Slicing STEP-based CAD Models for CAD/RP Interface

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ABSTRACT

SFF technologies have an ability of creating a physical part directly from its computer model by adding material on a layer by layer basis. One of the problems lies in their current file format for CAD data exchange. Current method using the *de facto* industry standard STL have at times resulted in problems such as accuracy, redundancy, and integrity in its representing CAD models. In this paper we propose a method of slicing and editing STEP-based RP models for the new data transfer paradigm between CAD systems and RP systems using STEP..

Key words: SFF, CAD, STL, Data Exchange Standard, STEP

1. INTRODUCTION

The major application of Solid Freeform Fabrication (SFF) has been the early verification of product designs and quick production of prototypes for testing. Despite this tremendous progress, many problems remain unsolved including several geometric issues [1] that must be resolved in coming years before this new technology is in common use. These include the issues of model slicing [2] or reverse engineering [3], which is, however, beyond the scope of this paper. We suggest the biggest problem lies in its *de facto* data exchange standard file format STL between CAD systems and SFF processes. In general, drawbacks of STL in its handling geometric information can be summarized as redundancy, accuracy, and integrity. Several research efforts have been far done in order to overcome these drawbacks. Generating topological information from this bucket of Facets [4] or, preferably, generating topological structures for surface models in the stage of pre-STL tessellation [5] has been done in resolving the issue of model redundancy. Repairing the model [6], if necessary, to ensure a well-formed representation is for model integrity, and, for overcoming its model accuracy, several research efforts for improving general polygonal models can be also applicable to an STL model. One among those approaches, for example, is simplifying a polygonal model by reducing the large number of polygons from a given polygonal CAD model. This simplification can be made by two approaches; one is re-tiling polygonal surfaces by positioning newly created vertex points using point repulsion [7] and the other re-triangulating within a distance tolerance from the surface to a plane that approximates the surface near the vertex [8]. Even with all these efforts, however, the biggest problem of STL confronted in future designs for SFF technologies still remains yet unsolved; STL does not carry, except the geometry, any design information at all. In other words, .STL file format does not compatible with any high level design information such as tolerance, mechanical properties, and surface patterns, which will be indispensable for further design applications made by SFF technologies. A next generation data exchange standard replacing

STL is hence required to be incorporated with high level design information for advanced design transformation into SFF technologies. Not surprisingly, the need of new data exchange standard will also steer research efforts toward solutions to a problem of how to handle, in the design stage, those high level design information remains open for those SFF processes. Several current RP research efforts are focused on development of a future alternative data format to address the shortcomings of STL and to enable data transfer for future advanced rapid manufacturing capabilities. This alternative data transfer mechanism is recently referred to as the Solid Interchange Format (SIF).

Since 1984 the International Organization for Standardization (ISO) has been working on the development of a new standard for the exchange of product data between computer-based systems in use for design and manufacturing. This standard, ISO 10303, is informally known as STEP (STandard for the Exchange of Product Data). STEP is coming standard. Many major companies are working with it, and all serious CAD vendors are beavering away generating translators for it. What makes STEP the first solution when other standards have not yet met expectations? In short, STEP has a well-defined internal components that can enable the data exchange easier while a design and engineering data are, in general, becoming increasingly complex. In addition, its open architecture and international acceptance to the world makes it valuable in terms of trade and growth. Carleberg is the first who mentions a STEP model as the input to a SFF system [9], and Gilman and Rock have also proposed a framework (an architecture and methodology) that integrates a heterogeneous environment of CAD and SFF systems using STEP [10]. Since then, developing new capabilities of STEP specifically designed for SFF purposes has been research issues around the world [11, 12, 13, 14] and, finally, an RP Interest Group was first formed within the standards organization developing STEP (ISO TC 184/SC4) to consider the requirements for RP data and the possible applicability of the existing STEP standard in 1998 [15].

In this paper, we propose STEP-Slicer, a model slicing paradigm using STEP standard for SFF processes. A tentative framework of working model based on the STEP for carrying SFF process features with part geometry is proposed for constructing CAD/RP interface, and the STEP-based CAD model is visualized, edited, and finally sliced using its own SFF process features.

2. FRAMEWORK FOR CAD/RP INTERFACE USING STEP

In this paper, as shown in the figure 1, a collaborative virtual environment (www.CyberRP.com) is constructed between various CAD softwares and different SFF processes. This environment can help smooth data transfer from CAD to RP by providing appropriate functional modules including visualization and virtual prototyping. In this paradigm of data transfer, people may exchange product models for fabrication using a tentative working model of AP_SIF (Application Protocol for SIF) using STEP. The AP_SIF can be developed based on integrated resource models such as geometric and topological representation (Part 42). It is now over the existing AP203 (Part203: Configuration controlled 3D designs of mechanical parts and assemblies) and provides information about specific SFF process features with the geometry. SFF process features here can be considered as layer thickness, material, and part orientation generally machine-dependent in relative to any specific SFF machine.

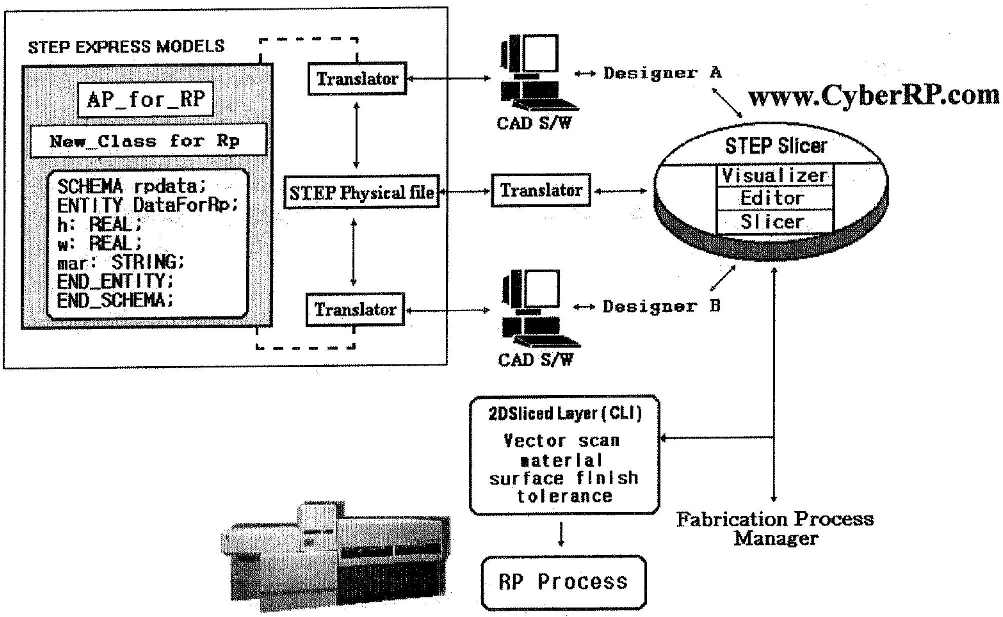

Figure 1. Basic framework for CAD/RP interface using STEP

Since there are many different and distributed SFF machines, these machine-dependent information (called MDI) must be captured by fabricator when the part geometry is translated into appropriate SFF machine process code. In order to do so, CAD softwares must initially assign necessary MDI onto the part geometry before it is translated into AP_SIF for data exchange. Nowadays, there are several different CAD softwares that can create product geometries with different applications. Similarly, most recent SFF processes have quite different capabilities, and most are not even isotropic, so that MDI such as part orientation, position, and size during the fabrication process becomes a crucial issue in integrating a heterogeneous environment of CAD and SFF processes using the data exchange standard. Although all of the SFF processes build one layer at a time, important differences exist among them in the nature of modeling and process planning. One of the most important issues is the layer thickness, which depends on the particular fabrication process. Many SFF processes are executed under a uniform layer thickness and homogeneous material during fabrication so the object geometry is decomposable into uniform sliced layers and, therefore, both the minimum layer thickness and the maximum layer thickness depends on the particular SFF process. In addition, material layer thickness, part orientation, and post process such as curing or unused material removing after the fabrication may also have to be generalized for all possible SFF processes. On the other hand, if the object needs support structures for its layered growth or there are composition variations, a process planning step is necessary to prescribe the orientation of the object and support structure before it is sliced into layers. In this paper, a tentative schema of SFF process features for defining the MDI is proposed as shown in figure 2. This will be compatible with AP_SIF so that they can exchange the information with each other at the time of translation. In the result, the real integration of geometry and the MDI for the fabrication must occur in the stage of 2-D slicing of the geometry (not SIF) after the translation.

As shown in the figure 2, for example, a part name can first be assigned to a part geometry, and the geometry itself can be specified with its dimension, position, orientation, and multiplicity within the physical fabrication space of an SFF process. In the meantime, for practical fabrication, the geometry consists of its own sliced layers (total layer No.) and, similarly, each layer consists of several segments (segment No.). Description of a part geometry will be also compatible with high level design information such as tolerance, surface finish and volume material, and each layer and segment in a part geometry can also be specified with its own SFF process features. Each layer, for example, has its own material index No. different with other layers. Each segment, on the other hand, has its own tolerance depending on its sectional geometry. In addition, depending on each different SFF process, part_support information will be needed in case of SLA process.

```
Part name=pt1

        part spec.:  1. dimension (L,W, H)
                     2. position (x, y, z)
                     3. orientation (i, j, k)
                     4. multiplicity (l, m, n)
                     5. surface finish (f)

        Layer No. =1
                     layer spec.: 1. dimension (t)
                                  2. position (z)
                                  3. material code (m, n, yes/no)

                     Segment No.=1
                                  Seg. Spec.: 1. position (e(q))
                                              2. material code (m, n)
                                              3. process resolution (r, s)
                                              4. part_support (yes/no)
                     End of segment

                     Segment No.=2
                                  •
                                  •
        End of layer

        Layer No.=2
                     •
                     •
End of part
```

Figure 2. A set of SFF process codes for MDI.

3. SLICING METHOD USING STEP-Slicer

STEP-Slicer is developed using OpenGL in Visual C++6.0 environment supported by ST-Developer Version 7.0, a commerical software product of STEP Tools Inc. The system architecture of STEP-Slicer is shown in figure 3. Its initial version first came out of a simple visualization module for STEP physical file, which uses AP203 when representing the part geometric data as many previous approaches did. It is now composed of three modules-visualization, editing, and slicing.

Suppose that a designer creates a CAD model using typically existing CAD tools. The geometry from the CAD tool can be converted into a STEP physical file (preferably AP_SIF) using the translator for export. STEP_Slicer then first reads the STEP physical file, generates an intermediate geometric representation, and quickly displays it to users via 3-D visualization. It, as the second module, also enables a users to edit the geometry-add or remove specific portions of the geometry as well as re-define position, orientation, and dimension of the part geometry for part lay-out within the 3D fabrication space. In most cases, not surprisingly, system users are supposed do these works by themselves unless they are original part designer. Many users, as the most important system feature of all, might want to add high level design information, such as minimum layer thickness, material for fabrication, and surface property, to the geometric design. Those high level design information can be also readily exchanged between different designers or fabricators. In fact, the part geometry is supposed to be sliced into a stack of 2-D layers and translated into machine codes for fabrication using the design information carried by itself. STEP_Slicer enables a user to carry out all these works inside the system. Figure 4, 5, 6 show some implementations that STEP files are read, edited, and sliced for SFF processes. Figure 7 shows an example STEP files built upon a mix of faceted boundary representation, cylindrical surface, and B-spline surface.

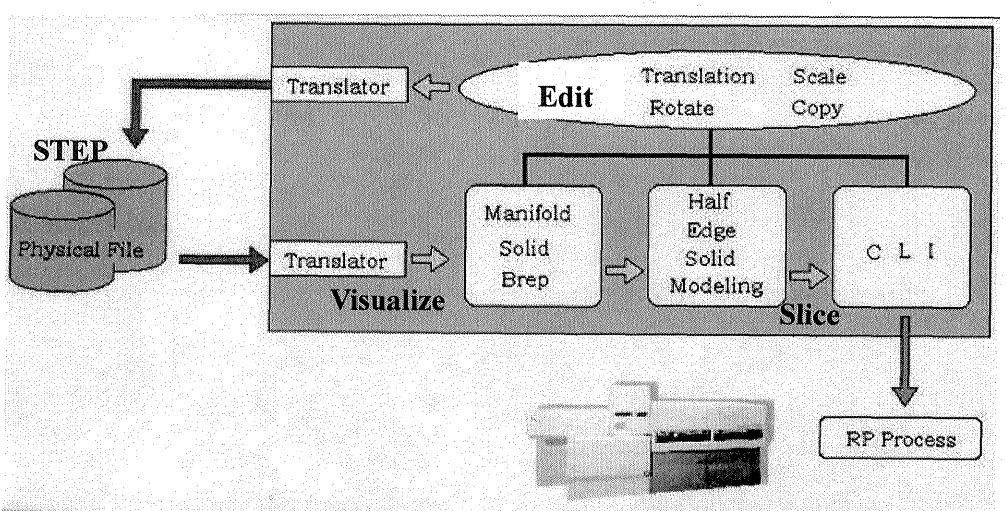

Figure 3. The system configuration of STEP-Slicer

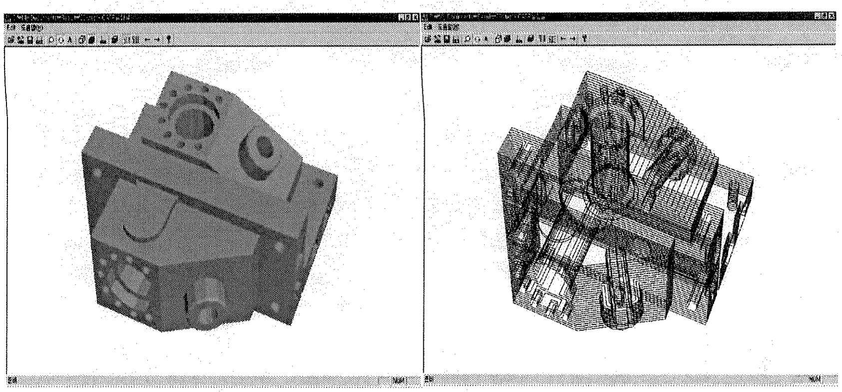

Figure 4. An example of STEP model edition (orientation/ position).

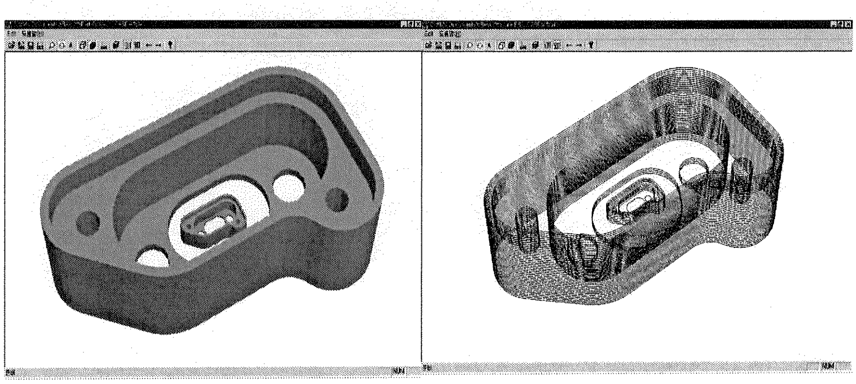

Figure 5. An example of STEP model edition (dimension).

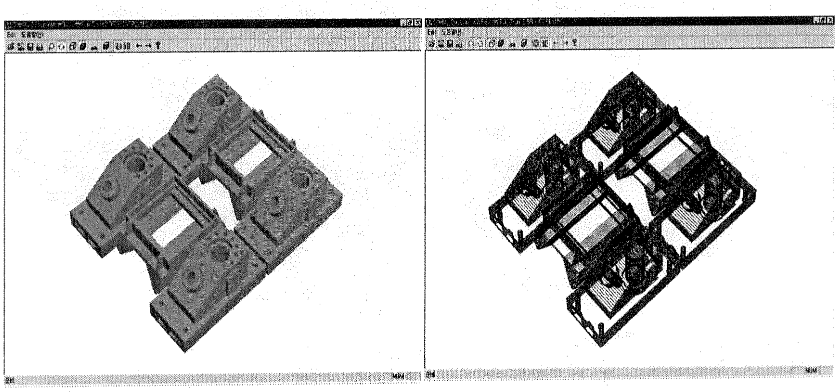

Figure 6. An example of STEP model edition (part layout).

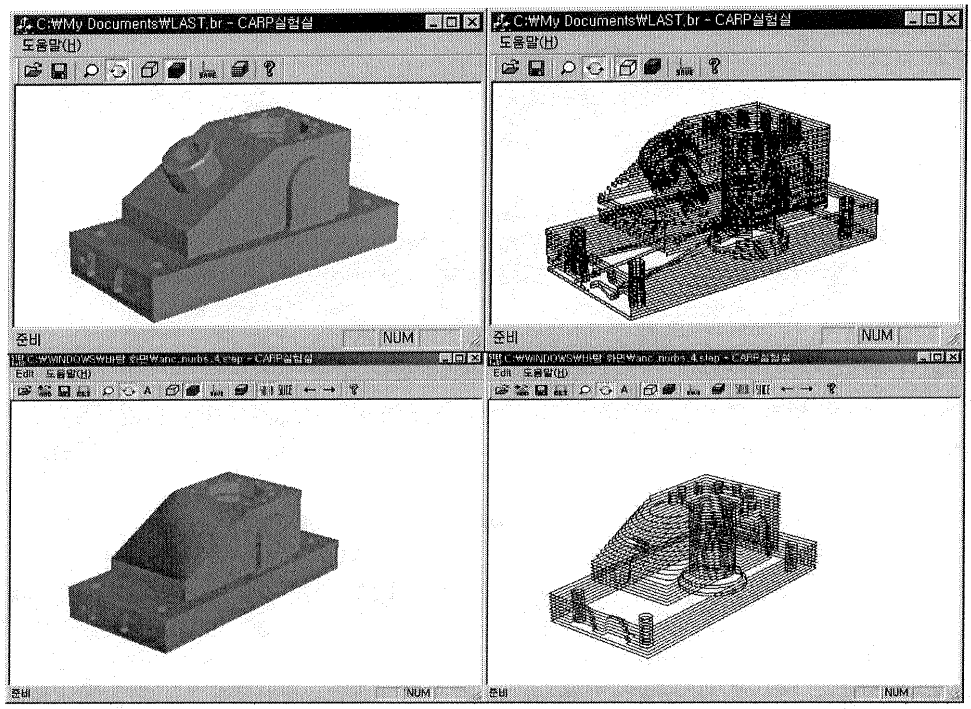

Figure 7. An example of STEP model edition (plane to B-spline suface)

4. CONCLUSION

Solid Freeform Fabrication technologies can create a physical part directly from a computer model. Though STL is current *de facto* industry data exchange standard between CAD models and SFF technologies, it is incomplete in its describing product geometry. STEP is the coming standard. Many major companies are already working with it. This is one of the biggest reason why STEP can be a useful way of exchanging CAD-SFF data. This paper proposes a method of slicing and editing STEP-based RP models for the next generation data transfer paradigm between CAD systems and RP systems using STEP. As the first step for the purpose, this paper propose a basic framework of working model based on STEP with a tentative schema of SFF process features. The new data exchange standard must be compatible with, but independent of, process fabrication features. An implementation of visualizing, editing, and slicing is also proposed based an information for a complete data exchange standard. As for future works, an information model of the schema using a proper modeling language like EXPRESS and AP_SIF, an application protocol for SFF over AP203, will further be developed for the complete new data exchange standard.

5. ACKNOWLEDGEMENTS

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