www.cadanda.com Computer-Aided Design AND APPLICATIONS

Has Digital Clay Finally Arrived?

Raphael Zammit and Juan Antonio Islas Munoz
University of Cincinnati, zammitra@ucmail.uc.edu

ABSTRACT

New *Stylus Based Polygonal Modeling* software being developed for the entertainment design industry may be able to augment or potentially replace the automotive design industry's traditional use of styling clay in early 3D conceptualizing phases of their design process. Within the University of Cincinnati's (UC) School of Design, and in conjunction with the Rapid Prototyping Center (RPC), the Autodesk's Mudbox software program was tested in terms of its usability and output quality, effectiveness in form exploration and development, the effort and time required to generate design iterations, and refinement and final execution. Results were evaluated by analyzing the Autodesk Mudbox flow, and the resulting tangible models fabricated with 3D printing technologies. A pilot project was executed, in which a vehicle was modeled in order to evaluate the ease and limitations of these new software programs' ability to intuitively create and control surface continuity across expressively complex forms developed in the automotive industry.

Keywords: Autodesk Mudbox, automotive design, polygonal modeling.

1. INTRODUCTION

Understanding and developing 3D form has always been a challenge that can be tackled both by a technical approach requiring precision and strategy and by an expressive passionate one which demands aesthetic and emotional sensitivity. One of the best examples where these two approaches coexist in a harmonious way is in automobile design. Cars strongly exemplify this combination since they work as technical machines which have to comply with safety, performance, space, and mass-manufacturing constraints (amongst others) while their success in terms of sales greatly depends on how they captivate the customer. Virtually every system and component comprising today's cars are heavily designed digitally. While the car's body and interior design components are still typically first hand-sculpted as highly refined physical clay models in tangible 3D materials, the end product that eventually reaches the consumer at some point will have been 3D scanned and processed digitally for final engineering and manufacturing. Looking into current developments in 3D modeling, this paper addresses the question: has digital clay finally arrived?

The use of 3D CAD modeling has been embedded in both Automotive Design and Engineering. There are three general types of 3D CAD modeling (solid, surface, and polygonal). Of these solid and surface modeling have dominated the areas of engineering. However, surface modeling (NURBS) has for more than two decades been the likely CAD choice for the creative design functions, with solid modeling only fairly recently making inroads to creative design as well. Autodesk Alias Automotive is the NURBS software package that is most widely used in the automotive design industry and will be referenced in this paper.

Retuning to the technical versus emotional approaches introduced earlier, both designer friendly solid and surface modeling software packages, while far more intuitive than many of the CAD programs strictly intended for engineering, fall into the category of requiring high technical aptitude and 'left-brain' thinking because they require strategizing different approaches for constructing a complex model. They both have long learning curves and require a thorough understanding of program features, tools, and the technical procedures needed to use them. They require the use of a three-button mouse and the entering of absolute numeric commands. Summarizing, the approach for modeling with these software packages demands an analytical way of thinking and developing form (Fig. 1), which frequently collides with the emotional and passionate sensitivities that creative design (and designers) usually possess and practice, especially when concerning automotive design.

Taylor & Francis
Taylor & Francis Group

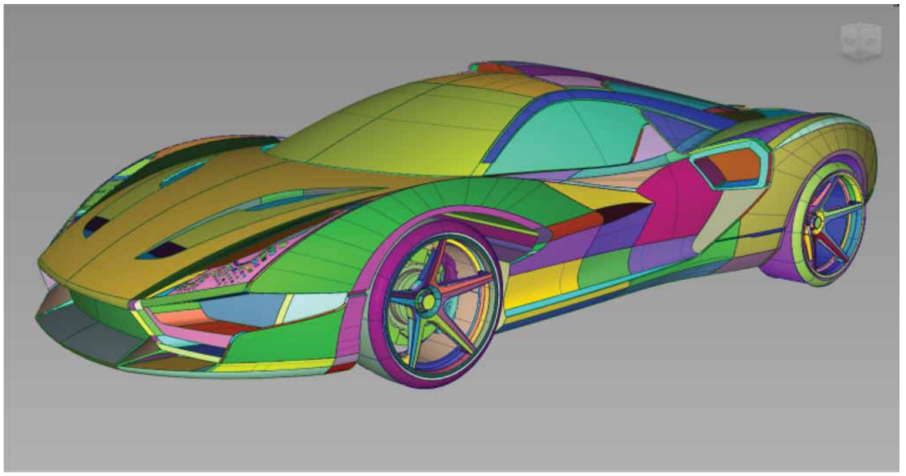

Fig. 1: Alias model by Vincent Christman. The complexity of the analytical thinking to generate this model can be observed through different colors being assigned to each individual surface.

Polygonal modeling, on the other hand, has dominated the entertainment industry (film, and videogame) as the primary software tool for designing since it allows for spectacular visual impact relative to much 'lighter' model geometries. Programs such as Autodesk Maya and Autodesk 3D Studio Max are widely used. And while they offer a somewhat more intuitive and forgiving approach to modeling, they also require an analytical approach to form development. They not only also require the use of a three-button mouse and numeric inputs, but still depend on complex understanding of how various surface construction components and construction procedures can effect how they will behave when modified. Furthermore, similar to solid and surface modeling, polygonal modeling fundamentally follows an abstract sequence of various steps to construct volumes from their most fundamental elements (lines and points) and rely upon these construction tools and methods to also manipulate the constructed volumes later. That is to say, to alter a surface or volume that a designer has constructed, one must do so through manipulating the original lines and points anticipating a cascade effect to trickle down to every other minor or dependent surface or volume that was constructed off of the first. This type of modeling requires a tremendous amount of mental visualization of not only a volume's inherent underlying structure or 'build strategy' (which only exists as a mental plan for construction) but also the actual sequence or 'history' of the methods that were used to construct it as well.

In stark contrast to this, in recent years, *Stylus Based Polygonal Modeling* (SBPM, a term created for the purpose of this paper) represented by software programs like Autodesk Mudbox or Pixologic Z-Brush, has emerged with the potential to parallel the advantages of using traditional clay in automotive design studios. This new approach to design CAD modeling falls into the family of polygonal modeling. However it utilizes polygonal meshes with densities of several million polygons, which provide the required mesh resolution to allow for an unprecedented level of manipulation to the original 'base mesh' without any need to modify its inherent construction. For example, to change or modify a surface or volume, one simply moves, pushes, stretches, or cuts into it instead of having to rebuild it. This approach offers an intuitive way to manipulate form that is closer to how a traditional sculptor would interact with traditional materials (soft or hard) within the realm of tangible reality. One great advantage offered by SBPM that enables this instinctual and immediate approach is the functionality of a pressure-sensitive stylus (rather than a mouse) as the main input device. Where a mouse initiates binary 'click' inputs that are essentially 'on or off', the pressure sensitive stylus provides over two and a half thousand levels of input variation between 'on or off'. This is what allows for a more intuitive skill-based sensibility to be incorporated into the process of model creation and manipulation. This better aligns with the emotional-passionate approach that is natural to creative designers. This is particularly helpful when building sculptural, organic surfaces which are very difficult to obtain using a surface modeling program. SBPM is already being used to design vehicles and other highly sculpted objects. Designers such as David Bentley, Joseph Drust, and David Lesperance [1] are clear examples of this trend and use it for exploration and visualization purposes. The caveat is that these models are intended for visualization, not actual 'final surface' production. The question therefor is, could SPBM transcend on-screen visualization and be used to develop a physical model such as the ones made from traditional clay in Automotive Design? To test this possibility, a project intending to mimic a typical automotive design process was undertaken to explore where SBPM may or may not succeed as a comparable tool and approach to the traditional process of clay modeling.

2. PROJECT

2.1. Description and Methodology

A vehicle was modeled using Autodesk Mudbox 2013 and sections of it were 3D printed to 1:16 and 1:3 scale. This had the objective of documenting an overview of the proposed workflow in order to identify where in the Automotive Design process it would be most effective, find opportunity areas for improvement in order to be tailored for Automotive Design, and learn if it is useful for the creation of presentation level physical models.

2.2. Project Execution

2.2.1. Proposed workflow

The proposed Autodesk Mudbox workflow for designing automobiles can be divided in three main phases: the pre-sculpting phase, the sculpting phase, and the evaluation phase.

Unlike NURBS, solid modeling, and other software packages based on polygonal modeling that start with a blank screen, Autodesk Mudbox requires the pre-existence of a base mesh. The **pre-sculpting** phase involves the process of generating such a mesh with basic "car like" features where the actual creative work will be applied.

The **sculpting phase** involves the shaping of the base mesh from the pre-sculpting phase into a design idea (or ideas). This phase can be further subdivided into exploration and refinement. The exploration sub-phase focuses on the generation of design ideas, iterations, and modifications of the overall design. Due to the intuitive nature and the input received from a pressure sensitive stylus, the resulting sculptures from the **exploration sub-phase** have many imperfections or ambiguities. The **refinement sub-phase** refers to "ironing out" such imperfections which usually involves generating the desired surface continuity, defining hard edges and lines, and planar-izing surfaces such as windows.

The **evaluation phase** involves the use of Autodesk Mudbox native materials and lighting in order to identify imperfections in the sculpture in order for them to be addressed and corrected.

2.2.2. The pre-sculpting phase

There are three different approaches in order to generate a base mesh: using the native car available in Autodesk Mudbox, importing a custom base mesh from Autodesk Maya, or modifying a native Mudbox primitive cube into a car-like mesh. Using the Mudbox car is useful when the proportions of the vehicle to be designed are the same as the ones in the base mesh (same wheelbase, similar height, etc).

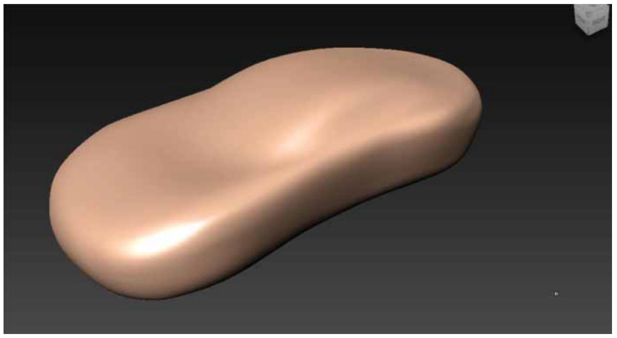

Fig. 2: Finalized base mesh sculpted from the Mudbox cube.

However, designing different vehicles to the Mudbox car is not efficient since the sculpting time would be too long. Importing a custom base mesh permits all car proportions. However, the requirement of a separate software package is inconvenient, since financial resources and the time necessary to undergo the learning curve are required.

Modifying the Mudbox cube into a car-like object (Fig. 2) was chosen as a method in order to test Autodesk Mudbox as a stand-alone product. While it is not the most efficient approach, the resulting base mesh can be used to generate many different vehicle sculptures. The main competitor of Autodesk Mudbox, Pixologic Z-Brush does have the capability to generate meshes within itself. This is a major opportunity area for Autodesk Mudbox to become a more effective software package for Automotive Design.

The process of transforming the Mudbox cube into a vehicle-like mesh involved severely stretching the mesh, which produced distorted polygons with an elongated rectangular shape instead of a square one, as well as an irregularly arranged wireframe. This produced resolution problems when applying tools with small sized brushes as seen in Fig. 3. This effect was somewhat limited (not eradicated) by increasing the amount of polygons in the sculpture. This also affected the ability to create drastic indentations in the model with defined edges such as would be necessary for the sculpting of wheel wells. This is the reason why the model generated in this project (using Mudbox 2013) does not have them. While generating automotive sculptures without wheels is acceptable for early exploration of design themes and gestures, it limits further exploration and refinement of ideas. The latest version of Autodesk Mudbox (2014) features a solution for both these problems with the *retopologize* tool, which allows for the redistribution and reorientation of the mesh resolution, and the custom application of soft and hard constraints like the edges of wheel wells and other automotive features.

2.2.3. The sculpting phase

2.2.3.1. Exploration Idea exploration, which requires the generation of iterations and fast design

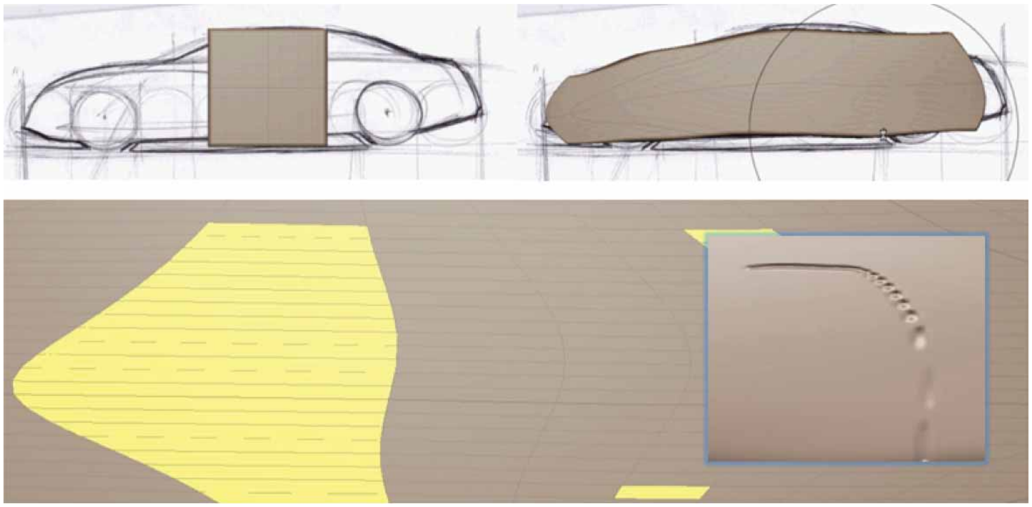

Fig. 3: Dramatic stretch of the Mudbox cube into automotive form (top). Polygon distortion as a result of that operation (bottom).

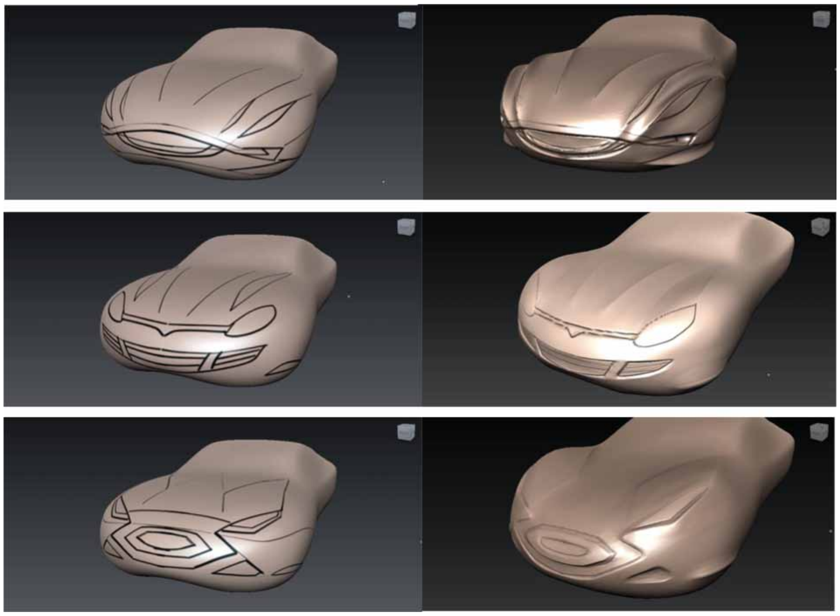

Fig. 4: Sketching on surface and 3D sculpting using different layers in the same file.

modifications, showed itself as the core strength that SBPM software like Autodesk Mudbox offers Automotive Design. The use of the simple tools that emulate the work on actual physical clay makes sculpting intuitive and simple, provided that as in sketching, the designer has skill. Sketching and sculpting in Mudbox are complementary. The ability to draw directly on the surface provided an effective way to visualize the idea in 3D form (Fig. 4). The paint layer options in Autodesk Mudbox allowed for several sketches to be applied to the same base mesh, which is desirable in idea exploration.

The capability of visualizing different designs on the same file goes beyond sketching on surface and into 3D sculpting (Fig. 4). Autodesk Mudbox's capability to have sculpt layers permitted a quick way to visualize and compare the different car design ideas with short turnover times that are unprecedented in NURBS, Solid, and non SBPM polygonal modelers.

Once a design direction was selected, further exploration within that idea was also done. The fast generation of iterations requiring quick design modifications were executed with ease by using paint layers for sketching on surface and sculpt layers for 3D modifications. This is shown in Fig. 5, which also shows a modification to the grill being pulled outwards using the *grab* tool in order to generate a more dramatic front. These modifications would take from

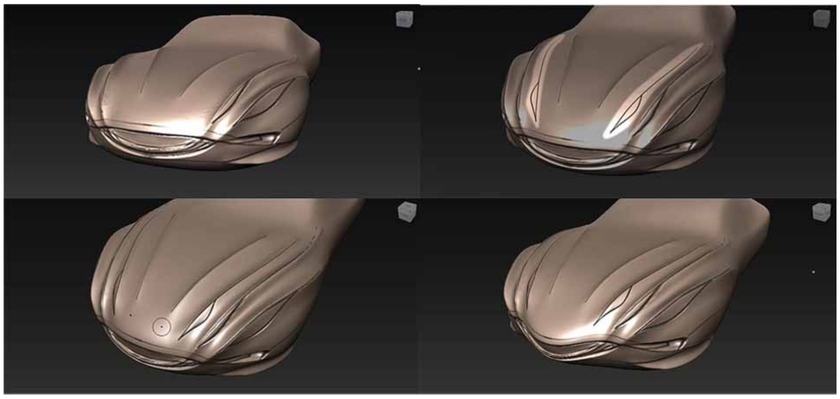

Fig. 5: Original exploratory sculpture (top-left). Third set of head lamps and grille in sketch form. The area around them has been darkened for better visualization (top-right). 3D interpretation of surface sketch (bottom-left). Modified grill pulled outwards (bottom-right).

Fig. 6: Window before refinement (left), window after refinement (right).

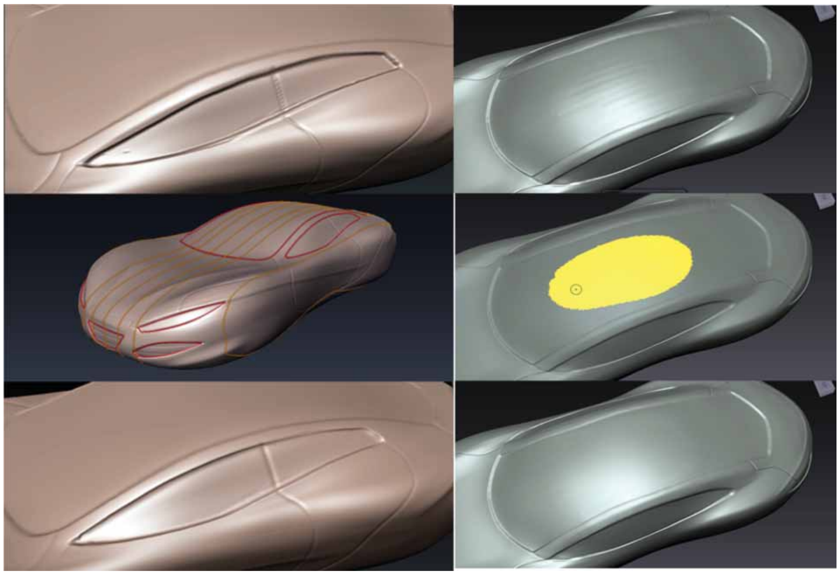

Fig. 7: LEFT: Mesh before retopology edges are poor (top). Hard and soft constraints indicated for retopology (middle). Retopologized mesh permits better edges (bottom). RIGHT: Non continuous surface (top). Selection of faces to be made continuous (middle). Continuous surface after tool (bottom).

several minutes to hours using NURBS, took seconds using Autodesk Mudbox.

2.2.3.2. Refinement After the final idea was selected and no more modifications to its overall concept were necessary, design refinement such as good surface continuity, planar surfaces, tight edges, and uninterrupted lines needed to be achieved. The tools offered by the software package are not the most. Long amounts of time had to be invested in order to only partially achieve the desired level of refinement, since the whole mesh has a tendency to move freely. Fig. 6 shows an example of a window surface that has been worked on, seeking the correct curvature with only partial success, both in terms of making the surface continuous and flat, and in tightening the edges defining the mentioned surface.

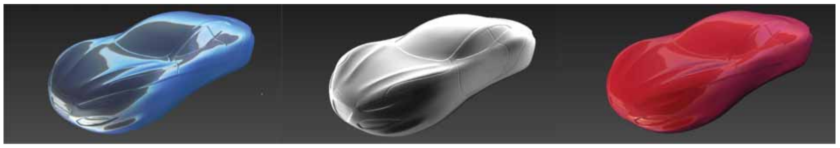

Fig. 8: Chrome material (left), high contrast material (middle), reflective paint material (right).

Fig. 9: 1:16 model put against a mirror to see the whole vehicle (top). Two angles of the 1:3 section (bottom).

The 2014 version of the software offers partial solutions to tightening edges in the form of the *retopologize* tool explained before, and to the surface continuity problem with the *tighten* and *fair* selection tools, which averages the surface by relaxing or tightening the polygons that are irregular (Fig. 7). This tool, while useful, is not ideal since the resulting surface calculated by the software might not be what the designer requires. Finding better tools to generate surface continuity and better edges is an opportunity area for Autodesk Mudbox.

2.2.4. *The evaluation phase*

While it is far from matching the evaluation capabilities of software packages such as Autodesk Alias, the native materials available in Mudbox helped visualize surface irregularities and allowed problems to be addressed. Chrome, reflective paint, or materials that show high contrast are the most useful. Fig. 8 shows examples of these materials.

2.2.5. *Rapid prototyping*

A 1:16 scale model of half the car and a 1:3 selected section were powder printed (Fig. 9). In order to achieve this, the Mudbox model was imported into Autodesk Alias 2014 as a *.obj file. The original resolution of 1.5 million polygons had to be reduced to half since rapid prototyping applications failed because of the model complexity. This raised concerns on whether the polygons would be visible in the physical model. However the printer's own resolution was less defined than the resulting polygons so they were not registered, except in detailed areas that are usually described graphically and not volumetrically in physical vehicle clay models, making the problem less relevant.

3. CONCLUSIONS

Has digital clay finally arrived? Yes, in the sense that Stylus Based Polygonal Modeling has reached the required resolution to generate models. It could be used today with great success in the early ideation stages of automotive design projects (Fig. 10). Such polygonal models could be used as a 3D template to build the final idea in a NURBS software package.

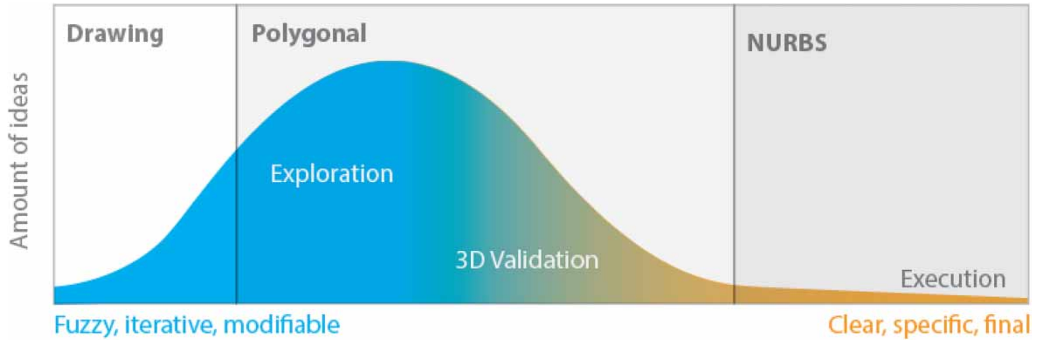

Fig. 10: Current areas where Stylus Based Polygonal Modeling would be effective in Automotive Design.

Achieving good surface continuity and precise detail is still a challenge. If this issue were to be resolved in the future, it would potentially create a revolution in the way automotive design studio workflow not seen since the introduction of digital modeling itself.

ACKNOWLEDGEMENT

This Work was supported by a gift from the General Motors Foundation.

REFERENCES

[1] Lesperance, D.: http://david-lesperance.squarespace.com/

[2] Bentley, D.: http://www.zbrushcentral.com/showthread.php?178005-ZBrush-INDUSTRY-SPOTLIGHT-with-David-Bentley-(12-videos)

[3] Drust, J.: http://www.zbrushcentral.com/showthread.php?159024-Joseph-Drust-Digital-Sculpture-Thread