Rendering of surface-geometries at job-generation level for camouflaging the layered nature of Additively Manufactured parts

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Abstract

The layered nature of Additive Manufactured parts, specifically those given from the Fused Deposition Modelling (FDM) process, exhibit a distinct surface definition. The origin of this is from the 2.5D deposition scheme, which leaves the seam between the individual layers clearly visible.[1] It is proposed to camouflage these layers in order to produce parts with a better visual appeal, and to add functional surface structures. In order to generate such surface structures without adding a challenging computational overhead at job-generation, inspiration from Computer Generated Imaging (CGI) is found. An often used method for visualization of complex geometries within CGI is by producing a geometrical primitive after which the primitive is passed through a renderer.[2] Examples can be geometries with hair, leather structure and their like. Should the entire geometry including surface definition sought to be modelled as one three dimensional surface, the geometrical complexity of this would be of intangible proportions and force even the most modern computer clusters to depletion of computing power. The task is therefore handled with an abstraction layer between 3D geometry and texture. It is here the renderer handles the task of adding the surface to the geometry, as a part of the workflow of generating a deflated 2D image.[3]

1. Proposed approach for surface structuring

A similar workflow is integrated at job-generation level, while preparing a three dimensional form for manufacturing using the FDM process. It is suggested that the slicing engine that processes the input geometry adds a surface structure as part of the job generation workflow, directly implemented in the slicing software. Fig. 1 show the analogy of the task of rendering hair in CGI to the task of surface-structuring a hair-like surface on a physically printed object.

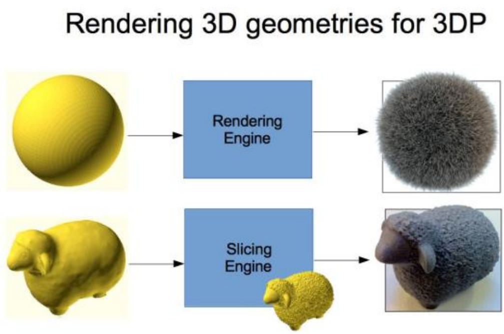

Figure 1: Rendering of hair in CGI compared to the analog of surface-structuring physical objects as part of job-generation.

By adding surface structure (hair, leather, wood, textile etc.) during tool-chain generation the computational load is kept to a minimum, and the strength and widely-accepted workflow from the world of CGI is mimicked. The advantages are: An STL input file that given its structure that is a binary per-vertice mesh description does not need to take up gigabytes in order to hold information about intricate surface structures[4]. Smaller STL files will be much easier to handle with job-preparation and mesh repair softwares. Render based generation of a job-file with embedded tool-paths for surface structuring can thus be generated with comparable speeds to conventional job-files and with structuring that can effectively camouflage the layers on the surface of the manufactured part.

2. Camouflaging of layer-structure

A demonstrator part has been produced at 100 µm layer height, exhibiting both structured and unstructured regions. The part was produced by traditional preparation of a 3D model containing structured and unstructured regions. As such, the job-generation did not benefit from the workflow described above. As seen on figure 2, it is almost impossible to distinguish any fabricated layers of the printed model, in the sections where the wool-like structure is present. However, in the face-region of the model, the layers are evident.

Figure 2: FDM part demonstrating how layer-structure can be camouflaged by surface structuring.

Patterning is tested by visual assessment as a means for camouflaging the layered surface definition of FDM manufactured parts. The ability to camouflage layer definition within surface structure patterns is driven by the mechanism where the human eye tend to interpret primary patterning over higher orders. This interpretation is known as a perceptual illusion. The human brain has a need to see familiar simple surfaces and has a tendency to create a 'whole' image from individual elements.[5] From a study where structured geometries were assessed by a group of test-persons, it could therefore be determined that most surface structures whether chaotic or following a pattern, proved efficient to camouflage the layered surface of the manufactured parts for the observer. There was a correlation between the ability to visually distinguish layers that test persons perceived comparable to that of when searching for repeating patterns in an analog signal with a large signal/noise ratio.

3. Computational load benchmarking

It was by experiments found that computational speedup can be substantial, not needing to read three-dimensional surface structures through the input 3D model. Structure rendering was handled by parallelisation by employing OpenMP, by which a *(2+(n*2))*-threaded slicing algorithm perform a look-ahead to the succeeding slice layer, while a *(2+(m*2))*-threaded boundary structuring thread execute a surface structure render-algorithm to the current slice. OpenMP provides a flexible model for irregular parallelism and allows for parallelization of work that is generated dynamically[6]. Therefore, on a multi-core the implementation will dynamically allocate either *n* or *m* extra cores to perform either task that is ahead based upon a code-race detection check. Abstracting structure from geometry in Additive Manufacturing has in cases where the geometry is extremely simple, such as for objects solely with planar surfaces, eg. boxes or polytetrahedrons, yielded improved job-generation generation times, when texture was rendered during the job generation operation. This with a gain up to 1200% and to an extend where job-generation became a trivial computational task.

4. Discussion and Conclusion

A new way of handling surface structuring to additively manufactured objects has been proposed. This method, with inspiration in CGI imagery, allows for incredibly detailed surface structures to be rendered directly into the job-file at job-generation. The ability to fast render structures into geometry has been proposed to use in order to 'hide' the layer-like surfaces of additively manufactured parts. There is of course many more areas of application than what has been exemplified. The proposed surface-structuring renderer is readily usable as a method for adding part-functionality during job-generation to improve grip, stick, alter appeal, bearing area etc. Finally it is worth to take into account that it is more efficient to deal with 3D modelling of geometries without the need to include surface textures directly in the CAD modelling phase. Mesh sizes has been reduced well over 90% which allow for better handling of the geometry in CAD, and during file preparation procedures such as mesh integrity checks.

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