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Evaluation of an Appearance-Preserving Mesh Simplification Scheme for Configura AB

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1 Introduction

For many years the field of computer graphics has been an important part in many industries, but especially in the entertainment industry (for instance video games and motion pictures). These industries generate a lot of money, and are quickly growing in size. A recent survey by *Kroon and Nilsson* [3] from *Dataspelsbranschen* have shown that the video games industry in Sweden generated €1325 M in revenue in 2016, a steep increase from the €392 M in 2012. Also, most movies nowadays use to some extent 3-D computer graphics in scenes where the cost would be to large to reproduce in reality, be too risky for actors, or simply be impossible.

The rendering of meshes (a collection of polygons describing a surface) is one of the main activities in computer graphics (usually, a collection of meshes; a so called scene description). In many cases, these meshes are very detailed, and require a large amount of polygons to fully describe a surface. This is problematic, since the rendering time of a scene depends on the number of polygons it has. Therefore, it is important to reduce the number of polygons in a mesh as much as possible. This is especially true in video games, where the scene needs to be rendered in real-time. However, if the number of polygons are reduced too much, it will degrade the visual quality of a mesh, giving a progressively flatter surface than intended and removing small surface details. This destroys the intended *geometrical appearance* of the mesh.

1.1 Motivation

While the geometrical appearance of a mesh is important, it is not the only factor which gives the final appearance of a mesh when rendering. According to *Cohen et al.* [1], both the surface curvature and color are equally as important contributors. *Textured appearance* will be used as the common name for these since surface properties are usually specified with a texture map.

In computer graphics, the process to reduce the number of polygons in a mesh based on some metric is called a *mesh simplification algorithm*, as seen in *Talton's survey* [5] on the subject. Historically, these have been mostly concerned with minimizing the geometrical deviation of a mesh when applying it. Somewhat recently, methods for minimizing the texture deviation when simplifying a mesh have also appeared. They attempt to reduce the texture deviation and stretching caused when removing polygons from a mesh, as described in *Hoppe et al.* [2].

By simultaneously taking into account the geometrical and texture deviation, one can preserve the *visual appearance* of a mesh when simplifying it. If polygons can be removed without affecting this appearance significantly, the rendering time can be reduced for "free".

1.2 Aim

To survey the field for state-of-the-art mesh simplification algorithms that preserve the visual appearance of a mesh, and integrate these into *Configura's* (see Section 1.5) graphics pipeline. This will enable Configura to generate better *Level of Detail* (LoD) meshes for speeding up their rendering time. Currently, Configura only takes into account the geometrical deviation when simplifying, with no regard for the textures (e.g. diffuse or normal) on top of the mesh.

Thereafter, we plan to evaluate each of these solutions by measuring their performance and ability to preserve the meshes' original appearance. In the end, the goal is to find the mesh simplification algorithm which both performs and preserves the mesh appearance well.

1.3 Research Questions

After implementing and measuring the performance of these mesh simplification algorithms, answers to the questions below should have been obtained. These will be used to decide on a suitable alternative for Configura and also other systems with a similar set of requirements.

1. What alternative *mesh simplification schemes* exist that *preserves the appearance* of a mesh?
2. Which of these alternatives give the best *performance* and *appearance preservation*? When:
   a) Measuring the algorithm's *computation time* while targeting an *appearance threshold*?
   b) Measuring the algorithm's *memory usage* while targeting some *appearance threshold*?
   c) Measuring the real-time *rendering time* of the LoD-hierarchy of the *simplified mesh*? (by using the meshes generated according to the target *appearance threshold* above)
3. Which of the alternatives gives the best *appearance preservation* for a target *polygon count*?

1.4 Delimitations

Since there are many mesh simplification algorithms in previous work, a proper literature review would have to be done to find possible candidate solutions. Since our thesis' goals are mostly concerned with implementing and evaluating each solution, we have decided to base our choices on existing surveys and literature reviews to skip doing some of these ourselves.

Also, since implementing and doing measurements on all algorithms would take too long, we have decided to only pick an interesting subset of the algorithms presented in the surveys. More precisely, we have chosen to pick three different mesh simplification algorithms, one that does not take texture deviation into account and two that do. In addition, we will also compare them to Configura's existing mesh simplifier scheme; for a total of four algorithms.

1.5 Background

This thesis was requested by Configura AB, a company in Linköping which provides space planning software. Their main product, *CET designer*, lets companies plan, create and render 3-D office spaces (among other things). These scenes can have a large amount of polygons that need to be rendered in real-time for customers to evaluate their creations in CET designer.

To allow larger scenes to be rendered with higher frame-rates (e.g. needed when exploring environments in *Virtual Reality* (VR), to prevent motion sickness), it would be beneficial to reduce the amount of polygons as much as possible. The meshes in these scenes usually have textures applied to them, and it is therefore important to keep the quality as high as possible.

While Configura already has a mesh simplification in their pipeline, it only accounts for surface simplifications, and doesn not take into account the texture appearance that might be degraded when applying mesh simplification. Hence, the given task was to integrate a new mesh simplification scheme that takes into account texture quality when simplifying a mesh.

2 Theory

Since several mesh simplification algorithms are being considered, Section 2.1 presents the most notable schemes found (through peer-reviewed surveys) in previous work. An outline of the algorithm and the results found by authors are given for the reader's convenience, and also to be used as a guideline when implementing the solutions into Configura's CG pipeline.

Afterwards, in Section 2.2, we discuss the different metrics that can be used to measure the appearance preservation after a simplification has been done. This will later be used to evaluate the solutions and provide an empirical way to answer research questions 2 and 3 by giving a concrete metric for appearance thresholds and the amount of appearance deviation.

Finally, in Section 2.3, the methods and common practices for measuring performance of an algorithm are discussed. Based on existing industry practices, we show how to measure the computation time and memory usage of the algorithms. Since these measurements can be noisy, statistical methods will need to be used to truthfully answer our research questions.

2.1 Mesh Simplification

According to *David Leubke's survey* [4] on the subject, mesh simplification is a technique which transforms a geometrically complex mesh (with a lot of polygons) to a simpler representation by removing unimportant geometrical details (reducing the number of polygons). It does this by assuming that some meshes are small, distant, or have areas which are unimportant to the visual quality of the rendered image. For example, if the camera in a scene will always face a certain direction, then we can safely remove all details on the back-side of the meshes.

Quadric-Based Error Metric

Appearance-Preserving Simplification

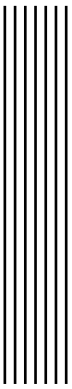
Texture Mapped Progressive Meshing

Given an arbitrary mesh, Hoppe et. al [2] presents a method to construct a *progressive mesh* (PM) where a texture parametrization is shared between all meshes in a PM sequence. In order to create a texture mapping for a simplified mesh, the original mesh's attributes, e.g normals, is sampled. This method was developed with two goals taken into consideration:

- Minimize *texture stretch*: When a mesh is simplified the texture may be stretched in some areas which decrease the quality of the appearance. Since the texture parametrization determines the sampling density, a balanced parametrization is prefered over one that samples with different density in different areas. The balanced parametrization is obtained by minimizing the largest texture stretch over all points in the domain. No point in the domain will therefore not be too stretched and thus making no point undersampled.
- Minimize *texture deviation*: Conventional methods use geometric error for the mesh simplification. According to the authors this is not appropriate when a mesh is textured. The stricter texture deviation error metric, where the geometric error is measured according to the parametrization, is more appropriate. By plotting a graph of the texture deviation vs the number of faces, the goal is to minimize the heighf of this graph.

2.2 Metrics for Appearance Preservation

2.3 Measuring Algorithmic Performance



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