realism in the content that is developed [11]. This is clear in the movie industry, and it is related to the so-called uncanny valley phenomenon. The uncanny valley phenomenon first appeared in the field of robotics, but later research has been actively pursued in the movie industry. This is because realism is directly connected to how the audience sympathizes with a character and whether a film is a box-office success. This applies not only to the movie industry, but also to all digital content, since natural emotional expressions have now become an important factor when designing digital characters. Particular attention must be paid to character design in the animation industry, which is character centered. The repeated failure of Dreamworks' animal-based animations in 2014 has increased interest in realism when developing animal characters[10].

Facial proportions are important for understanding characters. A well-balanced face garners more sympathy from the audience than a disproportionate one [5,13]. Because of this, research on the balance of the face—or, more specifically, on optimal facial proportions—is being conducted in a variety of fields such as art, medicine, and film. With the transition to digital media, a variety of research is being performed on optimal facial proportions for digital production environments. In particular, there is already a great deal of research on facial standardization and facial proportions. Moreover, there is an expanding effort to apply existing research on optimal proportions to upcoming movies [1]. Although standardization research is widely available regarding the design of human characters, almost no research is devoted to realism in animal characters.

In this paper, we examine the unique optimal proportions required to realize animal

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characters. In order to develop realistic animal characters, our research has the following aims:

- To define the measurements for each of the elements pertinent to expressing emotion, focusing on the eyes, nose, and mouth, by using pictures of actual mammals (viz., lions, tigers, leopards, cheetahs, and domestic cats) collected from existing research.
- To analyze the distances for each of the animals' defined measurements.
- To derive optimal ratios for the distances between facial features and the constants particular to each member of the cat family, such that the data is useful for producing digital content.

In this research, we examine the average ratios in animal faces from the cat family, and we define the optimal proportions of each animal from constants unique to each type. The aim of this research is to produce a standard model that can be manipulated to suit the needs of designers. Ultimately, the research can be used for more natural modeling when developing characters.

2. Research Trends Regarding the Facial Shape of Characters

2.1. Digital Production and Optimal Proportion Research

Research into the optimal proportions for the human body has been growing since the Renaissance, which witnessed a surge of interest in the dimensions of the human body. Subsequent research has been conducted in anatomy, medicine, and physical anthropology. As digital technology develops, research on the human face is more actively pursued. In particular, research on face standardization is continually increasing, as this is often addressed in the field of graphic design, which includes facial recognition and 3D modeling.

As mentioned above, research into optimal proportions is receiving attention and being actively pursued, owing to the rapid increase in digital content. Early research focused on how to determine the optimal proportions, whereas recent research has focused on how to use the optimal human proportions for producing digital content [3]. In particular, computer-generated imagery is the best example of this kind of academic research having commercial applications.

For a while now, advancements in graphics technology has allowed movies and animations to introduce characters that appear exceedingly realistic. In the movie industry in particular, the role of artificial characters grows more important every day. Performances or scenes that cannot be performed by actors are created with computer graphics. In the case of digital human characters, a great deal of research has been devoted to standardizing the human face. Much research has also been done in a variety of fields regarding the way emotions are expressed with face. Advances in graphics technology, motion-capture techniques, *etc.*, have attained a level of emotional expression that is close to reality [14,2,6].

Unlike human characters, however, animal characters have not been developed based on an examination of an actual animal's face. Rather, they are based on partial animal features combined with human facial features. Research on animal faces is important because animation tends to exaggerate and distort the facial expressions of actual animals [8]. However, whereas there is a great deal of research on the aesthetic structure of the human face, research is lacking regarding the structure of animal faces [7]. Furthermore, because animals are difficult to control, it is challenging to use the same motion-capture techniques that are used on humans. Indeed, a great deal of technology and money must be invested in order to create animal characters that look natural, and basic research on generating digital animals is needed.

2.2. Animal Characters and Research on Facial Feature Measurement Points

Research on animal characters is mainly focused on anthropomorphism and symbolism [17-18]. Among the practical research on animal characters, studies of anthropomorphism have mainly focused on the emotional expressions of animal characters. Lee Yong-sook, a leading researcher on this topic, defined the steps toward anthropomorphism in animal characters [20-21]. However, in such research the character is influenced by social and commercial recognition, and in this way differs from research on characters with a realistic appearance.

Because our research is aimed at the facial features of animal characters, we have defined animal facial forms for a morphing system based on recent animal taxonomy. To create facial standards for anthropomorphized animal characters, we compared and analyzed the facial features of several animals and established their facial structures in order to naturally morph the animal's face with a human face [16].

Animal taxonomy is based on Linnean taxonomic groups, and this categorization system continues even to this day. One of these groups, mammals, is characterized morphologically by four fur-covered body sections (viz., the head, neck, trunk, and tail) [4]. The first species of the cats appeared 40 million years ago during the Eocene epoch. Sometime between 5,000 B.C.E. and 2,000 B.C.E., both feral and tame domestic cats appeared in Africa and western Asia. Members of the cat family include lions, tigers, leopards, jaguars, cheetahs, lynx and pumas [15].

The public is more familiar with cats than other animals. An analysis of 48 long-form animations released in America between 1945 and 2009 featuring animals shows that cats accounted for 69 out of 456 characters, with as much as 15.13% of the 62 types of animals appearing in animations. In addition to the films in that study, animations and character-centered products featuring cats continue to be released. However, despite the high demand for these characters, research on their design remains insufficient.

Table 1. Animal Characters in 48 Long-form Animations Released in America between 1945 and 2009

No	Type	Characters	Products	Lead	Supporting	Minor	Percent
1	Dog	64	23	8	34	22	14.04 %
2	Mouse	45	20	6	21	18	9.87%
3	Cat	41	18	9	16	16	8.99%
4	Lion	14	6	3	6	5	3.07%
.	.	.	.	.	.	.	.
15	Tiger	9	6	1	7	1	1.97%
.	.	.	.	.	.	.	.
18	Leopard	4	4	1	2	1	0.88%
.	.	.	.	.	.	.	.
62	Cheetah	1	1			1	0.22%
Total		456		61	189	205	100%

After describing the optimal proportions of a lion's face [19], this research examines images of actual cats (viz., lions, tigers, leopards, cheetahs, and domestic cats) and presents a standard for their facial proportions. In doing so, we intend to derive the

standard facial proportions for five members of the cat family popular to audiences.

We present the optimal proportions for an animal's faces in order to facilitate the development of realistic animal characters. This study is an important preliminary to research on developing animal characters for use in digital content.

3. Optimal Proportions for the Facial Features of Cats

3.1. Measurements and Targets

In this research, the optimal proportions were measured for the facial features of five types of cats (viz., lions, tigers, leopards, cheetahs, and domestic cats) that appear in animations. Mammals such as lions, cats, elephants, and rabbits have typical forms and ratios that are different from those of humans. As such, in this research, each type of mammal is assumed to have its own characteristic proportions between facial features. Moreover, the optimal facial features for five members of the cat family were measured. Because it is difficult to obtain animal data from actual cats, a Google Image search was used to gather the data. Image data was generated using keywords for each of the five cats. To collect images of lions, the keywords "lion face" were used (searched on 2015.7.30) and a total of 6,203 images were found (excluding duplicate images).

Figure 1. Lion Image Data from Google Image Search and Selected Lion Images

>From these results, we selected 88 front-facing images that met with our standards. These images were selected because they were frontal images with no facial expression and an angle between the eyes of less than 10°.

The images selected for each of the five types of cats are tabulated below. We used 2,639 tiger images, 2,216 leopard images, 2,016 cheetah images, and 2,639 domestic cat images [Table 2].

Table 2. Sample Image Data by Type from Google Image Search [22]

Type	Keyword	Sample Images
Lion	Lion face	*6,203*
Tiger	Tiger face	*2,639*
Leopard	Leopard face	*2,216*
Cheetah	Cheetah face	*2,016*
Domestic cat	Cat face	*2,639*

First, the standard points are listed below. The pupils in both eyes were set as points A and B. Point C is in the center between both eyes. Point D is at the top of the nose. Point E is where the nose meets the philtrum. Point F is the center of the mouth. All of the

collected images were aligned to the center point between both pupils using Adobe Photoshop. In this research, each feature was measured as the distance between a straight horizontal or vertical line. The images' height and width were set at 8 × 9 cm, with a resolution of 72 pixels per inch.

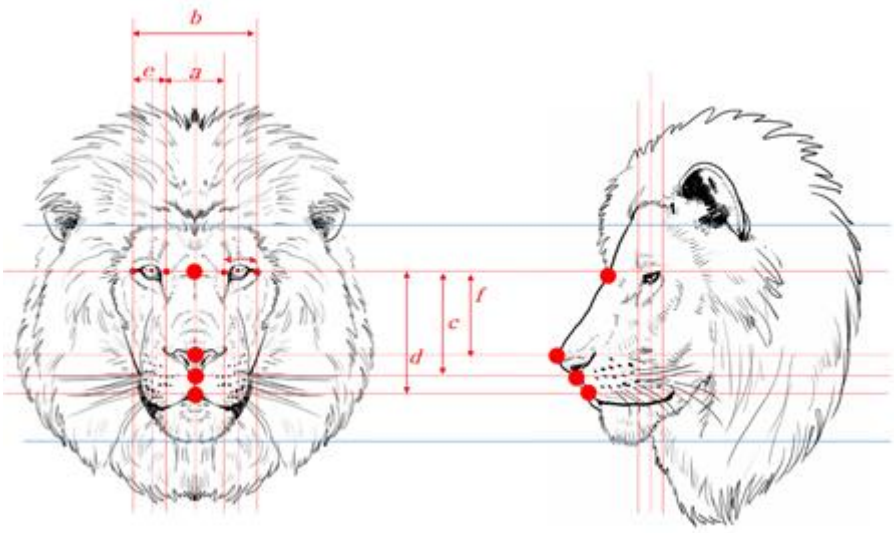

Figure 2. Measurement Values

- Width of one eye: d_e
- Distance between outside edges of both eyes: d_b
- Distance between inside edges of both eyes: d_a
- Distance from middle of forehead to top of nose: d_f
- Distance from midpoint between both eyes to philtrum: d_c
- Distance from midpoint between both eyes to middle of mouth: d_d

3.2. Measurement Outputs

Near-frontal data was extracted from the five types of cats that appear in animations (viz., lions, domestic cats, tigers, leopards, and cheetahs) and optimal facial proportions were calculated using the following standard.

From the sample images of lion faces, we measured the width of an eye (d_e), the distance between both eyes (d_b), the distance from the center of the forehead to the top of the nose (d_f), and the distance from the center point between both eyes to the center of the mouth (d_d).

Table 3 lists the data extracted from the lion images. These measurements were then used to generate average values for the data.

Table 3. Lion Data Measurement Output Value Sample

List	d_e	d_b	d_f	d_d
lion01	1.5	6	4.2	6
lion02	1.5	5.7	4	6
lion03	1.5	6	4	6
lion04	1.5	6.2	4.5	5.9
.	.	.	.	.
lion63	1.5	5.8	3.9	6
lion64	1.5	6	4.5	6
lion65	1.5	6	3.5	5.6
Average	1.456923	5.816923	4.130769	5.964615

Our research proposes the following equations for deriving the optimal facial proportions of cats. Eqs. (1), (2), and (3) yield values for *K*, *R1*, and *R21*, respectively. In this research, *K* is a constant unique to each type of cat, based on the ratio of the distance between both eyes. Likewise, *R1* denotes the ratio of d_b to d_f, and *R2* denotes the ratio of d_b to d_d. From these values, each animal's optimal facial proportions can be derived.

K: animal constant

R1: ratio of distance between both eyes and distance to nose

R2: ratio of distance between both eyes and distance to mouth

$$K = d_b / d_e \tag{1}$$

$$R1 = \frac{1}{T}\sum_{i=0}^{T-1} d_a / d_f \tag{2}$$

$$R2 = \frac{1}{T}\sum_{i=0}^{T-1} d_a / d_d \tag{3}$$

Next, Eqs. (1), (2), and (3) were used to calculate the optimal proportions for the five types of cats using the optimal proportion values, *K*, *R1*, and *R2*. These values are constants unique to each animal. At this time, T is the sample number of animal species used to compute an optimal ratio, 'K', 'R1', 'R2' is a unique constant for each animal. The resulting values were indeed similar, and this was expected given that all five animals are carnivorous mammals belonging to the cat family. Nevertheless, the lion resulted in the highest ratio, whereas the domestic cat resulted in the lowest.

Table 4. Optimal Proportions between Facial Features for 5 Types of Cats

Type	*R1*	*R2*	*K*
Lion	1.4	1	4
Tiger	0.7	1	4
Leopard	0.6	0.9	3.7
Cheetah	0.5	0.8	3.9
Domestic cat	0.4	0.6	3.2

4. Conclusion

This research measured the optimal proportions between the facial features of cats. The ratio of the distance between facial features was measured for five types of cats that often appear in animations (viz., lions, domestic cats, tigers, leopards, and cheetahs). The data was gathered from frontal images of cats using Google Images. The eyes, nose, and mouth of each animal were analyzed, and optimal proportions were derived based on the ratio of the distance between the eyes, and horizontal and vertical distances. We derived constants that are unique to each animal, despite the fact that they are all members of the cat family. In future research, this method will be applied to other animals, including mammals, reptiles, and birds, in order to derive optimal facial data.

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