Defects Defined by Form Making Method for Improving Generative Design System

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Abstract

Evolutionary-based Generative Design System (GDS) is generally designed for industrial designers during the early stage of conceptual design. Although "additive" Rapid Prototyping (RP) methods are commonly applied for the physical realization, grown Surfaces Object (SO) created from these GDS still has room to be considered to a combined workable volume, especially for the more complex design. The inarticulate processes from GDS to Generative Production System (GPS) are linking up with different aspects and contexts as well as the conventional Computer-Aided Design (CAD)/RP integration, which has been conducted for a long time.

There are design constraints existing between 3D SO in industry design representation and feasible 3D production solution. Perception to object designing with knowledge is limited at SO forming by incomplete interpretations. Meanwhile, it is difficult to discern the problems of *incomplete* object generation as hidden *illegal design* occurred from time to time because of the design constraints, despite the completion of the design representation. It has led to some of the invalidity of surface feature at the end. The reconstruction of the RP process of the SO pre-processing procedure can help to clarify these defects with thickness requirement in generative production.

The aim of this paper is to verify an effective generative design strategy as a possibility of implementing method(s) or tool. They will be built within a surface-oriented GDS by mapping a valid object directly accepted by any RP system without any influence on generative object creating. Through the involvement of Form Making processes of RP from selected instants with their solid phenomena, evidences are used for defending this viewpoint. Throughout the process, generative design method and CAD method have been utilized for the creation of virtual form. The 3D printer and Fused Deposition Modeling (FDM) technology with "trial and error" method were employed in the RP processes.

Keywords: Generative Design System, Rapid Prototyping, Surface Object, Generative Design System, CAD (Computer-Aided Design), and Form Making

1. Introduction

"Form Making" is originated from clay forming by hands in form design process. But creative human immersion is replaced here by automatic forming of the layer-by-layer RP material virtual object modeling. In manufacturing perspective, GPS like all "additive" RP system is a production system that material objects produced are through generative construction method and generative process planning. By means of GPS nowadays, form making can be physically realized.

Conventionally, industrial designers would create their designing through the application of surface modelers like 3D Studio Max, Rhinos, Pro/Designer by using surface modeling methods. Genetic evolution GDS intervention may change how industrial products are designed in a conceptual design process. The core of genetic evolution is the generative techniques, which are based on evolutionary programming to physical design through genotype encoding and genotype-phenotype mapping.

Encode Design Idea to Product or Idea-as-Product was defined by Soddu [1]. Motivated computing is beneficial for the design of physical as well as digital artifacts. The mapping result could not be just the predictable form or unpredictable form, but also the foundation of seamless object regardless of what the image *is* but how the thing came into being. To build the structure of a representation, a better understanding of what are defects to what represented will be required. These would reflect on the design constraints existing between 3D SO in industry design representation and feasible 3D production solution. Perception to object designing with knowledge is limited at SO forming and incomplete interpretations. Meanwhile, it is difficult to discern the problems of *incomplete* object generation as hidden *illegal design* occurred from time to time because of the design constraints, despite the completion of design representation has been built for design. It has led to some of the invalidity of surface feature at the end. Eventually, these defects may lead to an appropriate SO that cannot be represented in certain thickness under different contexts of the modeling system.

1.1 Simple Conceptual Model

Experimentation is not only utilized in natural science domain, but also can be applied in industry work with daily technology practice. On "Experimentation" application, Mascitelli [2] describes for 4 RP stages of form making functions for product design and development process. From his approach, the design process can be divided into 2 interactive design stages in term of 2 model types experimentation, including "Rough Models" and "Refined Model" of rapid prototyping model [3].

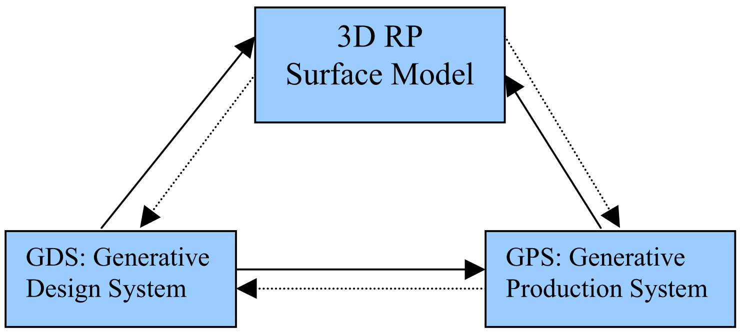
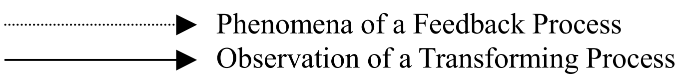


Fig. 1: Schematic diagram of an "Experimentation" illustrating relationship among GDS, 3D RP Model and GPS



A triangular conceptual model with these three elements is developed schematically illustrated in Fig.1. The defects defined through RP form making are dependent and closely related to other two elements: GDS and GPS. SO from GDS becomes testable model through GPS process for creating the reflective physical object. SO with its defects can be verified through the reflection from initial GDS configuration. Generative constructions can amplify any move made on a single object to affect many others related objects [4]. GPS user/designer can directly respond not only to the defective object through GPS modification, but also to the whole GDS review and refinement due to the concrete feedback (Refer to Fig. 1).

The RP model being built in terms of physical representation as an instrument is applied for the experimentation process as both of GDS and GPS belong to the same "machine" foundation. By borrowing from Bacon's theories to nature world, the phenomenon had been taken from the concrete output of the artificial world. Sequentially, these observations from the machine world could state the evidences, then leads to the analyses and reasoning that can be used to provide a picture of a new set of a GDS.

In this paper, RP form making from a GPS is used to clarify existing defects generated by GDS through the CAD system, and an understanding of defects will develop with the compensation methods for improving SO. The experiment is repetitive with data is exactly derived from the distinctive result of the physical RP output. In section 2, SO defect is defined and RP form making as instrument is pointed out. Experimentation method is set in section 3. In section 4, RP realization processes are overviewed. In section 5, 4 form making paradigms as the cases of experimentation are investigated. Finally, findings and factors that influence GDS are concluded in section 6.

2. Surface Object Defects Define

Defects define can be seen not only as flaw or errors, but also being undefined or ill-defined as deviations from levels of acceptance of a complete physical representation that could not be achieved. The deficiencies reflecting on an incomplete object realization through the emergence rendering of a design representation is virtually accepted. Any object discrepancy or any by-products formed from uncontrolled selection by an evolution process are also included in the defect catalogue.

In Webster dictionary, “Defect” is described under different explanations: flaw, vice, fault, foible, frailty; infirmity, weakness; deficiency, imperfection, shortcoming. One of the characteristics of defective SO generated from GDS is that they need to be compensated. It is not only a normal concern in any GDS, but also link to the CAD integration. This can be supported by virtual representation from surface modeling system with the SO generated from GDS, a similar setting within the computer graphic configuration for the design rendering.

2.1 RP Form Making as an Instrument

The “trial-and-error” attempts will involve the inarticulate and intricate process such as model conversion, repairing and pre-processing until the physical representation is formed. In doing so, the defects have created gaps along these processes. Although utilizing STL file, the main RP standard attempt will bypass these gaps. The triangulated model still carries these inherent deficiencies to the downstream RP processing process. There is still a lack of mechanisms that can be effectively translated to a structural solid object for a solid modeler upstream. Defective SO is hard to be converted to solid object through data conversion process, because the verification process is mainly focusing on geometry data safety and data accuracy transaction. On the other hand, GDS in the conceptual stage has some very usable tools, but have not been integrated or organized. Yet, there is no definite feature difference between "solid" slicing and "surface" slicing in RP pre-processing medium because boundary curve eventually will be produced on pre-processing platform for the machining process.

As a form of applied existing conceptual 3D-printer technology on the market, automatic pre-processing process is thought to be the direct method to correct these "particular" defects. These ineffectively compensation tasks cannot solve the problem because of their inarticulate processes and hidden defects shown in Experiment 1. Thus, due to negligence of partial representation [5] and incomplete-interpretation, or even a perfect STL model, there still be problem of open sliced curves in a RP pre-processing system. These GDS objects with the constructed layer segment defects always be shown during experimentation against the axiom of typical solid pre-processing slicing in RP realization process (for any closed surface, there can be one and only continuous chain of triangular facets per slice plane):

1) the cross-sectional contours are unclosed;
2) the cross-sectional contours do intersect each other, and
3) cross-sectional curves of some layers are missing

(Refer to section 5.1: Experiment1)

Therefore, the RP form making is adopted as an instrument to measure the defects of SO generated from RP realization process.

3. Experimentation

The three elements of Phenomena, Observation and Experimentation would occur during the RP form making process in these projects. They are derived through an inductive approach from Bacon's inspiration and thinking in the natural sciences.

Francis Bacon (1561-1626), is the philosopher who formulated a clear theory of the inductive procedure to make experiments and to draw general conclusions from them, which could be tested in further experiments in order to understand the meaning and significance of things rather than predication and control. [6]

The appearance of object defects can only be confirmed as procedural errors or corresponded with their shortcomings within the program framework, thus exercising the logical rules within the limit of the pre-set/defined computer environment. However, virtual object, at least most of which created from some of the existing artificial environment of computer system, must be examined for real world design as utilization. The design of an artificial life does need to select some of the rules acting in accordance with nature. In fact, the application methods are filtering useful ingredients in the real world usage of an artificial system.

If genetic evolutionary technology being seen as part of applied sciences for the development of any artificial intelligence system, then natural property and characteristic elements identified from nature applied in the artificial space followed by a variety of virtual object creations can be easily investigated by adopting Bacon science. If compared with the statistical methods, RP hardware is costly. Its mechanical limitations to object amount and object size; typical paradigm selection is inevitable for an inductive method. Contrasting with the deductive method, the utilization of the inductive method started with a series of observations of physical output from the GDS (like ad ho experiment). But it does not aim to find the defects. Nor does it make the powerful statements about how works (laws and theories) operate. The experiment progress is initially to test series of generative STL SO that come from a GDS, in the GPS RP realization.

3.1 Phenomena, Observation from RP Output(s)

We all know our physical senses have their limitations that it is only a small portion of the electromagnetic spectrum of perception. First, all the facts connected with the natural phenomenon under investigation must be identified and placed in their proper logical order. Second, these facts (RP outputs) must be analyzed for the purpose of discovering the causal connections between certain "antecedents" and "consequent" which appear in "invariable sequences". [7]

Through phenomena to observation, our experimentation leads to a design test and evaluation for the next observation. Then phenomena generated by the output of the last experiment will support the case for the next observation and experiment. As the "Record Output" come out from different stage of the experimentation, evidences can be found. As more outputs and evidences accumulate for evaluation, factors can then be identified to have the greatest potential influence to the problems at the end.

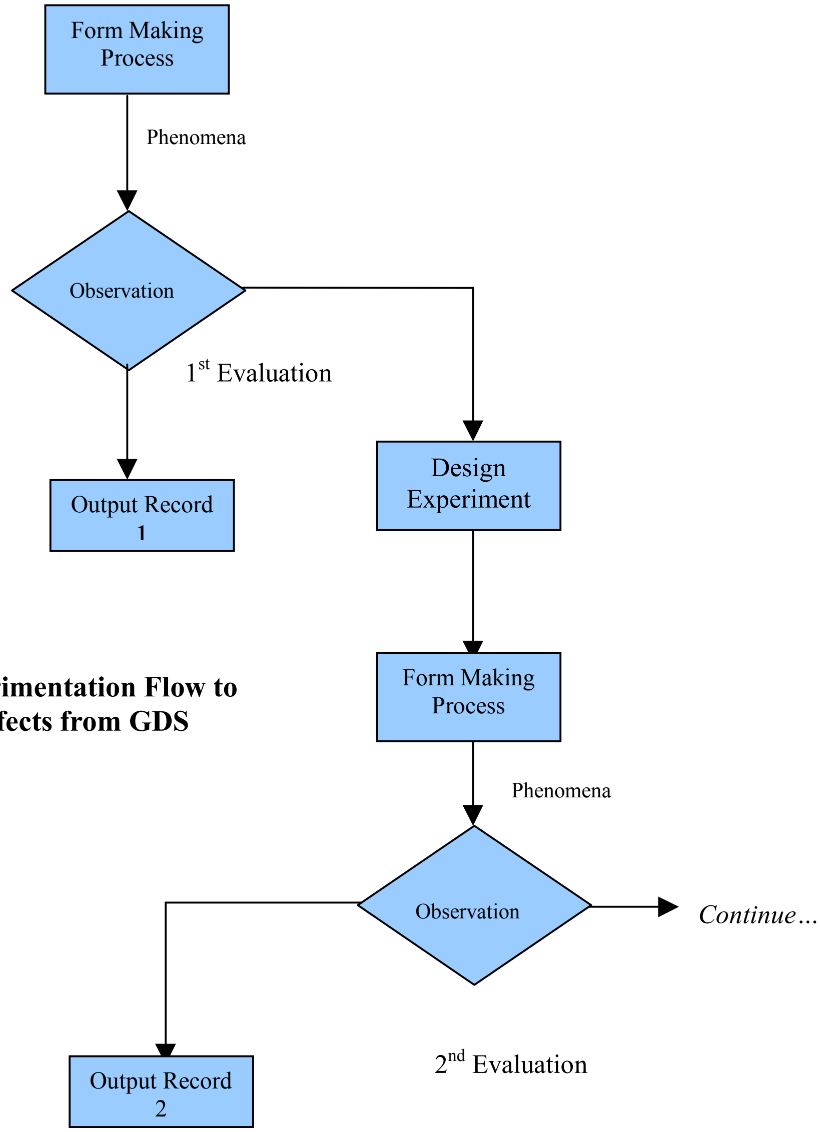


Fig. 2: Basic Experimentation Flow to Identify Object Defects from GDS

3.2 Design of Experiment

In the beginning, experimentation is done by observation of the phenomena under no selective and controlled conditions until more information and knowledge are built. Then a designed experiment is tested in which purposeful changes can be located, based on the trials relationships of unconscious to conscious process and on the relationship among GPS, GDS and RP form making as shown in Fig. 1. An experiment observed as a test is made to the input of a process or system so that the changes in the output response can be observed and identified. The objective experiment is to get the response after the feedback from the RP instrument tools (Refer to Fig. 1). The procedure as "invariable sequences" is fixed as the RP form making instrument is selected. "Output Records" building the maximum amount of information about the effect of input on the output response will be collected. As the evaluation of observation, a normal SO is generated again from a CAD system as well as a means of compensation to STL SO by the STL repair software.

4. Overview of the RP Processes

RP realization processes involves several processes including model conversion in different modeling software, STL model repairing and the main RP pre-processing process in various RP system until the instruction file is created for RP machining process, which is localized and shown in (Fig. 3). All SO generated from GDS needs to go through all the processes of RP realization as described in this section.

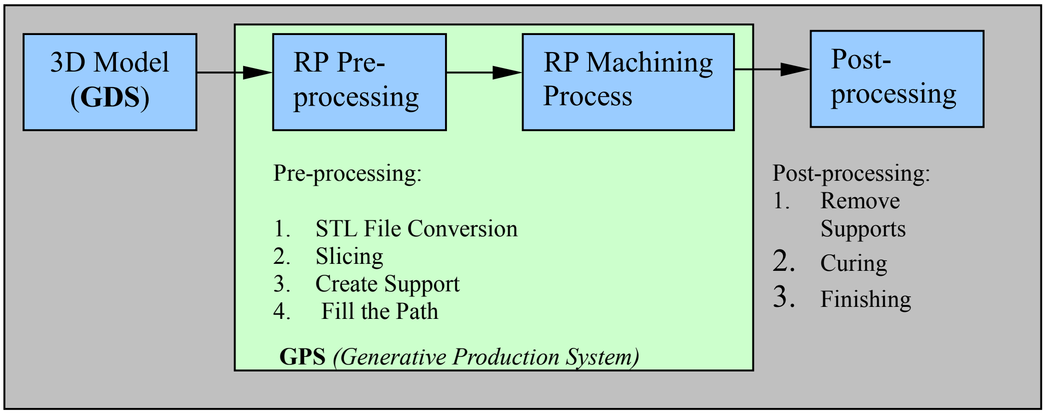


Fig. 3: 3D Surface Model to RP Realization

4.1 STL (Stereolithography) Format

STL format is the neutral data form of 3D-model triangulation either in the binary or ASCII form, which contains vectors, normal, and points defining the triangulation of the object surfaces. The facets describe and approximate the original CAD model. The degree of approximation relies on the size of the facets and total number of facets for the model. Typically CAD and RP conversions generally go one way only, with no feedback loop to allow integrating changes made in the STL model back into the CAD data set.

Note 1: FDM pre-processing system is "QuickSlices" under NT operating system. During the pre-processing process, a proper orientation of STL model is necessary to ascertain. A number of process parameters are selected and then the STL model is sliced into thin cross-sections at a proper resolution. Each slice layer must contain closed curve. Supports are then created if required, and sliced automatically. The sliced model and support are then converted into an SML file, which contains actual instruction code for the FDM machine tip to follow the specific tool paths, called "road" to create each cross-section.
The 3D printer as a realization tool under the NT operating environment is used for the experimentation. The STL model can be directly read by the processor and then transferred to machining codes after automatic pre-processing process. This 3D-printer system operates in a virtual platform for the STL object with its orientation set.

4.2 RP Pre-processing Process

This is the main RP processing activity, and normally there are several processes after the STL model is imported from other CAD system. This activity includes the selection of proper orientation, creation of supports and slicing, and other generation of filling in with the parameters corresponding to varying RP technology in order to prepare a proper machining code for the RP machine controller.

The FDM pre-processing is a programming sequence from slicing, creating supports to creating road in "QuickSlices".

a. Orientation setting is the first important step to individually establish the virtual processing model for the pre-processing processes. It is like a mirror reflecting on the quality of output.

The change of STL model orientation in the virtual working platform has determined two distinctive results of discrepant finishing, rough and fine, which can be used to distinguish and build up direction. Normally, the rough side is contacted with the supports or at the bottom.

Generally, the object is rotated according to X, Y, Z axle respectively in an expected angle every time after each *Slice Process* simulation until the orientation of the object loses the contour layer is minimum.

b. Slicing is the process to decompose STL 3D object to 2D contour curve for the 2D machining process. Layers can organize sets of objects, and blocks or groups can create new composite objects, making it possible to manipulate them as single ones [4]. Previously, interface based on Constructive Solid Geometry (CSG) has been brought up and developed. Based on evaluation of sliced primitives rather than 3-D primitives, CSG tree is sliced individually, generating a slice for each primitive. The contour of the part in a given slice plane is a collection of continuous curves [8].

The task of slicing for RP is beyond the abilities of the sectioning function implement within CAD system.

The problems are [9]:

a) The sectioning functions are mostly available for solid model, not for surface model.
b) The resulting sections are often for the purpose of visual effect, such as shading and displaying. The section contours are not in good resolution.
c) System is unable to handle the case of tangential intersections, which are important for RP processes.

On the other hand, “Adaptive Slicing” is the more advanced slicing method commonly being searched for all-around RP machine development. This is why the adaptive process is better than the normal constant in preprocessing and in reducing layer error problem. At the same time, constant slicing assumed by most RP control software is a straight slicing method from the strategic RP system design point of view for the efficient process planning of product realization for different type of RP system.

By empirical technique of problem solving and comprehension is to fulfil the design requirement to comfort the quality of design object. It is also to balance cost from the extra support and to ensure this orientation fits the next step without collapsing. Layer thickness can be determined that meet accuracy and build time requirements, as well as surface finish [10].

c. Create Supports: Same material but in different density is created in order to support and hold the part firmly during the bottom-up fabrication process.

d. Create Road: Create paths of the fiber fabrication in the space of being enclosed in the slice contour.

4.3 RP Machining Process

The process includes the RP machine movement with the material fabrication process corresponding to the defined filling path of RP pre-processing process. This may vary in different RP technology.

4.4 Post-processing Process

The process includes some final processes such as removing supports, postcuring for (SLA), and finishing.

5. Paradigms of the Experimentation

5.1.1 GDS Paradigm

The trivial, intricate surface object was generated by artificial intelligent through genetic-evolutionary process. The final surface was evolved under the control of genetic algorithm and later to be selected by designer.

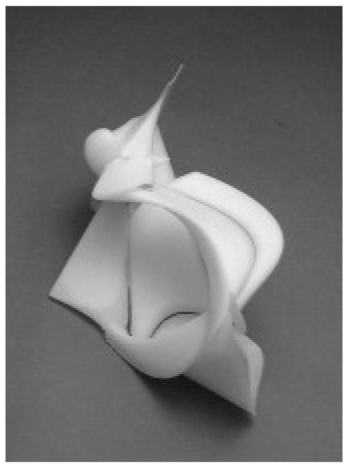


Photo. 1: Genetic-Evolutionary GDS Object
(GA Program Designed by Manit Rastogi, Made by Tong Kwok-hong and Chan Chak Lewis)

5.1.2 Phenomenon

Some deficiency properties of the STL object being sliced on the FDM pre-processing environment is shown as below: Some curves are cross. The continuous curve profile is maintained as shifting down to the next layer and some layer curves are missing. Some missing layers are substituted by copy curves from the neighbor layer practically. Surprisingly, the whole SO was a closed object as checked in a CAD system. This generative design SO is built as a well-defined surface by GDS before converted to the STL format. Although some of the extreme sharp parts and ambiguous corners are missing, this SO is nearly realized by the FDM RP system. Meanwhile, this GDS model was completely failure when make by the 3D printer, as the unrecognized wax structure was formed.

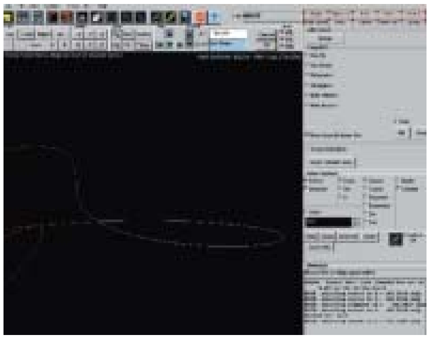


Photo. 2 This curve is cross

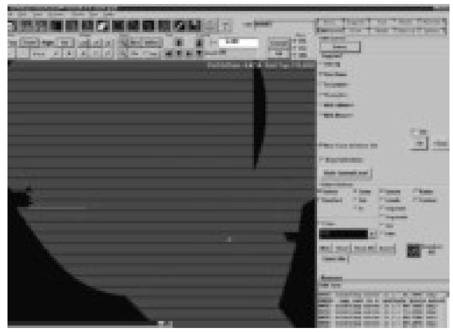


Photo. 3 Some curves in some layers are missing

This object can be seen as perfect GDS object and adopted as paradigm guide for the next three experiments. After this experiment, we thought that complex design can be created by artificial intelligent method like GDS. It may also appear commonly in conventional CAD modeling method or other reverse engineering method. Most industrial designer uses the surface modeling method like Rhinos, 3D Studio max. So the selected CAD object is used to show the possibility of compensation to SO through the RP pre-processing process to limit the amount of the generative models that we can use.

5.2 Experiment 2: Simple Freeform Object

5.2.1 Phenomena and Observation

Pre-processing process would be stopped after SO is sliced in a FDM pre-processor because the contour layer curves is open. A close block instead of surface object is created if this object of each corner is stitched by the repairing functions of “Magics”.

The design representation could be re-built from the layer level to redefine a new path of the contour curve with the constant width that will be filled by the ABS (material) fiber pattern. To offset the curves to close them for the simple freeform SO layer-by-layer, curve edit functions of pre-processing can be used. The details of the layer curve rebuilding are referred to Experiment 3: one sliced complex SO are depicted by the curves processing steps from photo 8 to photo 10.

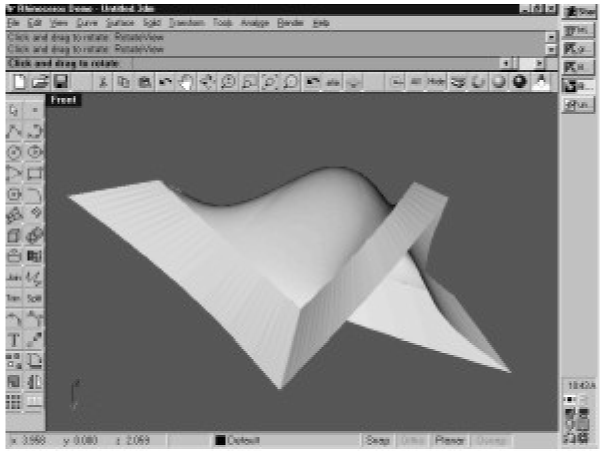


Photo. 4: Surface Object Rendering in Rhino1.1

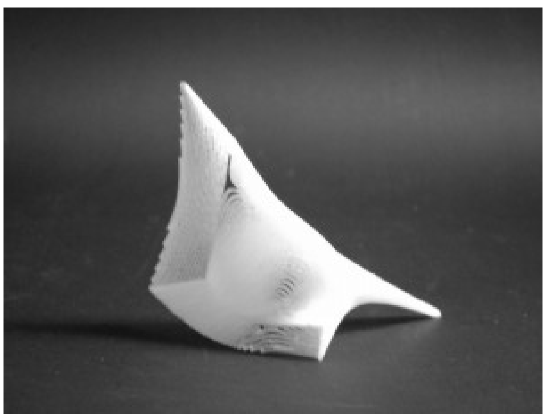


Photo. 5: Surface Object
(Made by Chan chak Lewis and Tong Kwok-hong, Material: ABS)

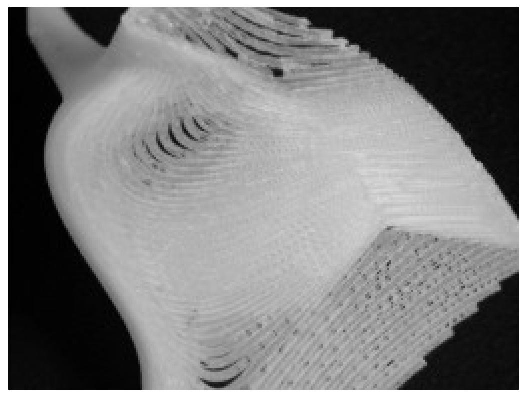


Photo. 6: Fabrication pattern creates a cloth fiber figure

5.2.2 Evaluation

Edit for the curve reconstruction by FDM pre-processing method is the well-defined compensation. But curves edit function can take effect on the straight or simpler object. Can this approach also be adapted for a more complex SO?

5.3 Experiment 3: Complex Freeform Object

A more complex freeform SO has been separately taken from three different redefine methods: direct GPS layer modification, original model modification, STL object compensation by STL repair tool. Besides, there are three RP objects created in this case, two by 3D printer and one by the FDM method.
A complex and ambiguous design has been selected for the experiment. The shape of the SO

is complex, as it is made up by 10 individual rolling, crumpling look ribbon. The SO is constructed in an active, freely expressive manner that their shapes are difficult to describe in any viewpoint.

5.3.1 Phenomena

Object A: After being sliced in “QuickSlices” (FDM processor) with the object oriented vertically, some bright open curve layers appear as in Photo.8.

Photo. 7: Zebra crossing as result of some “Part” fibers is accidentally replaced by “Supports” fibers

(Made by Chan Chak Lewis and Tong Kwok-hong)

Each of the closed contour curves is offset to a distance. Later, these curves are closed to path. Some “Part” fibers were accidentally replaced by the green (in dark) “Supports” fibers in these layers during “Road Creation” process, as in above Photo.7.

Note 2: An architecture student is estimated utilizing “NURBS” surface modeling technique to wrap up a semi-closed surface object.

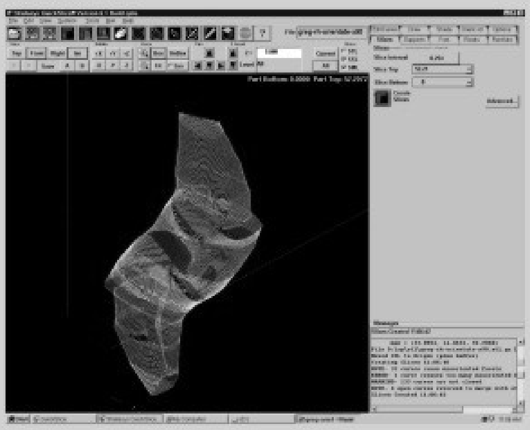


Photo. 8: Yellow as open curves layer

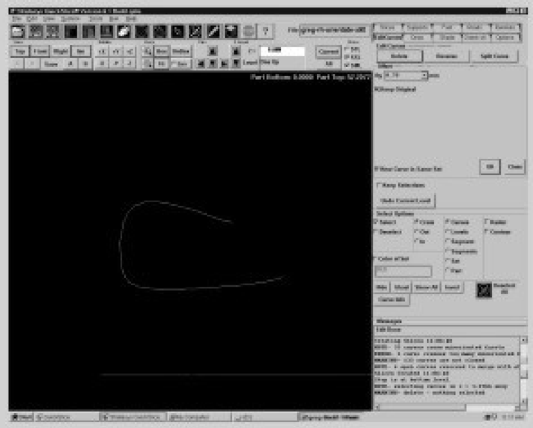


Photo. 9: Single open curve as one layer of SO

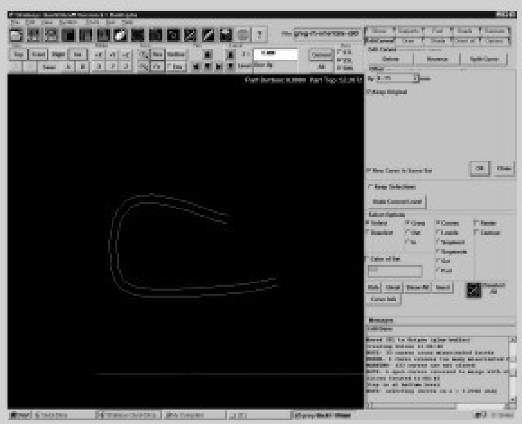


Photo. 10: Offset open curve

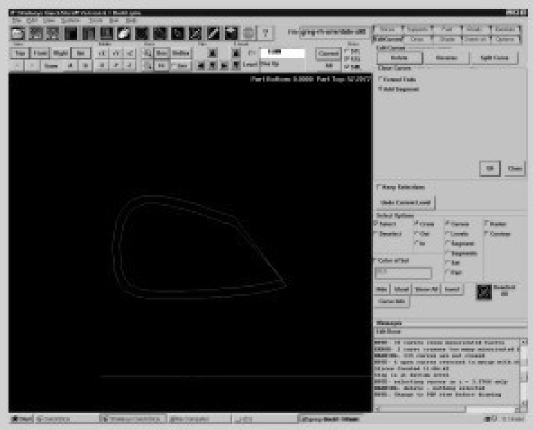


Photo. 11: Close open offset curve

Experiment 3: Object A Thickened by Advanced Curve Modification in Pre-processing Process

Object B: This RP object is created directly by a 3D printer. All the holes are filled up with the wax. Absolute solid type is built after the automatic process because of the SO defective and undefined thickness.

Fig. 12: Object B --3D Solid Object

(Made by Chan Chak Lewis, Material: Wax)

Object C: The RP object is offset by designer's modeling techniques in a modeler. It is produced from a 3D printer. The object is created after automatic repairing in "Magics". Additional solid feature to be added to the surface object is able to solve the problem of correct filling.

Fig. 13: *Object C* --Thickening Surface Object
(Made by Chan Chak Lewis, Material: Wax)

5.3.2 Observation

Direct well-defined pre-processing compensation recreates closed contour boundary with the physical material. It follows the "Road" path of this RP machine configuration to create a surface after the width of surface is defined exactly as the single fabric width.

Object B is created directly by 3D printer with no compensation processing as the thickness is redefined before STL format conversion. The whole object being filled-up as solid representation is greatly differentiated from wrinkle "ribbon" surface as original virtual design represented because the undefined freeform and ambiguous surfaces are unable to be recognized by the 3D printer.

Having created Object B, the author wants to compare the discrepancy of the thickening function between model offset function in a CAD system and pre-processing compensation to the complex SO. Object C is created in a good quality surface. The physical thickness has completely met designer's requirement.

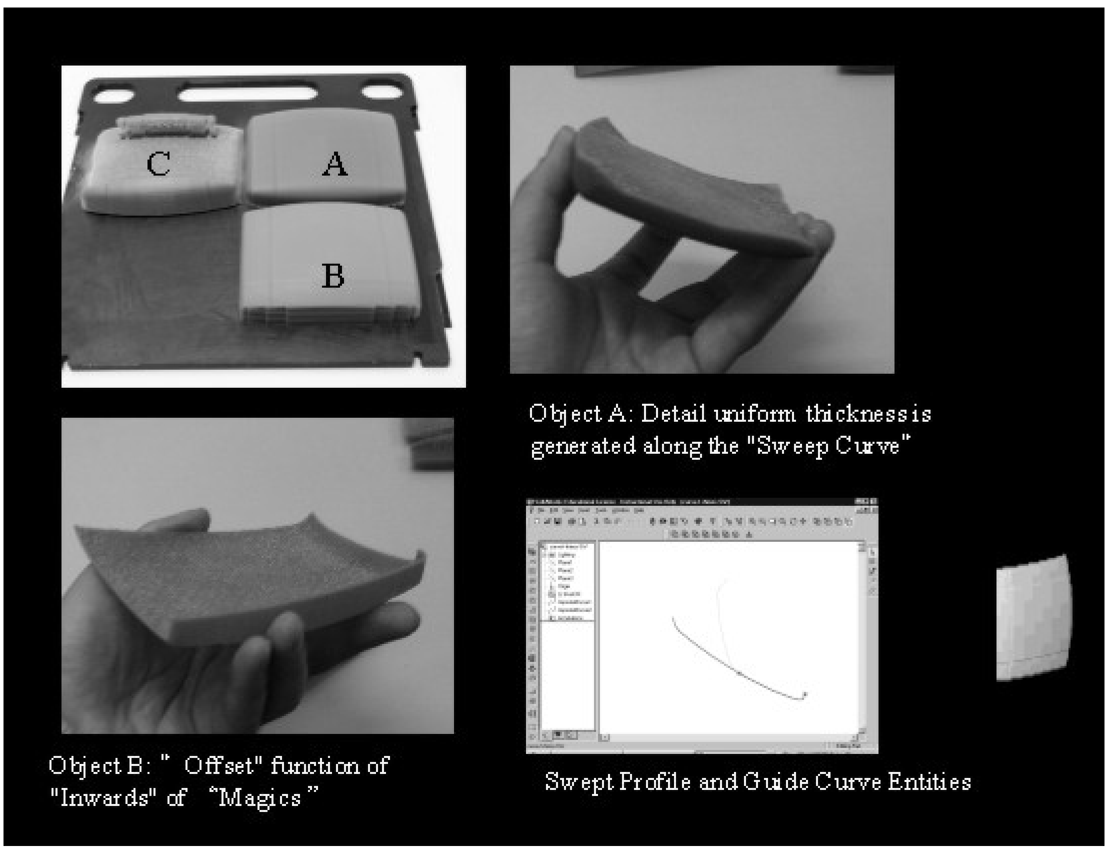
Note 3: When the STL Object B of experiment 3 is imported in "Magics" and automatic repaired by sub-parameter " Filled the hole", a message appears as " Not all holes could be filled".

5.4 Experiment 4: Design of Experiment

One compensated swept surface was made for this experiment. Three instants are utilized to demonstrate a variety of results in the surface thickness defined by means of repair tool ("Magics") to STL surface compensation. Simple "Sweep" surfaces are created in one of the CAD modelers rather than in GDS directly.

5.4.1 Ruled-based SO Processing: Well-Defined and Ill-defined Compensation

This process helps industrial designer to evaluate the surface design in term of discontinuously modifying the spline curves in a surface modeler sequentially for the forming of the physical prototype on a RP platform. Later this designed surface will be used to define Front Part shape of a "Walkman" for the downstream process.



Experiment 4: Well-Defined and Ill-Defined Compensation of Ruled-based RP SO Processing
(Designed and made by Chan Chak Lewis)

Note 4: Two spline curves, as one rail guide and one profile curve are used for the "sweep" generation in 3D studio Max version2 for experiment 4.

5.4.2 Phenomena and Observation

Three objects are directly created through STL model conversion. All STL SO was loaded with no error message in the 3D printer.

Object A: Original surface create without additional compensation.

Object B: With the surface reconstruction process in "Magics". Its thickness is created by offset function. A detail uniform thickness is generated along the "Sweep Surface".

Object C: The same offset function but outward parameter is selected leading to the 3D fabrication wax jetting in the wrong direction. Ill-defined compensation in “Magics” has created defect SO.

Only SO with well-defined thickness is able to be adapted as design processing object in this GPS system. So only well-defined surface compensations to the STL object can automatically produce a complete physical representation. Mechanical fabrication process only follows the directive horizontal path created by the slice process to feed to a thickness, while no detail guiding of the object by any thickness is defined. A complete and correct thickening procedure has been taken to prevent these defects.

Which is the cause to the above phenomenon? As 3D printer is utilized with no human involvement in the automatic “pre-processing” process, process shows a range of well-defined and ill-defined compensations, causing discrepancy of undefined and defected object.

5.5 Summary of the Evidences

There are three compensation processes leading to the exposure of the defects by these experiments:

1) *Original SO Modification*

There are some function (Offset function, Shell function and Fill function etc…) modifiers existing in solid or surface modeler. From Experiment 3 of object C: the undefined (zero) thickness can be enhanced to solid object under related CAD modification. In these processes, the defect problems of the SO will be exposed. Closed surface such as the SO from GDS in experiment 1 without thoughtful refinement can also be assigned to close surface object.

2) ***Model Repairing (compensation) Process***

In here, the STL SO object is repaired by additional software tools.
From Experiment 4: an additional tool (e.g. "Magics") has been employed to repair and to refine the outer shape of a STL SO, leading to extra parameter sets to control the object thickness. Compensation among undefined, ill-defined and well-defined has been compared. SO in these processes and undefined problems of the SO will be exposed.

3) ***Pre-processing Process in RP Platform***

Experiment 2,3 identify the SO problem after RP pre-slicing procedure of pre-processing. Slice SO with consistent open curve property in pre-processing environment show that SO is created with undefined problems between GDS and GPS.

6. Conclusions

Partial design constraints of the generative design approach are explored here through conceptual design realization process, by means of the physical RP output as an instrument from existing generative production method to clarify the limitations of GDS by demonstrating the conflicts to its related systems. Obviously, GDS development continuously set new hypotheses and requirements for the conventional systems and methods.

We have employed Bacon's thinking and scientific procedure for the preliminary study, from phenomena to observation through RP form making process, and then the whole experimentation is set for the output examination. Observations from experimentation could provide a clue to verify the design strategy for GDS to enhance its capability and practicality.

To overcome the defects from those gaps or from GDS itself, the compensation methods for revising the incomplete representation been set and tested indirectly from STL repair tools and RP pre-processing process. Compensations to the defects as in Experiment 2, and 3, which outputs show slice layer reconstruction of pre-processing with human involvement to produce a satisfactory result (surface quality) compared with other methods (like automatic 3D printer). With the application of CAD function, complex freeform SO can formed. A close thick surface as referred in Experiment 3, Object C is realized. Nevertheless, Manit's object realization as in experiment 1 to demonstrate how importance of GDS can perfect design representation. However complex the SO is, it can be adopted by any GPS if this SO has been optimized to a close one. GDS can be developed to overcome these defects. They will create much better results than any defect compensations relying on repair tools, or by employing CAD functions to modify these surface objects which is generated from completely different mechanisms.

Despite the complexity and unpredictability of form created by artificial design real world products can be realized and utilized. Although these SO paradigms may rang from simple to complex under the normal processing and within related computerizing graphic environment, they cannot be completely represented and directly made in a GPS. The approach may pick up complete design representation function, and lead to further development of the interface to allow a user as designer in a GDS to create his/her conceptual design. At the same time, SO tools verified and implemented inside GDS can be utilized for effective connection between the virtual design representation generated from GDS and the generative production representation.

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