Scientific Report

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Period of the fellowship	01/05/2013 to 30/04/2014

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

Driven by a significant technological progress during the last decade, the usage of the Internet applications, such as video conferencing, video streaming, Web-based video monitoring, and the like, has dramatically increased. In addition, the availability of relatively inexpensive heterogeneous devices (e.g., smartphones, tablets) has further supported the dramatic spread and high popularity of such applications.

In order to allow such enormous video content transfer over the network, efficient video compression methods should be employed. Especially, it is very critical for the delivery of High-Definition (HD) and Ultra-High Definition (UHD) video content, the demand for which is also expected to dramatically increase in the near future (it is noted that that the term UHD often refers to both 3840x2160 (4K) or 7680x4320 (8K) resolutions in terms of luma samples).

Major milestones in the evolution of video coding standards are the well-known H.262/MPEG-2 Video and H.264/MPEG-4 Advanced Video Coding (AVC) standards, the development of which was coordinated by the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Pictures Expert Group (MPEG). The H.264/MPEG-AVC standard successfully achieved an increase of about 50% in coding efficiency compared to its predecessor H.262/MPEG-2 Video. H.264/MPEG-AVC was designed for both low- and high bit-rate video coding in order to accommodate the increasing diversification of transport layers and storage media. However, both H.262/MPEG-2 Video and H.264/MPEG-AVC video coding standards, at least their first editions, were not initially designed for the HD and, especially, UHD video content. As a consequence, ITU-T VCEG and ISO/IEC MPEG established a Joint Collaborative Team on Video Coding (JCT-VC) and issued a joint call for proposals (CfP) on video coding technology in 2010, which in turn led to an intensive development of the so-called High-Efficiency Video Coding (HEVC) standard during the next two and the half years. The first edition of HEVC was officially finalized in January 2013, and after that, the final aligned specification was approved by ITU-T as Recommendation H.265 and by ISO/IEC as MPEG-H, Part 2 [6].

The H.265/MPEG-HEVC standard was designed to be applicable for almost all existing H.264/MPEG-AVC applications, while putting an emphasis on the high-resolution video coding. Since the development process of H.265/MPEG-HEVC was also driven by the most recent scientific and technological achievements in the field of video coding, dramatic bit-rate savings were achieved for substantially the same visual quality, when compared to its predecessor H.264/MPEG-AVC.

As a result, based on the above observations, the Fellow was involved in researching the HEVC-based encoding/decoding techniques and algorithms, with an emphasis on the real-time applications. It should be noted that in order to enable real-time encoding and decoding (substantially without any noticeable delay), significant modifications should be introduced within the encoder and decoder, respectively, especially due to the fact that one of the HEVC target applications is coding ultra-high resolution video (so called, 4K and 8K-resolution video).

In addition, the Fellow performed detailed comparison of the above-mentioned latest video coding standards H.264/MPEG-AVC and H.265/MPEG-HEVC, as well as the recently published proprietary video coding scheme VP9, which was developed by Google® Inc. It should be noted that in parallel with the open video coding standardization processes of ITU-T and ISO/IEC, a few companies individually developed their own video codecs, which often were based partly on their own secretly kept technologies and partly on variants of the state-of-the-art technologies used in their standardized counterparts, available at that time. One of these kind of proprietary video codecs is the VP8 codec, which was developed privately by On2 Technologies® Inc. that in turn, was later acquired by Google® Inc. Based on VP8, Google® Inc. started the development of its successor VP9 in 2011, which was announced to be finalized in 2013. The results of the above-mentioned detailed comparison were presented by the Fellow at the Picture Coding Symposium (PSC) in San-Jose, USA (December 2013), as an Oral Presentation, which had a lot of interest from many industry and academy members. In turn, an additional related work (for low-delay applications) was submitted to the International Conference on Image Processing (ICIP 2014).

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

1) Grois, D.; Hadar, O.; Marpe, D., "Network-optimized adaptive SVC-based live video streaming," *Consumer Electronics Berlin (ICCE-Berlin), 2013. ICCEBerlin 2013. IEEE Third International Conference on*, pp.352,354, 9-11 Sept. 2013.

   Abstract: In this work, a network-optimized live scalable video streaming scheme with adaptive preprocessing is presented, while showing significant improvements in visual quality. According to the proposed scheme, an adaptive pre-filter is applied prior to encoding each Scalable Video Coding (SVC) layer, while each pre-filter parameters are dynamically adjusted according to varying network conditions, such as the network Round Trip Time (RTT) and packet loss ratio, thereby enabling to continuously obtain an optimal visual quality at the decoder side. The performance of the presented scheme is evaluated and tested in detail, thereby demonstrating a significant gain of up to 5dB.

2) Grois, D.; Marpe, D.; Mulayoff, A.; Itzhaky, B.; Hadar, O., "Performance comparison of H.265/MPEG-HEVC, VP9, and H.264/MPEG-AVC encoders," *Picture Coding Symposium (PCS), 2013* , pp.394,397, 8-11 Dec. 2013.

   Abstract: This work presents a performance comparison of the two latest video coding standards H.264/MPEG-AVC and H.265/MPEG-HEVC (High-Efficiency Video Coding) as well as the recently published proprietary video coding scheme VP9. According to the experimental results, which were obtained for a whole test set of video sequences by using similar encoding configurations for all three examined representative encoders, H.265/MPEG-HEVC provides significant average bit-rate savings of 43.3% and 39.3% relative to VP9 and H.264/MPEG-AVC, respectively. As a particular aspect of the conducted experiments, it turned out that the VP9 encoder produces an average bit-rate overhead of 8.4% at the same objective quality, when compared to an open H.264/MPEG-AVC encoder implementation - the x264 encoder. On the other hand, the typical encoding times of the VP9 encoder are more than 100 times higher than those measured for the x264 encoder. When compared to the full-fledged H.265/MPEG-HEVC reference software encoder implementation, the VP9 encoding times are lower by a factor of 7.35, on average.

3) Grois, D.; Marpe, D.; Nguyen, T.; Hadar, O., "Comparative Assessment of H.265/MPEG-HEVC, VP9, and H.264/MPEG-AVC Encoders for Low-Delay Video Applications," *submitted to International Conference on Image Processing (ICIP)*, Oct. 2014.

Abstract: The popularity of low-delay video applications dramatically increased over the last years due to a rising demand for real-time video content (such as video conferencing or video surveillance), and also due to the increasing availability of relatively inexpensive heterogeneous devices (such as smartphones and tablets). To this end, this work presents a comparative assessment of the two latest video coding standards: H.265/MPEG-HEVC (High-Efficiency Video Coding), H.264/MPEG-AVC (Advanced Video Coding), and also of the VP9 proprietary video coding scheme. For evaluating H.264/MPEG-AVC, an open-source x264 encoder was selected, which has a multi-pass encoding mode, similarly to VP9. According to experimental results, which were obtained by using similar low-delay configurations for all three examined representative encoders, it was observed that H.265/MPEG-HEVC provides significant average bit-rate savings of 32.5%, and 40.8%, relative to VP9 and x264 for the 1-pass encoding, and average bit-rate savings of 32.6%, and 42.2% for the 2-pass encoding, respectively. On the other hand, compared to the x264 encoder, typical low-delay encoding times of the VP9 encoder, are about 2,000 times higher for the 1-pass encoding, and are about 400 times higher for the 2-pass encoding.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

During the fellowship period, the Fellow attended the following conferences:

- *International Conference on Consumer Electronics (ICCE-Berlin)*, September 9-11, 2013, Berlin, Germany.
- *Picture Coding Symposium (PCS)*, December 8-11, 2013, San-Jose, USA.
- *Packet Video (PV) Workshop*, December 12-13, 2013, San-Jose, USA.

In addition, the Follow attended the following HEVC standardization meetings:

- JCV-VC meeting in Vienna, Austria, 25 July - 2 August 2013;
- JCV-VC meeting in San José, CA, USA, 9-17 January 2014;
- JCV-VC meeting in Valencia, Spain, 27 March - 3 April 2014;

IV – RESEARCH EXCHANGE PROGRAMME (REP)

During the fellowship period, the Fellow visited the following research institutes:

1) Ghent University, Gent, Begium, from October 6, 2013 until October 12, 2013.

   During my visit at Ghent University, I met the research team of Prof. Rik Vande Walle. We conducted many fruitful meetings with Dr. Jan De Cock, Sebastiaan Van Leuven, and others, at which we discussed in detail our research activities, possible future collaboration, and other related issues. We made a special emphasis on projects related to the H.265/MPEG-HEVC standard.

2) Universitat Politècnica de València, Valencia, Spain, from March 27, 2014 until April 3, 2014.

   During my visit at Valencia, I conducted meetings with Dr. Damian Ruiz Coll from a research team of Prof. Narcis Cardona Marcet. We discussed various aspects of our research as well as possible future collaboration. We made a special emphasis on projects related to the H.265/MPEG-HEVC standard.