ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

ERCIM
European Research Consortium
for Informatics and Mathematics

Scientific Report

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Nationality	Spanish
Name of the *Host Organisation*	Fraunhofer – Institute for Integrated Circuits
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Period of the fellowship	04/12/2014 to 03/12/2015

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

My research activity at Fraunhofer IIS – Institute for Integrated Circuits (Erlangen, Germany) – has been focussed on the acceleration of coding technologies for movie post-production tools used in Digital Cinema. The aim has been to harness the power of Graphics Processing Units (GPUs) as massively parallel devices (a.k.a. GPU computing) in order to enable the generation and playback of Digital Cinema Packages (DCP) in, or even faster than, real time.

Today, the most time-consuming part in post-production workflows is the coding of frames to - and decoding from - JPEG 2000 files. Specifically, the most challenging aspects of my research involve a block within JPEG 2000 coding architecture named EBCOT (Embedded Block Coding with Optimal Truncation), which is the current bottleneck given its high computational complexity and high memory requirements. Basically, it consists of two stages: tier 1 generates the whole compressed image by using a context modeller and an entropy coder, and after that, tier 2 truncates the image at an optimal point (distortion versus length) to fit the desired bitrate.

Fraunhofer's software tools for digital cinema already include a fast JPEG 2000 codec, which is optimized for GPUs with NVIDIA CUDA from Fermi architecture. Hence, my research was twofold: on the one hand, to deploy more steps of the workflow (rather than coding) to the GPU, so that we can release the CPU from these tasks; and on the other hand, to further optimize and accelerate the already existing JPEG 2000 GPU-based encoder. It is worth to mention that my contributions have been implemented within these software tools, so they are really going to be used by customers worldwide.

In summary, the main contributions of my scientific activity during my ERCIM fellowship are:

1. Analysis and identification of opportunities to stop the encoding prematurely in JPEG 2000. One drawback of EBCOT is that it needs to first generate the whole compressed image at tier 1 before truncating it to the desired bitrate at tier 2. This leads to a loss of time and memory, which normally holds when working with certain 4k sequences and also at low bitrates. For this reason, there is a plethora of heuristics in the literature to identify in advance when a frame is going to be trimmed, so that we can stop its encoding earlier. However, these techniques are designed for sequential encoders, and not for parallel ones. Thus, I have defined three new methods to be used in parallel encoding. Although they have a strong trade-off between quality and performance, the achieved peak speedup is up to 20% with a loss of 3dB. I have implemented them in the GPU-based encoder, for which I redesigned the way to proceed in the EBCOT implementation so that the execution can be now stopped at a certain point, when the heuristic condition holds. This redesign also had a good side effect: it allows to reduce auxiliary memory and to overlap the execution of code on the GPU. This leaded to an extra speedup of up to 36% when coding 4k images.
2. Optimization of EBCOT on the GPU. The key enhancements were made to the context modeller at tier 1, for which I redesigned the already implemented

algorithm by using parallel patterns and reducing memory requirements. Compared to the starting version, a 40% of overall speedup was obtained for 2k image coding, and 25% for 4k.

3. Implementation on the GPU of two phases of the workflow for generating DCPs, which take place right before JPEG 2000 encoding: image resizing, cropping, letterboxing, watermarking as well as subtitle burning. These new features are now available in the software tools.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

Since I had to switch my research line at Fraunhofer IIS, keeping my expertise in GPU computing but requiring time to get familiar with JPEG 2000 and the framework of Fraunhofer's software tools for Digital Cinema, the main results have been obtained at the end of the year. However, we plan to publish some of the main contributions during 2016.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

I have attended the conference IBC 2015 (International Broadcasting Convention) in Amsterdam, in September 2015. I was at Fraunhofer Alliance Digital Media's booth, interacting with customers. I have also visited other companies and sessions to learn the state of the art in Digital Cinema, and multimedia content in general.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

I visited the Norwegian University of Science and Technology (NTNU) in Trondheim (Norway) from June 22 to June 26 2015, under the supervision of Anne C. Elster. During the REP, I was able to exchange ideas with her and most of the members of her *HPC-Lab* group. Specifically, I learned how to apply some of the parallel techniques I used in the second block of my contributions. I also gave a seminar entitled "GPU accelerated encoding of JPEG 2000 frames for Digital Cinema", in which I explained our current research challenge, and opened a discussion session with attenders where I got also several ideas.