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Ålesund, 19th March 2020

Dear Professor Jan Trlifaj
Vice-Dean
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Subject: Habilitation of Dr. Martin Kruliš

Please consider the enclosed review of the scientific quality of the Dissertation Dr. Martin Kruliš.

Sincerely,



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Review on the dissertation:

“GPU-Accelerated Methods for Content-based Retrieval” by Dr. Martin Kruliš, Charles University.

This dissertation addresses the problem of supporting the creation of efficient content-based image retrieval systems. Most of the described research outcomes focus on the proposal of GPU-based solutions aiming at increasing the efficiency performance (i.e., reduce response time) of image search services. Different areas of study in Computer Science are addressed, including among others Databases, Information Retrieval, Image Processing, and High-Performance Computing.

This dissertation introduces original contributions related to the proposal of novel GPU-based approaches to support similarity computation, content-based feature indexing, content-based feature extraction, and image denoising. The conducted research has been involved with relevant and complex topics, and contributed to advance the state of art in different computer science areas. The described research has been associated with original outcomes and opens novel opportunities for further investigation. In fact, several different applications may take advantage of the research outcomes described in this dissertation. Some examples include multimedia data classification, multimedia recommendation, and pattern recognition.

The dissertation is organized in ten chapters. This is a concise document, whose organization covers the main scientific contributions achieved. Most of the chapters are associated with articles published in selective venues (either conference proceedings or journals). The introduction of the dissertation provides a summary of the main topics covered in the conducted research, as well, points out the papers with which they are associated. Chapter 2, in turn, details the scientific contributions. From Chapter 3 to Chapter 9, different scientific contributions are presented, following a typical organization found in papers: introduction, overview upon related work and background concepts, description of the proposed approaches, discussion and analysis of experiments, and presentation of conclusions and possible future work. Finally, the last chapter, Chapter 10, summarizes the main scientific achievements and points out possible research directions concerning the use of parallel solutions for handling large volumes of multimedia data.

In the following, the content of each chapter is summarized, highlighting its main contributions:

- Chapter 1 covers motivational aspects and introduces the target problems and associated faced challenges. This chapter also presents the main objectives, the key ideas and concepts handled in the conducted research. The dissertation organization is also outlined.
- Chapter 2 provides contextual information and describes the main scientific contributions of the work. This chapter provides a big picture of the main achievements, which are described very carefully later on in the dissertation. The main addressed topics related to multimedia retrieval issues are also introduced. These concepts are very important as they provide contextual information that is necessary for understanding the proposed approaches.

- Chapter 3 introduces the first contribution of the dissertation: a novel approach, based on the combination of GPU and CPU to support the execution of similarity searches. The main focus was on the acceleration of the computation of the Signature Quadratic Form Distance (SQFD). SQFD-like distance functions are widely used in the content-based multimedia retrieval area. This contribution, therefore, is relevant for the area. Another positive aspect of this research venue relies on the combination of acceleration approaches with the use of indexing schemes, a subject often overlooked in the literature.
- Chapter 4 addresses the second contribution of the dissertation: the proposal of parallel approaches to processing matrix-based dynamic programming algorithms. This is a relevant research, as it opens the possibility of accelerating costly edit distances, widely used in similarity searches in different applications.
- Chapter 5, in turn, is dedicated to the acceleration of k-nearest neighbour (KNN) searches, by converting the problem to the one related to the execution of multiple parallel range queries. Again, a metric indexing context is considered. The idea of processing KNN searches by means of fast parallel processing schemes is an original strategy exploited in this work.
- Chapter 6 is also concerned with indexing-related problems. The goal here is to support approximate searches based on a permutation-based indexing scheme. The proposed parallel (GPU-based) solution advances the state of the art by allowing the efficient construction of such indexing structures.
- Chapter 7 describes research outcomes that advance the study of parallel solutions for permutation-based indexing problems. The main contribution of this work is the assessment of computational costs of different steps of the permutation-based index construction, considering large volumes of high-dimensional data. The employed approach relies on an original hybrid CPU-GPU solution.
- Chapter 8 refers to studies targeting to speed up the content-based feature extraction process. The GPU-based feature extractor is demonstrated to handle million-size image collections, opening new possibilities of using parallel architectures for applications dealing with huge volumes of data.
- Chapter 9 focuses on a different problem: image denoising. Again, a GPU-based solution is proposed. The goal is to speed up one of the most popular algorithms proposed for noise filtering, the block-matching and 3D filtering (BM3D) algorithm. The proposal is sound and potentially of high impact for different applications dedicated to noise filtering based on the computation of the similarity of image blocks.

- Chapter 10 provides the conclusions and draws possible future work. Advantages and limitations of the proposed methods are presented. Future research directions are promising and also serve to confirm the originality and the versatility of the conducted studies.

In summary, my evaluation is positive with regard to the presentation of this dissertation. This dissertation addresses very complex research topics, by proposing technically sound solutions. Practical original contributions to the area of multimedia retrieval are provided. Many of them can be adapted or extended to several other problems, which opens novel opportunities for future investigation.

Dr. Martin Kruliš has demonstrated commitment to research and scholarly activities evidenced by the development of substantive research in Computer Science, especially in the multimedia retrieval area. Dr. Martin Kruliš has also continuously provided the results of his research by means of articles published in very selective and high-impact peer-reviewed journals and conferences.

The examples provided in this dissertation represent a substantial body of work, which a positive impact to the areas of multimedia retrieval. According to the Scopus citation database (<https://www.scopus.com/> – As of March 2020), 36 documents co-authored by Dr. Martin Kruliš received a total of 97 citations, leading to a h-index score equal to 6. Special attention was given by the image retrieval community to the paper “*Combining CPU and GPU architectures for fast similarity search*”, with 20 citations; and to the paper “*Efficient extraction of feature signatures using multi-GPU architecture*”, with 15 citations. A similar citation record is observed in the Google Scholar system (<https://scholar.google.com.br/citations?hl=pt-BR&user=4KpPe0sAAAAJ> – As of March 2020). According to Google scholar, a total of 210 citations were observed, with a h-index equal to 9.

In summary, Dr. Martin Kruliš has been very productive in his research activities. Dr. Martin Kruliš also has demonstrated the analytical skills to diagnose problems and devise suitable solutions by developing innovative scientific research in an independent manner. From my point of view, Dr. Martin Kruliš has all the potentials in becoming a distinguished research leader.