# Digital Modeling of Buddha Sculptures

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**Abstract**

The Sukhothai Buddha (1238-1438 CE) a distinct sculptural style developed which is still characteristic of Thai Sculpture Style today. The Sukhothai style inherited some artistic elements from its precursors, yet evolved through a remarkable process of refinement and invention. This study considers the visualization of this evolution. Conventionally, styles are analyzed and compared through written descriptions with reference to still images. It is difficult, however, to visually appreciate the evolution of style by such means. A new technique is adapted from digital character animation to assist in the visualization of style differences and to illustrate style evolution. By modeling sculptures of different styles as variations on a common shape, blend animation allows one style to change smoothly into another by interpolation. The viewer can now better appreciate style differences, not by shifting gaze from one to another, but by watching one *become* another, wherein their differences attract visual attention.

***Key Words*:** Blend Animation; Morphing; Southeast Asian; Style; Sukhothai Buddha; Visualization

**Introduction**

Sculptural style can often be attributed to the physical objects we create. The specific style may reflect artistic choices by the individual artists or artisans who created it, as well as conventions common to their culture. Experts may focus on stylistic subtleties to date and identify the origins of archeological artifacts, when the underlying stylistic trends are well understood and documented. Style is a fundamentally important language of expression that is shared by the makers of the artifacts and their users. Across a very broad range of scholarly fields spanning archeology and art history to modern design, there are recurring methods for describing specific styles and for comparing styles. Most commonly, scholars will document and differentiate stylistic variations by employing two complementary techniques: textual descriptions and illustrations. It is conventional to select a representative example, or exemplar, and to subject it to a rigorous analysis wherein the stylistic features are described one-by-one, often using specialized terminology specific to the given field. Such a written analysis is usually accompanied with photographs or illustrations, as the words alone seldom suffice. When describing multiple styles, a common stylistic lexicon may be used to summarize their differences and commonalities, which is then graphically represented by a tabulation of these stylistic features. Again, illustrations of the various exemplars are usually provided, sometimes simplified representations to focus attention to the style elements under consideration.

To compare two styles, therefore, it is commonplace to describe examples of each, to present illustrations of each (often side-by-side), and optionally, to explicitly describe their differences, drawing the reader's attention to salient features or common style elements across the representative examples. Such a practice relies on the author's ability to capture style in words as well as the reader's ability to understand the text and more tacitly, to appreciate the stylistic features as depicted in the given illustrations. Both tasks may require much of the reader. When considering complex objects the style differences may be difficult to capture in words for the features may be locally similar across the two objects but

together create a very different stylistic expression. Also, two objects may be stylistically quite similar but the artifacts themselves may be so different in quality of preservation, size, material, and the images depict the two under very different conditions of lighting and viewpoint that it is difficult to attend to matters of style and to disregard these irrelevant aspects. Style is often difficult to abstract and to visualize, and this challenge arises in both formal and scholarly as well as informal and everyday considerations of style across a broad range of fields.

**Models Permit Abstracting Style**

When viewing an actual artifact, the observer is presented with not only an example of a given style of object, but also the specifics of that given object, including its idiosyncrasies, individual character, and many other visual aspects that distract from the appreciation of the style itself. When the artifact is of historical significance, and rare or perhaps unique, it is uncertain which aspects of the given object reflect an underlying style (which would have been shared by other examples, if available) and which are specific to that particular artifact. In such cases the underlying style of the specific object is hard to distinguish from what might be expressions and variations specific to it alone. But when multiple examples are available of a given style, there is an opportunity to abstract the style from the specifics of the individuals. A model can be created which represents the commonality across the individuals, without replicating any specific artifact. A two dimensional model might consist of an informal line drawing or sketch that is said to be 'based on' multiple examples. In three dimensions, a sculpted model might represent an idealization of a given style that is based on a distillate of multiple artifacts, or a so-called "artist's conception" sculpture. In the modeling process, the style may be enhanced and clarified subtly, as well as abstracted from the imperfections of the original. Modeling is thus important in removing the visual distraction of idiosyncrasies and imperfections when focusing on an underlying style. Often an archeological artifact is incomplete or damaged, but can be used as the basis for a restoration of the ideal, original, form (or at least an artistic interpretation thereof). Even if the original artifact is complete and undamaged, a model

has the potential to draw one's awareness away from the details of the surface condition and composition, and to focus more on the underlying style and artistic expression. When considering the style differences between two artifacts, it is often difficult to attend to their styles when only still photographs are available, especially when the objects of differing composition, physical condition, size, and photographed from different perspectives and under differing lighting conditions. By viewing models photographed or rendered under conditions of identical illumination, material appearance, and perspective, one may better attend to their style as one shifts attention alternately between the two models.

While a model may accurately capture the essence of the geometric shape associated with a given style, those style features remain implicit in the model and require an explicit description. Hence it is conventional to provide a guided written analysis, often feature-by-feature, to draw the reader's attention to the various aspects of a given style. To compare styles, it is commonplace to use comparative descriptors such as "feature X is more sharply delineated in style A than its counterpart in style B", where it is left to the reader to attend to this aspect in A versus B. There is variability, of course, in how well readers can appreciate style differences from such A-versus-B comparisons, and limits to the effectiveness of a written phrase such as "more sharply delineated" in capturing the stylistic difference.

Style comparison is distinct from shape comparison. Formal mathematical means have been developed for the comparison of shapes, and they only indirectly apply to the comparison of styles. For instance, two shapes may be shown to be related by a transformation, wherein distortion of an underlying grid or mesh can help visualize how one shape would transform into another (Thompson, 1917). That is, the distortions to the grid represent not the shape, but the changes in shape between two related forms. Mathematical methods have been developed to quantitatively measure differences between two shapes (Siegel and Benson, 1982), and to represent the differences graphically as a field of vectors showing how corresponding points are displaced from one shape to another. This concept underlies the familiar technique by which two-dimensional images can be

'morphed' by continuous interpolation of the pixel values in one to another while displacing them according to a continuous map that represents the deformation from one shape to another (Beier and Neely, 1992). While two- and three-dimensional morphing does not by itself capture and quantify differences in style, it provides the foundation for a new method that does significantly improve one's ability to appreciate style differences.

**Shape blending attracts attention to differences**

A fundamental problem in comparing the styles of two objects A and B (two vases, for example) is that visual attention must shift one's gaze and visual attention alternately between A and B. To appreciate how a specific feature differs on A versus B requires several sequential steps: 1) a given stylistic feature is located in A and some visual memory is retained regarding its appearance, 2) visual attention is then shifted to B and the corresponding feature is located, 3) the style observed in B is compared with the memory of its appearance in A. Usually the process is repeated with attention shifting from B back to A. If instead of considering two discrete objects A and B, suppose on object could change its shape ('morph') from A to B, through a continuous transformation. Then stylistic differences can be appreciated without the need to shift gaze and visual attention, alternately seeking its counterpart in B after examining A, or vice versa. More importantly, as A changes to B, features of the shape that are similar remain between A and B remain relatively constant, of course, while places that differ will be seen to undergo change. This is of considerable value, for an observer's visual attention is naturally attracted by visual change. Consequently, by having an object's shape change from one style to another, the observer's attention is naturally directed to those aspects where the two styles differ. Those stylistic features in common are relatively static and easily ignored. The dynamic transformation of shape between the two styles thus provides a 'self-guided tour', reducing the need for an explicit feature-by-feature discussion of the style differences. Of course, a formal analysis would typically accompany such a demonstration in a scholarly description. Recent advances in digital animation permit the blending between complex 3D models. This requires a modeling process for each style is to be considered, but once created,

continuous animation that blends between these models permits a dynamic appreciation of their style differences.

The technique described below in the context of visualizing differing styles of facial features across Buddha statues from different cultures. In addition to facilitating the appreciation of style differences, digital animations that show a *progression* of style transformations (from A to B to C …) will permits a visual appreciation of the evolution of style. Observing an hypothesized evolutionary transformation between styles provides insight beyond what may be appreciated from a written discourse. The animated progression does not prove the hypothesis; it permits one to envision it. Moreover, many artifacts carry with them an aesthetic that is especially difficult to put into words, but may be appreciated visually. Blending between models of artifacts that differ aesthetically may enhance those differences. In fact, both style differences and the less tangible impressions of aesthetic differences are enhanced by viewing their transformation in a continuous animation, a 'successive contrast' effect familiar to perceptual and cognitive psychology. Dynamic presentations such as these reveal more than can be easily achieved by a combination of static illustrations and text. This technique enhances, but does not replace, the conventional approach of text plus supplemental images that accompany the written analysis.

**A Case Study**

This study summarizes a novel approach towards the visualization of style that was introduced by Wisetchat (2011) wherein computer graphics was used to assist in understanding the evolution of the Buddha statue that emerged in Sukhothai, Thailand. During the Sukhothai period an artistic style developed which is iconic of much of modern Thai artistic style. Buddha statues of the Sukhothai style are especially distinctive in those examples where the face is lean and elongated and delineated by delicate and graceful, even effeminate, curves (Van Beek and Tettoni, 1991), such as the Sukhothai sculptures from the Kamphaengpet school (Figure 1).

The Sukhothai style emerged during a time when the geographic region that is now Thailand was divided into many kingdoms, with small ones under the control of larger empires. The Buddhist statues are

**Figure 1** A Sukhothai Buddha sculpture of the Kamphaengpet Style. 14th-15th century, National Museum, Bangkok.

important indicators of these cultures and their interactions. While trade and the spread of Buddhism resulted in the widespread adoption of common artistic elements, each region developed its own distinct style (Leidy, 2008; Rowland, 1963). The Sukhothai style could be regarded as a refinement and idealization of form, which emphasized graceful contours, a face that was androgynous and abstract, with highly sculpted facial features and an expression of peace and serenity.

The origins of this style are not well understood, but clearly some stylistic aspects were derived from precursor styles that were introduced from Sri Lanka and Pagan (modern Burma), while many other features of

the face, hair, and ornamentation have their origins in the Indian depictions of the Buddha from Pala and earlier (Rowland, 1963; Fisher, 1993; Krishan, 1996). Disregarding those features of the sculptures that constitute a common iconography broadly shared by Buddha statues across many cultures and periods (Brown, 1996; Fisher, 1993), some aspects appear to be unique inventions of the Sukhothai kingdom or in collaboration with the neighboring Lan Na Kingdom (Gosling, 2004; Woodward, 1997; Van Beek and Tettoni, 1991).

Wisetchat (2011) used digital animation to visualize the evolution of the Sukhothai Buddha style. While its stylistic origins are complicated, representative examples of three precursor styles (that of Pala, Sri Lanka and Pagan) were considered, plus the Khmer-influenced Dvaravati style, in addition to modeling the Sukhothai style. Digital 3D models of these five styles were created using a technique that allowed continuous shape interpolation between any two such models.

**Blend Shapes and Animation**

The digital technique of 'blend animation' has been widely adopted for use in character animation (Deng and Noh, 2008). The method is particularly useful when combined with smooth 'subdivision surface' modeling (Catmull and Clark, 1978), which produces a smooth surface from a relatively simple 'cage' of vertices. An initial (or 'base') shape is constructed that will be used as the basis for variations on that shape. Multiple copies of that base cage are constructed that will be made to resemble the other shapes. Each variation becomes a 'target', i.e., another shape that the base shape can be deformed into without adding or removing detail, but just moving and reshaping the details that are originally present in the base shape. The target shapes can be made to appear different from the base shape only by having their vertices shifted or displacing in 3D space relative to counterparts in the original base shape. A 'blend shape' can then interpolate between the base and target shapes to form a continuous and smooth transition from one to the other.

There are technical and artistic challenges to using this method. The first is that shapes can be modified only by the displacement of vertices; the

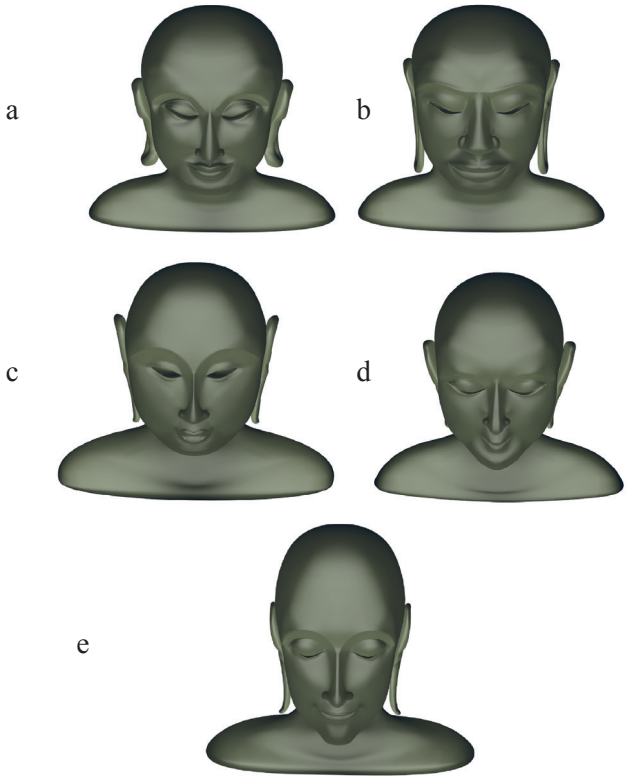


**Figure 2** One common polygonal model serves as a common cage for representing five distinct styles of Buddha statue. a: Pala, b: Dvaravati, c: Sri Lanka, d: Pagan, and e: Sukhothai. Since these models are sculpted from a common base shape by adjusting vertex locations, interpolation between the vertex locations between models can be used to create the impression of one statue 'morphing' or smoothly blending from one to another.

topology of the mesh cannot be modified. Thus entirely new features cannot be created (such as a hole in an earlobe that is present in one style but not another). A sharp crease in one cage, can be softened in another, but great care is required if the crease is intended to completely disappear. The artistic challenge is to create enough vertices to allow any of the desired features to be sculpted, but the more vertices that are added to the base cage, the harder

it is to manipulate them. A compromise is needed between complexity and simplicity. Also, shapes can only vary continuously based on what is there in the base shape, so features such as finials cannot be expected to come out of the topknot of a statue that does not have a finial in the base shape. Also, two models that differ between coarse coils of hair and fine coils of hair would be extremely difficult, even in concept, to blend between. Groups of fine coils would have to merge together to form a fewer number of larger ones, but the intermediate shapes would be very unnatural and meaningless. So blend animations are only attempted to show facial features that smoothly vary from one shape to another. Sometimes a sharp contour is sculpted such as the ridge of an eyebrow, or the double outline of a lip. Such a step-like edge which involves usually three parallel rows of vertices to force the surface to appear to crease between the outer two rows, with a steepness or sharpness determined by the middle row. To make the crease disappear, it is necessary to carefully separate the crease lines of vertices and to make them all lie in a common smooth surface. The use of subdivision surfaces makes this even more difficult, because when they are rendered, the surface will often still show a hint of that crease, especially for shiny surfaces.

Two software tools were used: Autodesk Maya (Autodesk, 2011) and Pixologic ZBrush (Pixologic, 2011). After experimentation with different approaches, the following work flow was chosen. Maya was first used to create a moderately-detailed basic model, then ZBrush was used to refine that model, and finally Maya was used to render the blending animations on these refined models. Maya allows precise control over the shape of the subdivision surface by adjusting the position of each individual vertex in a cage, but that approach would be impractical to create different target shapes if each cage has a large number of vertices. The approach used here is to model one side of the face using a simple polygon cage, then to mirror it, combining it into one face, then convert it to a subdivision surface, then convert it back to a higher polygon representation that can be imported into ZBrush to have the shape refined. With care the high polygon representation can then be re-imported into Maya and used as a complex blend shape for animation.

**Modeling from Reference Material**

The modeling of a given target shape is based on reference material. This reference can be photographs of museum artifacts that are placed in the 3D scene as 'image planes'. The 3D model is then sculpted to resemble the reference object from that photographed viewpoint. The use of image planes is only approximate, however, and many photographs would be needed to be sure the object has been modeled well from all viewpoints.

A more sophisticated approach would be to import 3D data of the object into the scene (such as from a laser or CT scan of the museum artifact). The sculpting of a model's cage could then be adjusted to closely match the shape of the digitized artifact, from all perspectives, and not just those available by the image plane photographs. Direct digitization of an artifact by scanning, unfortunately is often impractical or disallowed. Photogrammetry, the relatively new method of reconstructing a reference 3D shape from multiple photographs (e.g., Kraus, 2007) may be a useful alternative to digitization, assuming that photography of the artifact is permitted. Regardless how the 3D data is acquired, it is preferable to refine the blend shapes in 3D with reference to such 3D data, as opposed to photographs that are imported into the 3D scene.

The goal of this process is to create a set of blend shapes that can be deformed from one into another; this is ultimately a task of sculpting and modeling, not of precise replicating. The polygonal cage of the blend shape is adjusted until the surface that it creates fits the 3D data of the object that is being modeled. It would be representative of either a specific artifact, or be generic across a number of examples. The result is therefore best thought of as an illustration and not a precise replica.

**Discussion**

Blend shapes can effectively demonstrate style differences and evolution, but the modeling process is open-ended. It is impractical to create too close a replica, and like technical illustration in 2D, there is an art to efficiently conveying the essence. Unlike 2D illustration, this technique adds not only a third dimension (depth) but a fourth (time) to show

differences and evolution of style. Thus it is possible to go beyond using words and tables, to actually *see* the Sukhothai style as it differs from these other styles. Conventionally, photographs or diagrams are presented to illustrate different styles, where the viewer attempts to abstract away the essence of the style by comparing these alternatives. That is a very difficult task, especially when the statues differ in composition and condition, and the photographs show them from different viewpoints and lighting conditions, and so forth. It is important to remember that much is lost when viewing a simplified model compared to the original, but something new and valuable is also gained when that model can transform dynamically from one style into another. Without the distractions that come with viewing real artifacts, the abstract model captures the essence of the style itself. Changes in the model as it blends captures differences in styles. One can then return to observe the original artifacts with new appreciation.

With this method, a viewer can now appreciate style differences between two objects A and B, not by shifting gaze between A to B but by watching A *become* B. During the shape blends, the differences between the two styles will draw one's attention. For instance, if the nose changes from realistically rounded to highly sculpted and contoured, that will instantly reveal an aspect in which the two styles differ significantly. Equally importantly, shared aspects of the two styles will remain essentially unchanged and unnoticed. *Blend animation reveals differences by change, and similarity by constancy.*

Having one style blend into another also allows the viewer to appreciate subtle overall differences, such as the feeling that is evoked by a style. For instance, by blending from a very masculine and physically powerful face of the Pala style to the Sukhothai style, the Buddha is seen to transform into a delicate and more abstract form that has lost some of its individuality to be replaced with calm serenity and ideal form. The visual and emotional impact of the change is more apparent, it seems, when this comparison is watched as a blend animation than when it is only simply presented with adjacent examples of the two. So blend animation between styles can be used not only to compare style features, but to also feel the

emotional impact as the sculpture changes its character in front of your eyes. This might in turn provide insight into the ideals and motivations of the artists and their cultures.

Regarding future work, a practical next step would be to refine the method so that it is more efficient. The software tools used in this study, subdivision surface modeling and blend shape animation, are widely used for character and facial expression animation. This study blended not just expressions, however, but the basic structure of the face, e.g., adding sharp sculptural creases in some cases which are smoothly rounded in others. While the techniques did prove feasible for this study, the process was not efficient, because considerable experimentation with alternative polygonal base cages was needed to finally create one that would be adequate for representing all the various target shapes in the study. If the base blend shape was especially well suited for one target shape it was often less well suited for another style. After much revision, a low-polygon cage was eventually created that could approximate the various target styles, but then the end result for each target style was a compromise. Future work would involve alternatives where the base cage has a higher polygon count and is more capable of representing a large range of target shapes, and the higher polygon version is not simply used for final refinement of the various models. To illustrate, consider the two very different styles of eyebrows in Figure 3. In the Ming dynasty example the eyebrow is represented by only a sharp crease, while in the Sukhothai example the eyebrow is marked by a similarly sharp slope on the lower edge of the eyebrow down towards the upper eyelid, but there is additionally a raised ridge above the arc of the eyebrows that delineated from the forehead by a sharp crease. Note that in the former the brow is smoothly continuous across the bridge of the nose, while in the latter the two arcs meet at the center with a sharp v-like cusp. These two geometries can be represented by a well-crafted low-polygon count cage of polygons, but with some difficulty. The alternative which is becoming increasingly feasible is to use a very fine underlying polygonal cage such that the underlying mesh can be more readily sculpted to match either style of eyebrow. Likewise, one can note that the eyes have not only

**Figure 3** Upper image: Ming dynasty (1368-1644) Buddha sculpture, ca. 1500, Shanxi Province, Metropolitan Museum of Art, New York. Lower image: Sukhothai Buddha sculpture 14th Century, Ramkhamhaeng National Museum Sukhothai, Thailand.

differing morphology, but differing details, with the Chinese eye design showing details that are missing in the Thai sculpture. Making a fine line-like feature appear to disappear in one blend target and yet be crisply defined in another requires considerable skill on the part of the modeler.

A future extension is envisioned in which this technique is applied for public exhibitions, such as museums or educational websites. Buddha sculptural style, the subject of this study, is a particularly good test for this technique as it involves the sculpting of faces, which convey much meaning and aesthetic appeal, and being statues, they show abstractions and idealizations of form. The end result, if done well, allows the viewer to appreciate the subject matter in a virtual representation that is abstracted away from the details of the actual artifacts. This technique can be applied either in a museum setting, where the viewer can then turn to the actual artifacts and appreciate them with hopefully some added insight. The same media can also be presented in a classroom, or on the internet. The use of blend shape animation and the related digital techniques has far greater application than character animation. To become a mature tool, however,

more development would be needed to understand how best to apply it to create the visualizations, then how best to present the resulting visualizations.

**Acknowledgements**

I thank my supervisors Ms. Gillian Moffat, Dr. Martyn Horner, and Dr. Paul Chapman, Dr. Minhua Ma for her assistance, and my examiners Professor Irene McWilliam and Dr. Elizabeth Harris, Liverpool Hope University. I am also grateful to the following experts: Ms. Duangkamol Yuthaseri of Ramkhamhaeng National Museum, Professor Sakchai Saisingha of Silpakorn University for consulting of the Art of Sukhothai Buddha, and at the National Museum, Bangkok, Dr. Anan Chuchot, and Mr. Disapong Netlomwong and Dr. Kent A. Stevens for technical assistance.

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