Interactive Synthesis and Visualisation of Vast Areas with Geometrically Diverse Trees

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Thesis summary

This paper summarises a Doctoral Thesis which proposes a new approach for large-scale forest visualisation with geometrically diverse trees. The main contribution of the proposed method is an interactive visualisation of numerous trees without generating geometric data in advance, which is achieved by a new method for on-the-fly tree skeleton synthesis with a specific level of detail, and by a new procedural volumetric tree crown visualisation which avoids geometry formation altogether. The proposed method enables visualisation of forests with millions of trees, thus allowing rendering more trees than geometry-based visualisation methods.

Povzetek: Prispevek povzema doktorsko disertacijo, ki predlaga nov pristop za upodabljanje obsežnejših gozdov z geometrijsko raznolikimi drevesi. Glavni prispevek predlagane metode je interaktivno upodabljanje večjega števila dreves brez potrebe po vnaprej pripravljenih geometrijskih podatkih, kar dosežemo z novo metodo za sprotno tvorbo okostij dreves v določenem nivoju podrobnosti in z novo metodo za volumetrično upodabljanje krošenj dreves, ki se v celoti izogne tvorbi geometrijskih podatkov. Predlagana metoda omogoča upodabljanje gozdov z milijoni dreves in tako omogoča upodabljanje večjega števila dreves kot metode na podlagi vnaprej pripravljenih geometrijskih podatkov.

1 Introduction

Trees are natural objects which consist of numerous leaves and branches. Various applications require convincing visualisation of vast areas with trees. In contrast to artificial objects, which consist mainly of flat surfaces, trees are geometrically more complex and require significant amounts of memory for geometric representation. Therefore, large-scale visualisation of geometrically diverse trees is challenging, due to memory constraints. Numerous techniques for forest rendering were developed in the past [1], which only partially address these issues through various techniques (e.g., instancing, pre-processing, or parallelisation).

This paper summarises a PhD thesis [2], which proposes a comprehensive pipeline for large-scale synthesis and visualisation of geometrically diverse trees. The main findings are published in the corresponding paper [3]. The following sections summarise the proposed approach, the main results and findings.

2 Overview of the proposed method

The main aim of the proposed approach is interactive visualisation of numerous geometrically diverse trees while navigating through the forest. In order to achieve convincing visualisation of nearby trees, the nearest trees need to be visualised at the highest level of detail. In contrast, more distant trees can be visualised at lower levels of detail with lower memory requirements. However, in the case of millions of trees, geometric data of at least the most distant trees need to be omitted altogether due to memory limitations.

The trees in the proposed approach are generated procedurally by a new tree synthesis algorithm, based on a particle flow simulation, which generates tree skeletons of branches and leaves. The target tree structure is defined by a tree crown envelope and a few parameters, which define the branching pattern. The generated tree skeletons are visualised by generating actual geometric data directly on a Graphics Processing Unit (GPU).

In order to generate more distant trees without post-processing directly at lower levels of detail, multiple simplification schemes are introduced and integrated directly into the tree skeleton construction. However, tree synthesis needs to be fast, in order to achieve low latency of on-the-fly tree synthesis while navigating through the forest. Therefore, a new parallel tree synthesis algorithm for direct execution on the GPU is proposed, which is designed specifically for parallel tree synthesis of numerous trees.

To avoid geometry formation of the most distant trees completely, the thesis proposes a new procedural volumetric visualisation algorithm of tree crowns within the graph-

ics pipeline. Based on the defined tree crown envelopes, the volumetric visualisation method achieves identical appearance in comparison to the geometry-based visualisation. In this way, visual continuity is preserved when switching between the geometry-based and volumetric visualisation.

Finally, a new quad tree based framework is proposed, which integrates tree synthesis and visualisation algorithms to enable interactive visualisation and on-the-fly synthesis of the nearest trees while navigating through the forest.

3   Results

The proposed method was verified in terms of the tree synthesis duration, forest rendering rates, interactivity when navigating through forests, and similarity preservation of trees generated at lower levels of detail to the trees generated with the highest level of detail. Forests consisting of 400,000 branch segments were generated in less than 25 ms on the GPU Nvidia GTX 1060 with 4 TFLOPS of processing power, which enables generating larger numbers of trees between individual frames and preserving interactive rendering rates. Generating the trees with the lower levels of detail accelerated the synthesis even further, and enabled higher rendering rates. Additionally, the proposed simplification schemes generally achieved a gradual transition of similarity with the lower amount of memory. Hausdorff distance and precision and recall metrics, which were used for calculating similarity, agreed with these findings.

Performance of the geometry-based rendering was related closely to the amount of branch segments and leaves. In contrast, procedural volumetric rendering outperformed geometric rendering at a higher number of leaves or at a lower rendering resolution, which coincides with the visualisation of more distant trees. Overall, the proposed framework achieved stable rendering rates of more than 12 frames per second when displaying forests consisting of one million of trees.

4   Conclusion

The PhD thesis [2] has proposed a new comprehensive forest visualisation method, which enables detailed visualisation of close up trees and large-scale visualisation of distant trees without requiring the existing tree geometry. Procedural volumetric rendering is useful, especially for visualisation of distant trees, while a combination of tree skeleton synthesis and geometric rendering is used for the nearest trees.

References

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