Literature Survey: Chimera

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Introduction

Since humanity's stone age ending in 2000 BCE, we have learned how to craft tools molding the world around us as we desired by mixing and matching shapes and materials constructively. The more tools and objects humanity creates by these means, the more their environment reflects these technological changes. Alongside these changing tools, the one factor remaining the same is an affinity for animals and friendly faces, especially for children in search of comforting figures [L14].

Zoomorphic design is an application of animalistic features on non-animal objects. Found to be quite prevalent in architecture, furniture, and product design, these amalgamated shapes are appealing to the general public due to their seemingly cuddly and more friendly nature just by their features alone [AW03]; for example, a rigidly structured park carousel is made more friendly by turning its poles into the legs of the octopus [DYYT17].

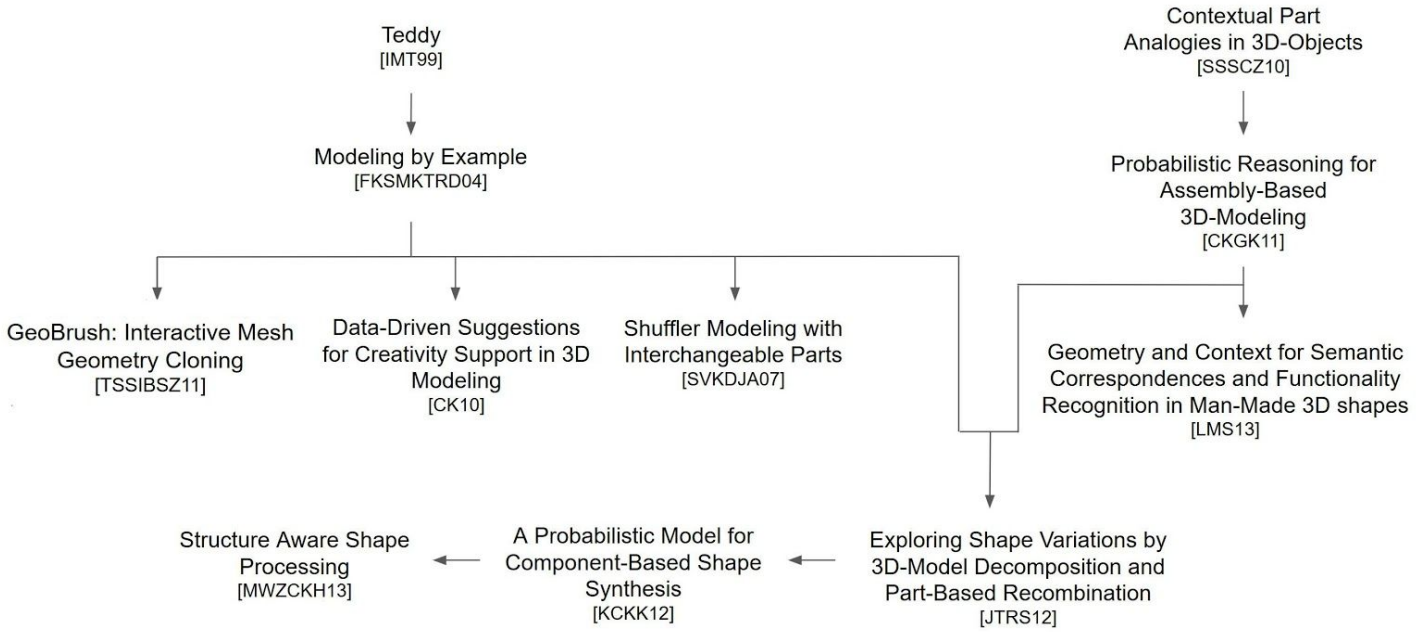
Our authoring tool, Chimera, is based on a seminal paper for zoomorphic design in graphics proposed by Duncan et al [DYYT17]. Though previous techniques and research have been used for zoomorphic design for general three-dimensional shape modeling and mesh composition, this paper is the first in computer graphics that actually develops a complete computational approach that combines mathematical and structural reasoning for this process.

In this literature survey, we trace from two separate ancestral seminal papers, [IMT99] and [SSSCZ10], to reach a combined understanding in terms of architectural, structural, but also figurative combinations of mesh. Additionally, these combinations remain art directable due to differing probabilistic and melding techniques to allow for multiple varying and interesting outputs given the same two input meshes. This includes determining possible connecting poses the two shapes can take to begin aligning with one another, forming the shapes together based on how similar certain aspects of the two shapes are to each other, and allowing for a sort of linear interpolation between how connected and disfigured the final shapes become.

Content

Tree of Life for Chimera Development

Research Evolution Graph for “Zoomorphic Design”



Noted Papers

[IMT99] Teddy: A Sketching Interface for 3D Freeform Design was a seminal paper that presented a system for quickly and easily designing freeform objects. Its major contributions included various construction algorithms that created 3D polygonal surfaces from a 2D silhouette. It was one of the first papers to present a semi-automatic method for creating models and led to more research on automatic and semi-automatic 3D model generation.

[FKSMKTRD04] Modeling by Example: A paper following Teddy by Funkhouser et al. presented a data-driven approach to constructing 3D geometric models by synthesizing existing models. The learning curve for creating 3D models is steep and the benefit of their approach was that it was easy to learn and create new models. The users would search an existing database of 3D meshes, cut out the desired parts and composite them to form new 3D meshes. This paper contributed new research on interactive segmentation of 3D surfaces, shape-based search to find 3D models as well as composition of 3D parts. Their system allowed untrained users to create interesting and detailed 3D models. The paper learned from sketch modeling tools such as Teddy by keeping the user interface simple. Whereas previous systems achieved simplicity by limiting the complexity and shapes a user could create, their system achieved simplicity by leveraging complex existing geometry stored in a database. Their work was also the first to apply data-driven synthesis to 3D surface modeling such as identifying similar parts of 3D objects from a database and how to stitch them together. The system was also one of the first to leverage a large database of example 3D models and shape-based search methods as a part of an interactive modeling tool. In terms of Shape interpolation, the focus was more so on recombining parts of shapes rather than morphing between them. The model created a new paradigm for creating 3D models from parts extracted from a large database, as well as algorithms for segmenting models into parts interactively and aligning parts automatically.

[SVKDJA07] Shuffler Modeling with Interchangeable Parts: Building on top of the model creation from parts of other models paradigm of “Modeling by Example”, Sheffer et al. presented Shuffler, a modeling system that automates the process of creating new models by composing interchangeable parts from different models within each family. The parts that they automated was the geometric operations on the part of

the user. The user would simply select which parts should come from which input models and the Shuffler system combines the chosen parts. The system precomputes interchangeable parts across each input family of models. To accomplish this, it segments the models into meaningful components and computes the correspondence between them. The paper presented two new novel algorithms for segmentation and part correspondence. This allowed for meaningful mesh segmentation and part matching.

[CK10] Data-driven suggestions for creativity support in 3D modeling: In this paper, Chaudhuri and Koltun propose data-driven suggestions for 3D modelling. Whereas previous semi-automated modeling approaches allowed for users to search themselves for model parts, this approach computes and presents components as suggestions to the artist. The paper builds of existing work for shape retrieval and shape correspondence techniques and use those techniques to support the generation of data-drive suggestions. The paper still uses a library of existing models, but automatically uses data-driven techniques to create suggestions. The benefit of suggestions over user-selection is that the models created can be more open-ended. Whereas a user must know and decide what they want in earlier methods and systems, in this system, they are allowed to choose based on selections. This method is useful for conceptual phases of design and could help concept artists for films and games.

[SSSCZ10] Contextual part analogies in 3D objects. International Journal of Computer Vision: Coming from the Computer Vision side of research, Shapira et al. presented an approach for partitioning objects into meaningful parts and finding analogous parts in other objects. This paper is not building off of the semi-automated 3D modeling systems described above, but rather addressing a problem that is crucial to creating effective systems. In the approach to finding analogies between parts of 3D objects, they define a similarity measure between two parts based on local signatures and geometry as well as the context within the shape they belong to. The context is used in a part-in-whole matching based on a bipartite graph. The matching function is computed using a flow algorithm that takes into account both the local geometric features and the partitioning hierarchy. In addition to finding part analogies from shape repositories, they demonstrate an annotation tool that carries textual tags from object parts from one model to another.

[CKGK11] Probabilistic reasoning for assembly-based 3D modeling: At this point, the form of modeling in which new models are assembled from components extracted from a database was called “assembly-based modeling.” Earlier papers provided the

foundation of assembly-based modeling. A challenge still was identifying relevant components for the user. This paper introduced probabilistic reasoning to assembly-based modeling. The model learns a probabilistic graph that encodes the semantic and geometric relationships among shape components in a given repository. The model increases the relevance of the components presented to the user.

[TSSIBSZ11] Geobrush: Interactive mesh geometry cloning: Building off of Modeling by Example, Takayama et al. proposed a method for interactively cloning 3D surface geometry with a paintbrush interface inspired by continuous cloning brushes used in image editing. They implemented a method that supports real-time continuous copying of arbitrary high-resolution surfaces. They used a novel method of generalized discrete exponential map parameterization to create a correspondence between source and target geometries. They align the source geometry with the target shape using Green Coordinates and compute an offset membrane to blend the pasted patch with C^1 continuity before stitching it to the target. They compute the offset membrane, which is a solution of a PDE, on the GPU in real time. Their method was the first to provide a complete solution that could handle general input for 3D surface cloning in real-time. The paint interface can handle irregular meshes and arbitrary surface details. GeoBrush is significantly different from normal displacements and allows for more creative expression.

[KCKK12] A probabilistic model for component-based shape synthesis: The primary contribution of this paper is a new generative model of component-based shape structure. The model allows for more automation compared to previous systems. Their work focuses on designing a compact representation of the relationships of the selection and placement of components of complex real-world models from airplanes, cars, to furniture and biological forms. The model creates a compact representation that can be learned without supervision from a limited number of examples. Their probabilistic model of shape structure can be trained on segmented shapes from a particular domain. The model gives way to two applications: amplifying an existing shape database and enabling interactive shape synthesis interfaces for rapid creation of plausible shapes. The first application could synthesize new shapes and expand an existing database. The second application affords more user control similar to previous methods, but allows for more rapid creation.

[JTRS12] Exploring shape variations by 3d-model decomposition and part-based recombination: This paper takes us much closer to zoomorphic design. Jain et al. present a system in which new shapes are created by blending between shapes taken from a database. Rather than assembly-based modeling, they perform blending by

recombining different parts from the two shapes using shape analysis and deducing the necessary constraints. The analysis includes shape segmentation, contact analysis and symmetry detection. The key simplification of this method is to avoid geometry inside of individual parts that constitute a shape. Similar to previous methods, they segment database models into parts and synthesis the new models from combining the component parts. In comparison to systems where users specify individual parts to be replaced, such as the Shuffler approach, their system performs complete blends. They also have a different segmentation and shape-matching strategy relying on positional and contact information instead. The approach does not allow for the deformation of individual parts, so shapes have puzzle-like structures.

[LMS13] Geometry and context for semantic correspondences and functionality recognition in man-made 3D shapes: This paper addresses the issue of balancing the automatic recognition of generic man-made 3D shapes while balanced with large topographical variations that make the more detailed man-made shapes harder to distinguish. To do this, they represent a graph of interspatial relationships between the connecting parts in the shape to model similarities. This allows piece-wise correspondence between underlying shapes of the larger object to be recognized without needing user-specified denotations while also using design classifiers to learn the organization of the shape components of the current object for future uses of the algorithm. This context-aware measurement of the similarity between existing parts of the object is much more optimal than previous geometric-based techniques when dealing with larger shapes that have many more surface-based variations.

[MWZCKH13] Structure-aware shape processing: This paper focuses more on semantic relationships among different parts of an overall shape being created instead of the more detailed inter and intra relationships between the local geometries themselves. Using more basic 3D models as reference for look up, this algorithm analyzes then processes key extracted information for synthesizes towards the more novel shapes. Using a mixture of previously defined and available structure-aware techniques to combine larger databases of simple shapes into more specific creations. This is helpful because it removes the difficulty of the content creation bottle-neck and allows researchers and other tinkerers to focus more on the end product with faster and more iterable designs than original detailed 3D models that can take a longer time to create. For example, instead of constructing a new chair every time for iteration, the algorithm can pick different aspects of previously created chair designs to form a new, not yet seen combination (such as the recent StyleGAN by Nvidia that creates faces that don't exist from currently existing faces previously submitted to their database [KALL17]).

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