Review Statement for Věra Skorkovská's Doctoral Thesis
"Modeling of Errosion Impact on Geometric Objects"

As the reviewer nominated by University of West Bohemia I respectfully make the following statement concerning the doctoral thesis of Mrs Věra Skorkovská, submitted for the fulfilment of the requirements of the PhD degree in Computer Science and Engineering. I consider the following details of the thesis: the position in the research field, fulfilment of specified goals, originality, formal criteria and contributions, including also the candidate's publications.

This thesis investigates the methods for erosion simulation as a specific and important problem in Computer Graphics. It focuses on weathering and hydralic erosion. The goal is to extend the state-of-the-art methods and develop novel methods for eroded objects represented as triangular meshes. The candidate identifies new problems related to mesh modifications such as inconsistency and treatment of objects composed of multiple material layers.

Thus, the topic of the thesis is very well motivated. The candidate motivates the proposed approaches by describing the shortcomings of the current approaches and shows experimentally that the novel approaches are efficient and applicable in various scenes and state-of-art simluation techniques.
As a conclusion, the topic is appropriate to the particular area of the dissertation and it is up-to-date from the viewpoint of the present level of knowledge.

The thesis consists of 12 chapters plus summary and conclusion part. The first part of the thesis (chapters 1-6) shortly introduce the research field, defines the focus of the work and describes the various approaches to erosion simulation. In the second part starting at chapter 7, the objectives are presented clearly either as research challenges followed by specific contributions. Research results include 3 core methods for erosion (hydraulic erosion, curvature-driven approach, multi-material approach), robust approach for computation of meshes intersections and erosion-inspired simulation of aging. The methods were implemented, thoroughly tested and published.

Question for defence:
Explain the distance functions 11.2 and 11.3. What is the origin of it, can it be used in general?

Based on the considered matters and published papers, I claim that the work is original and contains a sufficient contribution to the area.

Related to the thesis, the candidate has published two journal articles in Computer Graphics Forum, and Computers& Graphics, the second as the first author with major contribution ratio. List of publications also include 6 conference papers, candidate was the first author in 5 papers. The candidate has proven to be able to co-operate efficiently with other scientists.

As a conclusion, the doctoral thesis has been published at an appropriate level and *the candidate has published actively.*

The candidate has shown a good understanding of the key issues in the research field. The thesis contains contribution to knowledge in the field of natural-phenomena simulation for computer graphics. There are many references to related work, research problems are considered properly, and there are several scientific papers published based on the results of the thesis.

Based on the considerations presented in this review statement I conclude that the doctoral thesis meets the requirements of the proceedings leading to the PhD title conferment and I recommend it for defence.

Brno, 20.5.2019

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Ph.D. Dissertation Review

Author of the dissertation: Ing. Věra Skorkovská
Title: Modeling of Erosion Impact on Geometric Objects
Review written by: doc. Ing. Jiří Bittner, Ph.D.

The Ph.D. thesis of Věra Skorkovská deals with methods for erosion simulation using triangle meshes. The work consists of fourteen chapters and one appendix. The chapters discussing core contributions are based on already published work. The dissertation puts the content of these papers into a single document with unified formatting and style to with the aim of providing a consistent document on the presented topic.

The introductory part of the thesis (chapters 2 to 6) provide a compact informative introduction to erosion modeling, 3D fluid simulation, data structures for erosion modeling, mesh repair methods, and material representation. The core of the thesis consists of chapters 8 to 12 and covers the following areas: hydraulic erosion modeling on a triangular mesh (chapter 8), curvature driven approach for weathering and hydraulic erosion simulation (chapter 9), robust mesh intersection computation (chapter 10), multi-material dynamic simulations (chapter 11), erosion-inspired simulation of aging (chapter 12). The common focus of all these chapters is the idea using triangular meshes for erosion modeling and simulation on different scales ranging from terrains to smaller objects.

Chapter 8 describes a technique for modeling hydraulic erosion using a triangular mesh. The method is based on calculating the vertex displacement so that the resulting volume represented by the mesh corresponds to the amount of eroded or deposited material. The work contains an indirect visual comparison to a reference method of Kristof et al. [Kri+09].

Chapter 9 models weathering and hydraulic erosion using curvature estimation combined with the Laplace-Beltrami operator. Uniform discretization of Laplace-Beltrami operator is used to compute a displacement vector, and the mean curvature is used to compute the displacement magnitude. The displacement magnitude is evaluated differently depending on whether weathering or hydraulic erosion is simulated. The results show weathering applied on smaller scale objects (Stanford bunny, hand model) and hydraulic erosion on smaller scale object as well as larger terrain. Visual comparison to a reference method of Tychonievich and Jones [TJ10] is provided.

Chapter 10 presents a robust method for computing mesh intersection. The method is based on computing the intersection boundary, followed by a mesh fixing step. Unlike previous work, the method uses floating point arithmetic and careful classification of possible error cases, which makes the method potentially much more efficient than techniques based on the arbitrary precision arithmetic.

Chapter 11 presents a technique for representing multi-material scenes using BSP trees. The results evaluate two multi-material models (Cave and Tooth) converted to BSP representation using iso-surface extraction.

Chapter 12 presents an erosion inspired simulation of wrinkles on a human face. The method uses control points defined by the user. The proposed method automatically connects the control points with wrinkle curves that are used to compute local mesh subdivision followed by (inverse) erosion step that inflates the mesh in the nearby the wrinkle curves. Indirect visual comparison to the method of Wang et al. [WWY06] is shown.

The thesis presents a set of methods for using triangular meshes for erosion modeling. The dominating data representation in this area is either the layered representation or the regular volumetric representation. The work of Mrs. Skorkovská provides fresh, innovative ideas into this topic and shows that using triangular meshes is a viable alternative in this context. I see a great potential of the proposed methods in simulations applied on larger scenes where the mesh can be used to adaptively focus the detail of the representation towards the eroded regions. The work also deals with the mesh inconsistency issues that arise in the dynamic mesh simulations. Having an efficient and robust mesh repair algorithm at disposal is an important practical obstacle for wider usage of mesh-based simulations. The method for repairing mesh intersections proposed in the thesis uses fast floating-point arithmetic for solving this issue and is an important part of the presented work.

As a weaker point of the thesis, I consider the evaluation of the proposed methods and in particular missing direct comparisons to other alternative techniques. I would like to see more side by side visual comparisons of the proposed methods with some state-of-the-art alternatives applied on the same model rendered from the same angle (the thesis gets quite close to this in Figure 9.11). Also, a direct comparison of the computational efficiency of the proposed methods with the alternatives would give a clearer picture about their practical potential. On the other hand, I understand that evaluating the alternative approaches is complicated as most of these are not open source and require significant implementation effort.

The thesis is written with care using very good English. The overall structure is very good, the summary of contributions and conclusions give a good overall picture about the work. The thesis contains a number of helpful illustrative figures both in the introductory part as well as in the core parts of the thesis. The methodology used corresponds to scientific standards and is correctly rooted in the related work.

The work presented at the thesis was already published in several papers. The publication list includes one journal paper and five conference papers, where Mrs. Skorkovská was the first author. She was also a co-author of one additional journal paper and one conference paper on closely related topics. During her studies, Mrs. Skorkovská conducted three research visits at Purdue University that lead to common publications with prof. Benes who is one of the most recognized researchers in the field of natural phenomena simulations.

Overall, it was a pleasure to read the thesis. The work of Mrs. Skorkovská provides several novel ideas that advance current the state-of-the-art in mesh-based erosion simulation. I have no doubts that the author of the dissertation proved the ability to conduct research and achieve scientific results. I do recommend the thesis for the presentation and defense with the aim of receiving the Ph.D. degree.

Questions for the defense:

1. How would you compare the efficiency of the methods from chapters 8 and 9 to the stack-based representation commonly used for terrain modeling?
2. Are there some cases in which the algorithm for mesh intersection presented in chapter 10 fails?
3. How would the BSP representation presented in chapter 11 be used for dynamic simulations? Can you provide some performance estimations for such an application?

Prague 28.6. 2019 doc. Ing. Jiří Bittner, Ph.D.