Joint Collaborative Team on Video Coding (JCT-VC)
of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11
1st Meeting: Dresden, DE, 15-23 April, 2010

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Summary

The Joint Collaborative Team on Video Coding (JCT-VC) of ITU-T WP3/16 and ISO/IEC JTC 1/SC 29/WG 11 held its first meeting during 15-23 April, 2010 at the Art'otel Dresden, DE. The JCT-VC meeting was held under the chairmanship of Dr. Gary Sullivan (Microsoft/USA) and Dr. Jens-Rainer Ohm (RWTH Aachen/Germany).

The JCT-VC meeting sessions began at approximately 9:30 a.m. on Thursday 15 April. Meeting sessions were held on all days (including weekend days) until the meeting was closed at approximately 1:45 p.m. on Friday 23 April. Approximately 190 people attended the JCT-VC meeting, and 40 input documents were discussed. The meeting took place in a co-located fashion with a meeting of ISO/IEC JTC 1/SC 29/WG 11 (MPEG) – one of the two parent bodies of the JCT-VC. The local host for the meeting was the Institut für Informationsverarbeitung of Leibniz Universität Hannover. The subject matter of the JCT-VC meeting activities consisted of work on the new next-generation video coding standardization project now referred to as High Efficiency Video Coding (HEVC). Although the meeting was held during a period that included severe air travel disruption related to the eruption of the Eyjafjallajökull volcano, the large number of people who were able to come to the meeting prior to the start of this disruption enabled the meeting to proceed without difficulty.

The primary focus of the meeting was to review responding proposals and subjective test results for the Joint Call for Proposals (CfP) on Video Compression Technology, which had been issued in January 2010. The Joint CfP, which was issued by ISO/IEC MPEG and ITU-T Q6/16 VCEG in January 2010, had a very successful outcome. Twenty-seven complete proposal submissions were received, and the associated video material was evaluated in extensive subjective tests. The test results clearly indicated that some proposals exhibited a substantial improvement in compression performance as compared to the corresponding AVC (ITU-T H.264 | ISO/IEC 14496-10) anchors - and, in a number of cases, the performance of the best proposals could be roughly characterized as achieving similar quality when using only half of the bit rate.

The JCT-VC produced five important output documents from the meeting: three documents that surveyed various aspects of the proposed technology designs, a report of the subjective test results (which had an editing period prior to its release after the meeting), and a consensus-supported "Test Model under

Consideration" (TMuC) document. Although it is not a formally-adopted complete test model, the TMuC is a coherent collection of design components that appear promising from among those of the various proposals. The coding tools in the TMuC should be further tested to confirm their effectiveness when used together in a unified coding architecture. The inclusion of a technology in the TMuC document does not indicate a final adoption of the technology as an element of an approved test model or draft standard of the JCT-VC committee. Rather, it indicates a preliminary selection which may require further evaluation and justification to achieve that status. The TMuC includes design elements found in the seven of the well-performing CfP response proposals. Some of those design elements are probably also found in some other proposals as well, as there was substantial similarity among many proposals.

Given the level of contributions and participation, the subjective test results indicating substantial technology advancement demonstrated by the proposals, and the positive spirit of the discussions, we can predict that this meeting of the JCT-VC has been only the first of a successful series of meetings for the new collaborative work between ITU-T and ISO/IEC JTC 1 on video coding. For the organization and planning of its future work, the JCT-VC established four "Tool Experiments" (TEs) to evaluate specific proposed coding tools and nine "*Ad Hoc* Groups" (AHGs) to work on more general subject areas. A draft of the plan for each Tool Experiment and mandates for each AHG were approved at the meeting. The next JCT-VC meeting will be held during 21-28 July 2010 in Geneva Switzerland under the auspices of ITU-T WP3/16, and the subsequent meeting is planned for 7-15 October 2010 in Guangzhou China under the auspices of JTC 1/SC 29/WG 11. The reflector to be used for discussions by the JCT-VC and all of its AHGs is the JCT-VC reflector: jct-vc@lists.rwth-aachen.de. For subscription to this list, see http://mailman.rwth-aachen.de/mailman/listinfo/jct-vc.

1 Administrative topics

1.1 Organization

The ITU-T/ISO/IEC Joint Collaborative Team on Video Coding (JCT-VC) is a group of video coding experts from the ITU-T Study Group 16 Visual Coding Experts Group (VCEG) and the ISO/IEC JTC 1/ SC 29/ WG 11 Moving Picture Experts Group (MPEG). The parent bodies of the JCT-VC are ITU-T WP3/16 and ISO/IEC JTC 1/SC 29/WG 11.

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1.2 Meeting logistics

The JCT-VC meeting sessions began at approximately 9:30 a.m. on Thursday 15 April. Meeting sessions were held on all days (including weekend days) until the meeting was closed at approximately 1:45 p.m. on Friday 23 April. Approximately 190 people attended the JCT-VC meeting, and 40 input documents were discussed. The meeting took place in a co-located fashion with a meeting of ISO/IEC JTC 1/SC 29/WG 11 (MPEG) – one of the two parent bodies of the JCT-VC. The local host for the meeting was the Institut für Informationsverarbeitung of Leibniz Universität Hannover. The subject matter of the JCT-VC meeting activities consisted of work on the new next-generation video coding standardization project now referred to as High Efficiency Video Coding (HEVC). Although the meeting was held during a period that included severe air travel disruption related to the eruption of the Eyjafjallajökull volcano, the large number of people who were able to come to the meeting prior to the start of this disruption enabled the meeting to proceed without difficulty.

Information regarding logistics arrangements for the meeting had been provided at http://mpeg.tnt.uni-hannover.de/.

The JCT-VC meeting started with proponent bitstream cross-checking activity on 15 April 2010, with the remainder of meeting held during 16-23 April 2010.

1.3 Primary goals

The primary focus of the meeting was to review responding proposals and subjective test results for the Joint Call for Proposals (CfP) on Video Compression Technology, which had been issued in January 2010.

1.4 Documents

The documents of the JCT-VC meeting are listed in Annex A of this report. The documents can be found at http://ftp3.itu.int/av-arch/jctvc-site/2010_04_A_Dresden/.

The formal deadline for registering and uploading contributions was April 13, 2010. However, contributors were asked to try to make their contribution available by April 11 if feasible, due to the logistical difficulty of handling documents of handling documents after that time, and most contributors did provide their documents by April 11.

Contribution documents JCTVC-A029 and JCTVC-A033 where submitted late. There were no objections raised by the group regarding presentation of these late contributions.

Contribution document registration JCTVC-A024 was withdrawn (no document had been provided).

Contribution document registration had been conducted by email to the Chairs, and document registration lists had been sent to the email discussion reflectors of the JCT-VC, the Q.6/16 Visual Coding Experts Group (VCEG), and the *Ad Hoc* Group on High-performance Video Coding of the ISO/IEC JTC 1/ SC 29/ WG 11 Moving Picture Experts Group (MPEG).

1.5 Attendance

The list of participants in the JCT-VC meeting can be found in Annex B of this report.

The meeting was open to those qualified to participate either in ITU-T WP3/16 or ISO/IEC JCT1/SC29/WG11 (including experts who had been personally invited by the Chairs as permitted by ITU-T or ISO/IEC policies).

Participants had been reminded of the need to be properly qualified to attend. Those seeking further information regarding qualifications to attend future meetings may contact the Chairs.

1.6 Agenda

The agenda for the meeting was as follows:

- IPR policy reminder and declarations
- Contribution document allocation
- Cross-checking of CfP proposal response data
- Consideration of results of CfP proposal response testing activity
- Consideration of proposal contributions
- Coordination activities
- Consideration of informal naming of joint project
- Future planning: Determination of next steps, discussion of working methods, communication practices, establishment of coordinated experiments, establishment of AHGs, meeting planning, refinement of expected standardization timeline, other planning issues
- Other business as appropriate for consideration

1.7 IPR policy reminder

Participants were reminded of the IPR policy established by the parent organizations of the JCT-VC and were referred to the parent body web sites for further information. The IPR policy was summarized for the participants.

The ITU-T/ITU-R/ISO/IEC common patent policy shall apply. Participants were particularly reminded that contributions proposing normative technical content shall contain a non-binding informal notice of whether the submitter may have patent rights that would be necessary for implementation of the resulting standard. The notice shall indicate the category of anticipated licensing terms according to the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form. Contributions of software source code for incorporation into the Reference Software for the standard shall be provided with a suitable copyright disclaimer header text in a form acceptable to the parent bodies to enable publication of the source code and to enable users of the software to copy the software and use it for research and standardization purposes and as a basis for the development of products.(while the submitter separately retains any associated patent rights for licensing to be conducted outside of ITU-T/ITU-R/ISO/IEC).

This obligation is supplemental to, and does not replace, any existing obligations of parties to submit formal IPR declarations to ITU-T/ITU-R/ISO/IEC.

Participants were also reminded of the need to formally report patent rights to the top-level parent bodies (using the common reporting form found on the database listed below) and to make verbal and/or document IPR reports within the JCT-VC as necessary in the event that they are aware of unreported patents that are essential to implementation of a standard or of a draft standard under development.

Some relevant links for organizational and IPR policy information are provided below:

- http://www.itu.int/ITU-T/ipr/index.html (common patent policy for ITU-T, ITU-R, ISO, IEC and guidelines and forms for formal reporting to the parent bodies)
- http://ftp3.itu.int/av-arch/jctvc-site (JCT-VC contribution templates)
- http://www.itu.int/ITU-T/studygroups/com16/jct-vc/index.html (JCT-VC founding charter)
- http://www.itu.int/ITU-T/dbase/patent/index.html (ITU-T IPR database)
- http://www.itscj.ipsj.or.jp/sc29/29w7proc.htm (SC29 Procedures)

The chairs invited participants to make any necessary verbal reports of previously-unreported IPR in draft standards under preparation and opened the floor for such reports: No such verbal reports were made.

1.8 Communication practices

JCT-VC documents had been made available at http://ftp3.itu.int/av-arch/jctvc-site.

These could also be accessed via ftp with the site name ftp3.itu.int, user ID avguest and password Avguest. Upon login, documents were then found in the directory "jctvc-site". Uploading of contributions was done by upload via ftp protocol to the "jctvc-site/dropbox" directory using this account ID and password.

JCT-VC email lists are managed through the site http://mailman.rwth-aachen.de/mailman/options/jct-vc, and to send email to the reflector, the email address is jct-vc@lists.rwth-aachen.de. Only members of the reflector can send email to the list.

Since this was the first meeting of the JCT-VC and the reflector and document site had only recently been set up for this purpose, all email for JCT-VC activities had also been cross-posted to the email reflectors of VCEG (vceg-experts@yahoogroups.com) and the MPEG *Ad Hoc* Group on High-performance Video Coding (mpeg-newvid@lists.rwth-aachen.de).

1.9 Some terminology

Some terminology used in this report that is not explained elsewhere in the report is explained below:

- **AVC**: Advanced video coding – the video coding standard formally published as ITU-T Recommendation H.264 and ISO/IEC 14496-10.
- **BD**: Bjøntegaard-delta – a method for measuring percentage bit rate savings at equal PSNR or decibels of PSNR benefit at equal bit rate (e.g., as described in document VCEG-M33 of April 2001).
- **R-D**: rate-distortion.
- **RDO**: rate-distortion optimization.
- **JM**: Joint model – the primary software codebase developed for the AVC standard.
- **KTA**: key technology area – the nickname for an activity recently conducted in VCEG toward identifying promising new video coding technology and for the software codebase used in this activity.

1.10 Liaison activity

The JCT-VC did not send or receive formal liaison communications at this meeting.

2 Joint Call for Proposals (CfP) review and responses

2.1 CfP overview

The Joint CfP, which was issued by ISO/IEC MPEG and ITU-T Q6/16 VCEG in January 2010 (as N1113 by MPEG and as VCEG-AM90 by VCEG), had a very successful outcome. Twenty-seven complete proposal submissions were received, and the associated video material was evaluated in extensive subjective tests.

Some background information about the CfP is described in this section. Further detail is provided in the text of the CfP itself.

Proponents were required to submit complete results for all test cases. All source video test material was progressively scanned and used 4:2:0 YCbCr color sampling with 8 bits per sample.

The classes of video sequences used in the CfP were as follows

Class A: Cropped "Ultra-HD" areas of size 2560x1600 taken from the following sequences (frame rates unchanged): "Traffic" (4096x2048p 30 fps), "PeopleOnStreet" (3840x2160p 30 fps).

Class B: 1920x1080p 24 fps: "ParkScene", "Kimono"
1920x1080p 50-60 fps: "Cactus", "BasketballDrive", "BQTerrace"

Class C: 832x480p 30-60 fps (WVGA): "BasketballDrill", "BQMall", "PartyScene", "RaceHorses"

Class D: 416x240p 30-60 fps (WQVGA): "BasketballPass", "BQSquare", "BlowingBubbles", "RaceHorses"

Class E: 1280x720p 60fps video conferencing scenes: "Vidyo1", "Vidyo3" and "Vidyo4"

Five seconds of video duration were used for objective quality measurement for class A. Ten seconds of video sequence duration were used for classes B through E, which were also tested subjectively.

Constraint cases were defined as follows:

- **Constraint Set 1 (CS1)**, also known as **Random Access** encoding: Structural delay of processing units not larger than 8-picture "groups of pictures" (GOPs) (e.g., dyadic hierarchical B usage with 4 levels), and random access intervals of 1.1 seconds or less.
- **Constraint Set 2 (CS2)**, also known as **Low-Delay** encoding: No picture reordering between decoder processing and output, with bit rate fluctuation characteristics and any frame-level multi-pass encoding techniques to be described with the proposal. (A metric to measure bit rate fluctuation was implemented in an Excel file submitted for each proposal.)

Three types of *anchor* encoding were used. Anchor encodings were generated by encoding the above video sequences using an AVC encoder (JM16.2 with minor modifications as necessary for support of selected encoding structures). The anchor encodings can be roughly described as follows:

- **Alpha (α) anchor** (satisfying Constraint Set 1 random access encoding): AVC High Profile encoding, Hierarchical B structure (with 4 temporal layers of P and B frames, a maximum of 3 frames of reorder buffering, and a maximum of 4 reference frames buffered) and CABAC entropy coding.
- **Beta (β) anchor** (satisfying Constraint Set 2 low-delay encoding): AVC High Profile encoding, Hierarchical P structure (with 3 temporal layers of P frames, no frame reordering, and a maximum of 4 reference frames buffered) and CABAC entropy coding.
- **Gamma (γ) anchor** (satisfying Constraint Set 2 low-delay encoding): AVC Constrained Baseline Profile encoding with IPPPP coding structure (with no temporal layering of P frames and a maximum of 2 reference frames stored), no frame-level multi-pass encoding optimizations, and CAVLC entropy coding.

In terms of overall quality, on the test set material used for the CfP, we would typically observe that the quality of the Alpha anchor video encoding is better than the Beta anchor encoding, and that the quality of the Beta anchor encoding is better than the Gamma anchor encoding.

No CS2 anchors were encoded for the Class A material, and no subjective testing was performed for this material, for reasons of logistical difficulty.

No CS1 anchors were encoded for the Class E video conferencing scenes, since these scenes were intended to represent low-delay application usage.

2.2 Considerations regarding review of CfP results

The review of CfP related input contributions was started on Friday April 16. In the beginning, some commonalities among proposals were identified. Based on this, the following clusters were grouped and presented first:

- Presentation Cluster A: JCTVC-A107 (Mitsubishi) & JCTVC-A122 (NHK + Mitsubishi)
- Presentation Cluster B: JCTVC-A116 (HHI) & JCTVC-A120 (RIM) & JCTVC-A101 (TI)
- Presentation Cluster C: JCTVC-A124 (Samsung) & JCTVC-A125 (BBC)

The remaining proposals were presented approximately in an order corresponding to their sequence of contribution numbers (see sec. 2.7).

During the presentation of the proposals, the following issues were discussed which are related to the judgement of the results:

- A rough complexity indication, in terms of encoder and decoder runtime, was to be provided in proposals. It was remarked that the software speed measurements seem to not be entirely consistent and to be very rough overall. Some reported run-time comparisons used a different version of the JM as the reference for decoding, rather than the JM 17.0 version that had been requested. In some cases this involved the use of JM 16.2 rather than JM 17.0, and it was remarked that the two versions are actually not very different in speed. It was suggested to perform more cross-checking of runtimes beyond the bitstream cross-checking that had been done on April 15. A side activity was established to do this (coordinated by Karsten Suehring), for which a report is given in the document listed below. For the proposals that were tested, no significant divergence was found compared to the results that had been reported.

  - JCTVC-A201 Results of break-out work on decoder speed measurement

- Some remarks were made related to the quality of the anchor encodings, as outlined below:
  - The proponent of JCTVC-A110 reported that a color blurring effect is frequently found in the JM Alpha anchor encodings – especially for low bit rates in the PartyScene and BasketballDrill sequences of Class C. The reason for this was reportedly investigated and the author suggested that this is because chroma distortion is only considered on the whole-macroblock level of R-D optimization. Including chroma distortion in R-D optimizations at the sub-macroblock level was asserted to be likely to improve the JM encoding visual quality.
  - A participant remarked that an AVC encoder that used better motion estimation techniques could have produced better visual quality than the anchors used in this test.
  - Another participant remarked that the AVC anchor in a hierarchical B case was run with an incorrect (out of date) name for a configuration parameter, which may have caused a loss of compression capability of up to 8% in at least one case.
  - JCTVC-A106 reported an average 7.2% BD bit rate reduction and 0.3 dB BD PSNR improvement observed in the KTA software version 2.6r1 for the High Delay random access ("Constraint Set 1") mode relative to the performance of the Alpha anchor.
- Intra-picture coding was not especially tested in the experiments so far. Many proposals have intra-only improvements proposed. Although it was remarked that in "constraint set 1" encoding there was often a significant percentage of the bit rate that was spent on intra (e.g., 40%), there would still be a diminished impact of intra savings on the overall bit rate in such a case.
- Some reported BD values were computed somewhat differently than intended for CfP responses (using 4-reference point rather than 5-point integrations). It is however assumed that this would not highly affect the qualitative results.

2.3 CfP response submission cross-checking activity

The first day of the meeting (Thursday April 15) was devoted to proponent cross-checking of bit rates and proper decoding operation for the submitted bitstreams. This effort was conducted in as "blind" a fashion as was feasible – i.e., each party checking a data set was not informed of which proponent had generated the data that they were checking. The group encountered some minor issues during that process (such as crashed hard drives, checking the wrong version of some bitstreams, platform dependencies, and not having time to check all of the data that the group might have wanted to), but ultimately the group decoded a sampling of bitstreams for every proposal, and did not find any significant problems with any proposal materials that had been submitted.

On Wednesday April 21, the group agreed that no further need was anticipated for the hard drives that had been submitted by the proponents, and the return of the disks to the proponents was authorized.

2.4 Architectural structure of proposal designs

It was noted that, more or less, all proposals had used a rather similar basic hybrid block-transform motion-compensated coding structure. However, most proposals have multiple tool features that differ from AVC, with test results that are mostly just for the entire set of tools. To create an optimized unified design, we will want to understand the relative importance of the individual tool components, how they interact with each other, their complexity, etc.

The architectural structure of the proposal designs was reviewed in further detail, and two output documents were produced to capture this analysis:

- JCTVC-A202: Architectural outline of proposed High Efficiency Video Coding (HEVC) design elements
- JCTVC-A203: Table of proposal design elements for High Efficiency Video Coding (HEVC)

2.5 Subjective test results

The results of the subjective testing effort were studied, and the following output document was produced to describe the results:

- JCTVC-A204: Report of Subjective Test Results of Responses to the Joint Call for Proposals (CfP) on Video Coding Technology for High Efficiency Video Coding (HEVC)

An editing period was authorized for the finalization of this document, with an estimated availability date of 14 May 2010.

The subjective test results indicated that a clear quality improvement has been achieved by many proposals, as compared to the quality of the AVC anchors, for both constraint conditions (Random Access and Low Delay). For a considerable number of test points, the subjective quality of the proposal encoding was as good, for the best performing proposals, as the quality of the anchors with roughly double the bit rate. Even when considering the fact that some proposals certainly used more advanced encoder optimization than the AVC anchors, a substantial gain can be identified for a prospective starting point of the new generation of video coding standard to be developed in the HEVC initiative. A more thorough analysis is given in the JCTVC-A204 test report document.

2.6 Tools for CfP response evaluation

JCTVC-A031 [S. Pateux (Orange - FT)] Tools for proposal evaluations

This contribution presented a set of tools for performing objective analysis of responses to the Call for Proposals of the JCT-VC. A first tool was proposed for helping to perform proponent cross-checking. It allows regenerating the PSNR template file to be filed by proponents by re-computing frame PSNR from provided decoded YUV files. The second tool proposed is an Excel sheet with advanced customization functionalities to compute and graph various objective metrics (e.g. BD-rate, BD-PSNR, …). These tools were intended to help the JCT-VC group to analyze the results of the Call for Proposals.

The group expressed its appreciation for the submission of this valuable contribution.

2.7 Formal proposal responses to CfP

JCTVC-A101 [M. Budagavi, V. Sze, M.U. Demircin, S. Dikbas, M. Zhou (TI), A.P. Chandrakasan (MIT)] Video coding technology proposal by Texas Instruments

Presented Friday (16th).

This contribution described three tools that were submitted as a part of video coding technology proposal in response to the CfP. It was emphasized that the proposal addresses complexity reduction rather than coding efficiency. The three tools are:

- Orthogonal mode dependent directional transform (OMDDT) which was described as a simplification of the mode dependent directional transform (MDDT) explored in KTA2.6r1, using only one transform matrix per intra prediction direction.
- Massively parallel CABAC for CABAC throughput improvement (assignment of bins to parallel-processed partitions for equal balance of workload, interleaved entropy slices), and

- Compressed reference frame buffer for memory bandwidth and memory size reduction. This is a lossy technique which must be run in the loop of encoder and decoder to avoid drift: The applied method involves (lifting-based) transformation, rate-control, quantization, DC prediction, and Exponential-Golomb and unary variable-length coding. The frame buffer compression scheme is controlled to reduce the frame buffer memory by 50%.

The video coding technology proposal consisted of these three tools plus the following tools of KTA2.6r1:

- extended macroblock size,
- adaptive loop filter,
- motion vector competition, and
- adaptive interpolation filter.

OMDDT was reported to save half the memory required to store transform matrix coefficients when compared to the mode dependent directional transform (MDDT) scheme of KTA2.6r1. On some hardwired architectures, it was asserted that OMDDT is expected to use about half the area of the original MDDT. Massively parallel CABAC was reported to achieve an effective throughput improvement between 2.78x to 4.49x for "Constraint Set 1" (CS1) conditions and 1.68x to 4.81x for "Constraint Set 2" (CS2) on Class A, B and E video sequences. The compressed reference frame buffer tool was reported to achieve 50% reduction in reference frame memory access bandwidth and memory size on Class A, B, and E video sequences. These gains in complexity reduction, throughput increase, and memory bandwidth and memory size reduction were reportedly achieved at a cost of an average bit-rate increase of 0.48% for CS1 and 0.58% for CS2 when compared to KTA2.6r1 under similar coding conditions.

JCTVC-A102 [K. Nakamura, S. Saito, T. Murakami, Y. Komatsu, T. Yokoyama (Hitachi)] Video coding technology proposal by Hitachi

Presented Friday (16th).

This contribution describes a proposal response to the Joint Call for Proposals (CfP) on Video Compression Technology. The proposal was designed by applying three modifications to AVC. Simulation results reportedly showed an average of 12.5% bit rate reduction relative to the Beta anchor. The proposed encoding model primarily focuses on low delay and modest complexity cases. It was tested with IPPP configuration with random access points relative to the Alpha (hierarchical B) anchor case also, and the simulation result was an average of +11.37% bit rate increase relative to the Alpha anchor. The proponent indicated that the complexity aspect of the encoding model should be well discussed in the process of standardization.

The three modifications relative to AVC were:

- Enhanced Adaptive Interpolation Filter (EAIF) (COM 16-C464-E) is used in this proposal. The interpolation filter is adaptively applied to sub-pixel and full-pixel positions with filter offsets, and improves coding efficiency.
- Furthermore, motion vector competition (VCEG-AC06) is also introduced. Predictive motion vector is calculated from temporal and spatial predictor.
- Extended block sizes (VCEG-AJ23) 64x64, 64x32, 32x64, 32x32, 32x16, 16x32 block sizes were added to AVC. 64x64 MBs were used for all resolutions and adaptively divided. 16x16, 16x8, 8x16 transforms are added to the transforms of AVC.

JCTVC-A103 [T. Suzuki, A. Tabatabai (Sony)] Video coding technology proposal by Sony

Presented Friday (16th).

This contribution presents 6 new tools to enhance the coding performance of AVC with the potential to form the basis for the next-generation video coding standard architecture. The tools can be classified into 4 categories - prediction, motion vector coding (MV coding), transforms, and filtering.

The prediction category includes the following:

- Recursive Adaptive Interpolation Filter (RAIF) generalizes the fractional pel interpolation concept and, due to its recursive nature, it can spatially adapt to image local characteristics. In the proposed RAIF scheme, there is no need to transmit filter coefficients since the decoder can derive the filter coefficients based on the reconstructed neighboring samples.
- Separable Fixed Interpolation Filter (SFIF) refers to a set of fixed, high precision and separable filters that are used for fractional pel interpolation in reference frames. They are designed in such a way to minimize the error accumulation due to rounding and clipping.
- Separable Adaptive Interpolation Filter (SAIF) filters are separable Wiener filters derived separately for B and P pictures. In addition, the overhead due to the transmission of filter coefficients for B pictures is reduced based on a symmetry assumption.

For MV coding, the contribution proposed to use both a temporal predictor and spatial predictor for motion vector prediction. The temporal predictor refers to the motion vector of the co-located block in the reference frame.

For the spatial transform of intra block residuals, two types of transforms are introduced: Directional Discrete Cosine Transforms (DDCT) and Directional Discrete Wavelet Transform (DDWT, derived from Haar basis). They are applied along and perpendicular to the direction of the intra prediction mode on either a 4x4 or 8x8 block basis. In addition, making the transform a function of QP and prediction direction based fixed scanning pattern for scanning of the transform coefficients was also proposed.

A Separable Adaptive Loop Filter (SALF) refers to a set of Wiener filters placed in the loop filter between the deblocking filter and the reference frame buffer. These are used to minimize the MSE between the original frame and the deblocking filter output. The key characteristics of these filters are their lower complexity relative to non-separable schemes, as well as in their frame/slice based adaptivity.

The software basis for this proposal was the JM KTA software.

JCTVC-A104 [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda (NEC)] Video coding technology proposal by NEC

Presented Saturday 9:15am.

This contribution presented a video coding technology based on a new in-loop filter that integrates noise-shaping mechanisms and the Wiener filter. As the noise-shaping mechanisms, a conditional joint deblocking-debanding filter and a "comfort noise" injection method based on pseudo noise were proposed. The conditional joint deblocking-debanding filter is an extension of the conditional deblocking filter of the AVC standard, and in a manner amenable to parallel processing, its algorithm is designed to jointly reduce the blocking and banding artifacts associated with intra-coded macroblock boundaries. The comfort noise is further added to LSBs of the processed image areas where structural signal-dependent noise remains, in order to mask the signal-dependent noise with signal-independent noise that can be attenuated by the Wiener filter (only when internal bit-depth increase was used, i.e. in the CS1 case). The Wiener filter reduces the signal-independent noise (optimally in the minimum-mean-squared-error sense for a linear filter) and reportedly prevents motion compensated prediction performance losses for subsequent pictures. The proposed in-loop filter was reported to reduce signal-dependent noise, especially banding noise, while retaining the overall coding efficiency. Simulation results reportedly indicate that the combination of KTA coding tools and the proposed in-loop filter leads to rate reductions 10.5%, 19.8%, 16.2%, and 14.0% in BD-rates relative to Alpha-type Class A, B, C, and D sequences, respectively. Representative video frames in which substantial signal-dependent noise reduction was achieved were shown.

The proponent recommended a study of the proposed in-loop filter as a potential part of the next generation video coding standard. A study of generalized syntax for encoding noise parameters of related technologies was also recommended by the proponent.

Features:

- Excluded small motion partitions of 8x8, 4x8, and 4x4 from the syntax support
- Motion partitions of 32x32, 32x16, 16x32, 16x16, 16x8, 8x16, and 8x8
- Motion vector competition
- Internal bit depth increase (IBDI) – only for "Constraint Set 1" – random access case
- Comfort noise is conditionally added to the LSBs of the processed picture (inspired by Q15-B-15, in loop – only used when IBDI is used)
- Did not introduce new intra-frame prediction tools
- Added 16x16 integer transform – used only for intra 16x16 case in proposal
- Conditional joint deblocking-debanding filtering (inspired by JVT-C056)
- Wiener filter (adaptive symmetric 5x5) is then applied to the entire picture
- Did not use hierarchical P encoding
- CABAC entropy coding (note that low-delay Gamma anchor did not use CABAC)qq

JCTVC-A105 [A. Segall, T. Yamamoto, J. Zhao, Y. Kitaura, Y. Yasugi, T. Ikai (Sharp)] Video coding technology proposal by Sharp

Presented Saturday 9:45am.

This contribution proposed a video coding system reported to have both higher coding efficiency and higher parallelization than the current AVC standard. The system was reported to be well suited for transmitting modern video content that is acquired by both professional and consumer methods. Moreover, it was asserted to be well suited for both sequential and parallel processing architectures. The proposed coding scheme includes support of larger block sizes, adaptive interpolation and loop filters, and higher bit-depth processing with parallel designs for entropy coding and intra prediction. The resulting system was reported to provide a 21% bit-rate reduction in higher delay mode, a 34% bit-rate reduction in low delay mode, and higher parallelization when compared to the anchors provided by MPEG and VCEG in the Joint Call for Proposals.

Features:

- Larger coding block sizes (superblock consisting of 2x2 MBs)
- 16x16 transform
- E-AIF motion interpolation (with multiple filters), two filter parameter sets sent to decoder
- QALF quadtree-adaptive loop filter
- Motion vector competition
- High precision filtering
- Parallel intra prediction (two-pass checkerboard scheme)
- Adaptive multi-directional intra prediction: Two partitions (passes) that are arranged in a checkerboard structure. For the first pass, more-distant samples are used for prediction, additional refinement of prediction directions, and horizontal/vertical modes with 7 directions each; in the second pass also prediction from lower and right blocks is possible (i.e. additional modes), bi-prediction with weighting was also applied
- Parallel entropy coding with "entropy slices" (the number of entropy slices being variable according to the desired degree of parallelism)

- Loop filtering with "codeword restriction" adaptive signal range clipping operation (max/min values explicitly coded)

JCTVC-A106 [Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)] Video coding technology proposal by Intel

Presented Saturday 10:10am.

This Joint CfP response contribution primarily proposed two techniques, Self Derivation of Motion Estimation (SDME) and Adaptive Loop (Wiener) Filter (ALF), to be considered as video coding tools to improve the coding efficiency for the incoming new generation of video compression standard. With SDME, the motion vector information is self derived at video decoder, the transmission of the motion vector from the video encoder side is skipped and thus better coding efficiency is reportedly achieved. Compared to the anchor bitstreams for the test scenario of "Constraint Set 1", an average 13.9% BD bit rate reduction and 0.5 dB BD PSNR improvement was reportedly achieved for the SDME technology and an average 18.5% BD bit rate reduction and 0.8 dB BD PSNR improvement was reportedly achieved for the combined case of SDME + ALF on top of a reported "baseline" average 7.2% BD bit rate reduction and 0.3 dB BD PSNR improvement observed in the baseline KTA software version 2.6r1. Compared to the anchor bitstreams for the test scenario of "Constraint Set 2", an average 6.0% BD Bit rate reduction and 0.2 dB BD PSNR improvement was reportedly achieved for the ALF technology on top of the "baseline" average 0.5% BD bit rate reduction and 0.01 dB BD PSNR improvement observed in the baseline KTA software version 2.6r1.

Features:

- Self Derivation of Motion Estimation (SDME); Mirror based motion estimation for B pictures; spiral search pattern, starting from center. One starting point is (0,0) and the other is the usual MV predictor. Search range is 8 for integer accuracy, adaptive search range; fractional position refinement afterwards. Four spatial neighbors are investigated. Flag is coded to signal use of SDME
- Adaptive Loop (Wiener) Filter (ALF) from previous BALF and QALF proposals
- ALF (KTA feature)
- AIF (KTA feature)
- HPFilter (KTA feature)

It was remarked that SDME has high complexity impact (>500% decoder runtime compared to KTA).

JCTVC-A107 [K. Sugimoto, Y. Itani, Y. Isu, N. Hiwasa, S. Sekiguchi, R.A. Cohen, P. Wu, N. Sprljan (Mitsubishi Electric)] Video coding technology proposal by Mitsubishi Electric

Presented Friday (16th).

This contribution presented specifications of a new video coding algorithm developed for submission as a response to the Joint Call for Proposals on Video Compression Technology. The proposed video coding algorithm is based on well-known macroblock based hybrid coding architectures with block motion compensation and orthogonal transforms with coefficient quantization, and additional new coding tools. Major technical differences from the existing AVC design were to enable adaptation of macroblock size together with multi-level hierarchical motion partitioning, adaptive transform decision including new directional transforms, a new intra coding mode exploiting self-correlation within a coded block, localized weighted prediction, and adaptive Wiener loop filtering. The performance gain with the basic part of the proposed architecture was reportedly verified in some practical implementation studies including responses to MPEG's Call for Evidence or KTA (Key Technical Area) work being conducted by ITU-T VCEG (Q6/SG16). The proposed algorithm reportedly showed around 1 dB PSNR gain on average relative to high-complexity usage of the AVC High profile over a wide range of test sequences. More gain can reportedly be observed especially for high-resolution video sources such as classes A and

B. The proposed architecture was asserted to have more functional extensibility than the existing use of 16x16 fixed-size macroblocks, and to potentially be a good starting point for further performance improvement, while maintaining product implementability.

Differences relative to AVC are listed below.

- Extension of macroblock size and ability of its adaptation at a higher syntax level
- Inter prediction with hierarchical and non-rectangular shaped motion partitioning
- Adaptive transform with multiple block sizes and directional basis functions
- Block-based pyramid intra prediction
- Adaptive motion prediction (for selection of spatial/temporal candidate), extending MV competition
- Improved direct mode (selection of spatial/temporal candidate without signaling, SAD competition at decoder and encoder)
- MB-based weighted prediction
- Combined in-loop adaptive de-blocking and Wiener filtering
- CABAC design that accommodates extended macroblock size syntax

The proposed technology was described as having similar encoding speed to the JM anchor.

Regarding decoding: the filtering adds complexity, and there is SAD computation for direct MV derivation – roughly perhaps a few times the complexity of AVC High profile decoding.

The software was reportedly written from scratch, but modular in a way that was asserted to be possible to include JM/KTA.

The proponent particularly suggested for the group starting point for collaborative work to include MB size extension and Wiener filtering.

JCTVC-A108 [S. Sakazume, M. Ueda, S. Fukushima, H. Namamura, K. Arakage, T. Kumakura (JVC)] Video coding technology proposal by JVC

Presented Saturday 11:30am.

This contribution presented proposed tools which were asserted to achieve an improvement of intra-frame prediction and motion representation as an extension of AVC, and the proposal was based on JM16.2 software.

For intra-frame prediction, "AC prediction using DC and intra prediction mode" was proposed. For motion representation, "Geometric Transform Prediction (GTP)", "Decoder-side Block Boundary Decision Motion Compensation (DBBD)" and "Refinement Motion Compensation using Decoder-side Motion Estimation (RMC)" were proposed. In addition to the above tools, the "Quadtree Adaptive Loop Filter" (QALF) tool was applied in the proposal software.

This proposal reportedly achieves an average bit rate reduction of 10.0% (up to 24.1%) for "Constraint Set 1" operation relative to the Alpha anchor, and achieves an average bit rate reduction of 3.6% (up to 22.7%) for "Constraint Set 2" operation relative to the Beta anchor.

Features:

- AC prediction using DC and intra prediction mode (intra) – DC value is coded, and prediction signal is a ramp shape starting at the edge with the predicted DC value and sloping through the coded DC value at the middle of the block
- Geometric Transform Prediction (GTP) (inter) – code MVs for four corners and create 4x4 block vectors using warping interpolation

- Decoder-side Block Boundary Decision Motion Compensation (DBBD) (inter) – changes the boundary between motion compensation units, to maximize the discontinuity of the prediction signal across the samples across the motion discontinuity edge
- Refinement Motion Compensation (RMC) using Decoder-side Motion Estimation (inter) – with a small search range
- Quadtree Adaptive Loop Filter (QALF)

JCTVC-A109 [Y.-W. Huang, C.-M. Fu, Y.-P. Tsai, J.-L. Lin, Y. Chang, J.-H. Guo, C.-Y. Chen, S. Lei, X. Guo, Y. Gao, K. Zhang, J. An (Mediatek)] Video coding technology proposal by Mediatek

Presented Saturday 12:10pm.

This contribution described the MediaTek proposal in response to the Joint CfP. This proposal includes many well-known tools of the KTA software, e.g., extended macroblocks, High Precision Interpolation Filter (HPIF), Internal Bit Depth Increase (IBDI), and Motion Vector Competition (MVC). It also included a few effective KTA tools that have been somewhat modified by MediaTek, e.g., Adaptive Interpolation Filters (AIF), Adaptive Loop Filters (ALF), and scaled motion vector predictor. Several new tools were also included in the proposal, e.g., spatial-temporal direct mode, enhanced intra coding, modified decoder-side motion vector derivation, and 32-point transform. The reported average BD-rate reductions in comparison with the Alpha, Beta, and Gamma anchors were 30.0%, 28.8%, and 46.4%, respectively.

Features:

- Advanced AIF with multiple interpolation filters, time-delayed Wiener filters based on previous frames, and optimal Wiener filter of current frame, with high-precision interpolation filtering (1/8 pel)
- Overlapped block intra prediction
- Replaced intra prediction mode 4 with a plane prediction mode
- Intra prediction mode coding modified; 9 modes for 16x16 prediction; context-dependent mode representation
- 16x16 and 32x32 and 16x32 and 32x16 transforms
- Multiple Model KLT for intra – lots of different transforms (each direction has 3 different transform classes)
- Adaptive scan for intra macroblocks (sorting after coding each MB is avoided)
- Improved Multiple QALF (IMQALF): Derived from QALF with multiple filters; if a partition is divided into blocks, each block can switch filter on/off
- Spatial-temporal direct mode: Partition based; temporal similar to direct, but usage of division instead scaling
- Decoder-side motion vector derivation: B-frames and weighted prediction supported; adaptive template distortion criterion, adaptive search range
- Scaled MV predictor – scaling MVs of neighbors based on temporal differences

Encoding was roughly 16x slower than JM16.2 decoder, with decoding approximately 3.5x slower than JM11 (approximately, after compensating for difference between JM16 and JM11 decoder speed difference) – rough approximation.

Versus JM 17 (as requested in CfP), the proponent did not measure this. However, JM 16.1 was asserted to have about the same speed for decoding as JM 17.

The Excel spreadsheet of results was not initially provided as part of the contribution and was uploaded during the meeting.

Subjectively in the test results – overall this proposal seems to have been among the 10 best.

The software was JM11 KTA-based.

It was noted that the JM16.2 decoder is much faster than the JM11 decoder.

JCTVC-A110 [B. Jeon, S. Park, J. Kim, J. Park (LG)] Video coding technology proposal by LG Electronics

Presented Saturday 3:00pm.

This document proposed a video coding scheme in response to the Joint CfP that was asserted to be substantially increased in compression capability relative to AVC. The proposed coding scheme is based on the same coding framework as AVC, while providing a number of differing components.

The proposed technology is primarily based on a macroblock size of 32x32 which it was asserted could be expanded up to 64x64. The residual coding scheme employs various transforms of 4x4, 8x8, 16x8, 8x16, and 16x16 sizes. Along with the enlarged macroblock structure, various coding tools were altered or added, which include partial skip mode with variable block size, an Inter-Intra Mixed Mode (IIMM) for a macroblock, a Mixed Intra Mode (MIM) for a macroblock, a Scaled Motion Vector Predictor (SMVP), template-based Illumination Compensation (IC), border handling scheme, Adaptive Deblocking Filter (ADF), and modified chroma intra prediction. Besides, some efficient KTA coding tools such as Motion Vector Competition (MVC), Switched Interpolation Filter Offset (SIFO), and Quad-tree based Adaptive Loop Filter (QALF) are found in the proposal – with some modifications.

The proponent of JCTVC-A110 reported that a color blurring effect is frequently found in the JM Alpha anchor encodings – especially for low bit rates in the PartyScene and BasketballDrill sequences of class C. The reason for this was reportedly investigated and the author suggested that this is because chroma distortion is only considered on the whole-macroblock level of RD optimization. Including chroma distortion in RD optimizations at the sub-macroblock level was asserted to be likely to improve the JM encoding visual quality.

Experimental results were asserted to show that the proposed model outperforms the JM anchor, averaging 25.8% bit rate reduction for all classes under the "Constraint Set 1" conditions and 37.0% bit rate reduction for all classes under the "Constraint Set 2" conditions. For each constraint set, the proposed model reportedly provides a significant improvement in coding efficiency performance. For class B (1080p) sequences in particular, under the "Constraint Set 1" case, 30.6% bit rate reduction was reported achieved. For class E (720p) sequences, under the "Constraint Set 2" case, about 45.0% bit rate reduction was reported.

Features:

- 64x64 macroblock units
- Inter prediction block size down to 8x8
- Partial MB skip mode
- Scaled motion vector predictor
- Template-based illumination compensation
- Modified motion vector competition
- Switched interpolation filter with offset (SIFO)
- "Mixed intra mode" – transform type coupled to segmentation size for intra prediction
- Intra-inter areas within same MB
- 32x32 and smaller (square) block sizes for intra prediction

- New chroma prediction mode added (derived from sub-sampled luma)
- Overhead removed for region outside the cropping window (boundary handling for skipping sub-MBs)
- New mode-dependent directional transform (MDDT) kernels
- Transforms 4x4, 8x8, 16x8, 8x16, 16x16
- Adaptive scan order
- New chroma estimation mode with phase shift
- Adaptive deblocking filter (based on Wiener filter), QALF
- Some additional tools were proposed that were not included in the submission for subjective testing: Adaptive warped reference, Parametric adaptive interpolation filter, motion vector comp. in B skip & direct modes, chroma estimation with phase shift.

In regard to speed relative to JM 17 (as requested in CfP), this was not not measured; however, JM 16.1 was asserted to have about the same speed for decoding as JM 17. The proposal was estimated as having roughly 7-8 times the decoding time relative to JM 16.1. For encoding, the proponent estimated roughly 5 times encoding time for "Constraint Set 1" (high delay), and 9 times encoding time for "Constraint Set 2" (low delay).

The software development activity for this proposal used JM 11 as the starting codebase.

JCTVC-A111 [H. Yang, J. Fu, S. Lin, J. Song, D. Wang, M. Yang, J. Zhou, H. Yu (Huawei), C. Lai, Y. Lin, L. Liu, J. Zheng, X. Zheng (Hisilicon)] Video coding technology proposal by Huawei Technologies and Hisilicon Technologies

Presented Saturday 4pm.

In response to the Joint Call for Proposal (CfP) on Video Compression Technology, Huawei Technologies together with Hisilicon Technologies proposed a new video coding technology to JCT-VC for evaluation. This document described the proposed design, including descriptions of the coding algorithms and their implementation, discussions of the coding performance in terms of subjective and objective quality compared with the JCT-VC CfP anchors, and complexity evaluation and analysis of the proposed tools.

As a response to the call for proposal, this document proposed a video coding technology with the following features:

- Template based motion derivation: Usage of candidate comparison, also multi-hypothesis. For B frames, replacement of B_skip and B-direct modes by the template-based derivation
- Template-based interframe DC offset
- Flexible macroblock partition for inter-frame prediction: Includes diagonal, horizontal and vertical sub-divisions at arbitrary positions
- Resample-based intra prediction (perhaps sort of similar in spirit to H.261 Annex D)
- Line based intra prediction: 4 modes: 1x16, 16x1, 2x8 and 8x2. Zigzag scan modified for this case.
- Inter-frame DC offset
- Second order prediction for inter-prediction residual: directional prediction in inter coding, flag to signal the usage
- Rate-distortion optimized transform for intra-prediction residual: Separable KLT, 2 matrices for 4x4, 4 matrices for 8x8, 8 matrices for 16x16.
- Directional transform for inter-prediction residual

- Adaptive frequency weighting quantization: Three quantization matrices for textured, flat and edge regions. Switching at MB level, transmission at slice level
- Other KTA tools used: EAIF, QALF, MDDT, RDOQ

The software was based on the KTA2.6r1 software. KTA2.6r1 was developed from the AVC reference software JM11.0, with additional coding tools such as adaptive loop filter, adaptive interpolation filter, mode dependent direction transform, etc.

Encoding was reportedly a few times slower than KTA software. Decoding was reportedly a few times slower than JM 17.

JCTVC-A112 [S. Kamp, M. Wien (RWTH Aachen)] Video coding technology proposal by RWTH Aachen University

Presented Saturday 4:30pm.

This contribution described RWTH Aachen University's response to the Joint Call for Proposals on Video Compression Technology issued by ITU-T SG16 Q.6 (VCEG) and ISO/IEC JTC1/SC29/WG11 (MPEG). The proposal was based on the KTA software and used some of the KTA tools, such as large macroblocks, adaptive interpolation filter, adaptive loop filter, motion vector competition, and directional intra transform. In addition to these existing tools, decoder-side motion vector derivation had been implemented to the KTA software and was proposed as a coding tool for future standard development.

Features:

- large macroblocks
- adaptive interpolation filter
- adaptive loop filter
- motion vector competition
- directional intra transform
- decoder-side motion vector derivation

The proponent was asked to estimate the gain from decoder-side motion vector derivation alone, and provided an estimate of 5%.

The software development codebase was KTA software.

JCTVC-A113 [J. Lim, J. Song (SK telecom), H. Park, C.-W. Seo, D.-Y. Kim, J.O. Lee, M.-J. Kim, S.-W. Hong, M.-H. Jang, H. K. Kim, Y.-L. Lee, J.-K. Han (Sejong Univ.), B. Jeon (Sungkyunkwan Univ.), J.-H. Moon (Sejong Univ.)] Video coding technology proposal by SK telecom, Sejong Univ. and Sungkyunkwan Univ.

Presented Saturday 5pm.

This proposal submitted in response to the CfP was based on a traditional block-based hybrid coding architecture with spatial-temporal prediction and spatial transform. As general features, the size of a macroblock (MB) in AVC was extended to use the 32x32 extended macroblock (EMB) size instead of 16x16, and multiple reference frame buffers were used for motion compensation. The AVC CABAC technology was used as the entropy coding basis for header and coefficient information.

For intra prediction, an EMB is divided into four 16x16 blocks. For each 16x16 block, non-square prediction sizes such as 16x8, 8x16, 8x4 and 4x8 each with three modes of horizontal, vertical and DC predictions are used in addition to AVC based 16x16, 8x8, and 4x4 spatial prediction partitions and their prediction modes. For coding intra prediction residual signals, mode-dependent directional transform (MDDT) is used as transform.

For inter prediction, a whole 32x32 partition is added to the existing partition types of AVC. This 32x32 partition mode supports skip, direct, and motion with residual coding. Larger transform sizes than 8x8 such as 16x8, 8x16, and 16x16 integer DCT are used. Groups of possible transform sizes are dependent on partition sizes. For example, a group of 16x16, 8x8 and 4x4 transforms is used for 32x32 or 16x16 partition block. The selected transform size for actual coding is signaled in 16x16 block or EMB level. For motion estimation, motion vector precision is adaptively selected on EMB or 16x16 block level among 1/2 pel, 1/4 pel, and 1/8 pel precisions (AMVP: Adaptive Motion Vector Precision).

For filtering processes, the AVC deblocking and quad-tree based adaptive loop filter (QALF) processes are applied to the reconstructed frame after de-quantization and inverse transform on the way to be stored in frame buffer.

The proposed technology was implemented by modifying JM15.2 by inserting new tools and changing necessary parts accordingly. In its evaluation of coding performance, the encoding was carried out with the following options: trellis based rate-distortion optimized quantization (RDO-Q), EPZS motion estimation, and RDO process.

For coding efficiency as compared with the anchor, the proposed codec reportedly always outperforms the anchor codec in terms of coding efficiency. The average bit rate reduction of 17.8% for "constraint set 1" (random access encoding) was reported for equal PSNR (with the best result of 29.3% bit rate reduction for BQsquare and the worst case of 15.2% reduction for Cactus). For the "constraint set 2" (low delay encoding), the average gain is 13.9 % bit rate reduction for equal PSNR (with the best result of 20.7 % for Kimono and the worst 3.4% with BlowingBubbles).

For complexity analysis, the JM16.2 encoder and the JM17.0 decoder and the encoder and the decoder of proposed method were executed on Intel Xeon two Quadcore CPUs 64 bit Windows 7 with 16G bytes memory and hard disk of SATA2 (NTFS file formatted). The _ftime() function was used for measuring the computational complexity.

Compared to the JM16.2 encoder, the encoding time of the proposed method was reported to be longer on the average by 136.39% for "constraint set 1" and by 199.73% for "constraint set 2". The decoding time of the JM17.0 decoder and the proposed decoder were checked with YUV output enabled and reference PSNR measurement disabled. The decoding time of the proposed method was reportedly longer on the average by 199.01% for "constraint set 1" and by 275.55% for "constraint set 2".

Features:

- 32x32 MB, transform up to 16x16
- Adaptive MV precision (down to 1/8 pel)
- Intra prediction of larger blocks, special coding of modes
- Tree coding for partition type
- MDDT (only for intra)
- QALF
- HPF

The software codebase was JM 15.2.

JCTVC-A114 [I. Amonou, N. Cammas, G. Clare, J. Jung, L. Noblet, S. Pateux (FT), S. Matsuo, S. Takamura (NTT), C.S. Boon, F. Bossen, A. Fujibayashi, S. Kanumuri, Y. Suzuki, J. Takiue, T.K. Tan (NTT DoCoMo), V. Drugeon, C.S. Lim, M. Narroschke, T. Nishi, H. Sasai, Y. Shibahara, K. Uchibayashi, T. Wedi, S. Wittmann (Panasonic), P. Bordes, C. Gomila, P. Guillotel, L. Guo, E. François, X. Lu, J. Sole, J. Vieron, Q. Xu, P. Yin, Y. Zheng (Technicolor)] Video coding technology proposal by France Telecom, NTT, NTT DOCOMO, Panasonic and Technicolor

This response to the joint call for proposals for video coding technology (JCfP) was jointly developed by France Telecom S.A., NTT Corp, NTT DOCOMO, Inc., Panasonic Corp., Technicolor S.A. and their affiliated companies. It comprises an encoder, a decoder, and relevant documentation. A "blank sheet" approach was asserted to have been taken to design the algorithm and implement it in software. It was thus indicated not to be an extension of the AVC standard, and the software was new – not based on the the JM or KTA software codebases.

Objective quality (BD-rate) improvements were reported as follows: For constraint set 1, average BD-rate improvements of 31.6% (Y component), 29.2% (U component), and 30.0% (V component) with respect to the Alpha anchor were reported. For "constraint set 2", the reported improvements were 30.4% (Y), 10.6% (U), and 10.9% (V) with respect to the Beta anchor, and 47.4% (Y), 34.1% (U), and 35.1% (V) with respect to the Gamma anchor.

This proposal was asserted to perform equally well for all the sequence classes, target bitrates, and constraint sets, and to be robust, adaptable, and not tuned to specific conditions, sequences, or resolutions. The algorithm was reportedly designed with parallelism in mind, and both single- and multi-threaded decoding are supported by the software.

A large potential for parallelism was asserted. The complexity was indicated to be scalable, as several tools may reportedly operate in lower-complexity modes.

The proposed scheme was asserted to be approached a new codec design – not an extension of AVC.

Features:

- Basic coding unit is 8x8
- Motion block boundary position can be displaced by 2 or 4 samples (when indicated)
- Intensity compensation with offset in motion prediction
- Motion representation to 1/8 pel (1/16th in chroma)
- Separable AIF (Wiener)
- Internal bit-depth increase (14 bit)
- MV competition in P frames
- Intra prediction 16x16, 8x8, 4x4, 2x8 and 8x2
- Chroma intra partitioning inferred from luma partitioning
- Chroma intra prediction with adaptive filtering
- 9 intra prediction modes for each of the 5 block sizes, plus
- Additional "edge-based prediction mode" for intra – depending on edge detection in neighboring blocks
- Additional "template match averaging" for intra – displacement vector referencing within the previously-coded region of the current picture, inferred by the decoder using template matching (something similar was in Samsung / BBC proposal JCTVC-A125), and averaging the predictions for several such candidates
- Low-pass filter (adaptively selected from two filters) applied during intra prediction for 8x8 chroma
- A filter as in AVC was applied during intra prediction for 8x8 and 16x16 luma prediction
- Intra transforms: 16x16, 8x8, 4x4, 2x8, 8x2 (chroma 4x4 or 8x8)
- Inter transforms as in AVC (8x8 and 4x4)
- Adaptive choice between 2 transforms for each block size (DCT and fixed KLT) for intra, switching signaled at 16x16 level
- Quantization control with finer resolution than AVC (doubling period of 16 rather 6) quantization weighting matrices supported

- (CABAC-encoded) "Zerotree" coding of significance map of frequency classes for transform coefficients
- (CABAC-encoded) Zerotree coding of when a non-zero horizontal or vertical MV delta is used, and of when a non-zero scale or offset for illumination compensation is used
- CABAC-like entropy coding
- After residual decoding – apply a "denoising filter" (not a typical denoising post-filter, but something involving multiple applications of a transform) – based on thresholding in an over-complete transform domain (one 8x8 DCT per pixel position was used in the CfP submission, but could in principle be less)
- Wiener filtering using, as input, three signals: prediction, residual, and reconstructed (with filter coefficients transmitted)
- Deblocking filter, with encoder decision regarding whether this is applied before or after the denoising

The software codebase was new – written from scratch in C++ – and was asserted to be well structured and well validated.

The reported decoding time ratio relative to JM 17 was approximately 11-16x.

The reported encoding time ratio relative to JM anchor encoding was not measured – after discussion, it was remarked that the ratio would perhaps be (very) roughly in the neighborhood of 5-10x.

Extensive documentation was provided.

Subjectively in the test results – overall this proposal seems to have been among the 5 best.

JCTVC-A115 [K. Kazui, J. Koyama, A. Nakagawa (Fujitsu)] Video coding technology proposal by Fujitsu

Presented Sunday 9:30am.

The technical description of FUJITSU's proposal in response to the Joint CfP was described in this document. The proposed technique was to improve coding efficiency of the sign of a quantized DCT coefficient in CABAC entropy coding mode.

In the AVC standard, the sign is encoded by the bypass process of CABAC.

The proposed technique estimates the signs of a block from data in neighboring blocks, and encodes the difference (0: same, 1: not same) between estimated signs and true signs using CABAC. If the signs are well estimated, the difference tends to be '0', and the coding efficiency can be improved by CABAC.

This proposed technique was implemented onto the JM version 16.2 codebase.

The overall improvement for constraint set 1 (random access) encoding relative to the Alpha anchor was reported as 0.04 dB in BD-PSNR and 1.0 % in BD-Bitrate. The overall improvement for constraint set 2 (low delay) encoding relative to the Beta anchor was reported as 0.03 dB in BD-PSNR and 0.8 % in BD-Bitrate.

The increment of processing complexity compared with the JM was reportedly an 8% increase for the encoder and a 5% increase for the decoder on average. The difference in memory usage was reportedly negligible.

JCTVC-A116 [M. Winken, S. Boße, B. Bross, P. Helle, T. Hinz, H. Kirchhoffer, H. Lakshman, D. Marpe, S. Oudin, M. Preiß, H. Schwarz, M. Siekmann, K. Sühring, T. Wiegand (Fraunhofer HHI)] Video coding technology proposal by Fraunhofer HHI

Presented Friday (16th).

The contribution document provided a description of the video coding technology proposal by Fraunhofer HHI. The proposed algorithm was based on the hybrid video coding approach using temporal and spatial prediction followed by transform coding of the residual and entropy coding.

The conceptual design could reportedly be considered as a generalization of AVC. The individual building blocks of the hybrid coding approach are kept similar to those in AVC, while the flexibility of the block partitioning for prediction and transform coding was increased. The use of two nested and pre-configurable quadtree structures was proposed, such that the spatial partitioning for temporal and spatial prediction as well as the space-frequency resolution of the corresponding prediction residual can be locally adapted. A modified entropy coding design was used which was asserted to allow a parallelization of the entropy decoding process and/or the use of variable-length codes while retaining the coding efficiency of arithmetic coding.

Objective gains of 29.9% in terms of average BD-rate improvement were reported for "Constraint Set 1". For "Constraint Set 2", the reported average BD-rate improvements were 22.1% relative to the Beta anchor and 42.4% relative to the Gamma anchor.

An overview of the most relevant aspects of the video coding algorithm as proposed by Fraunhofer HHI is as follows.

- **Entropy coding**: An entropy coding scheme is employed that supports a decoder parallel processing and that can reportedly be configured to operate at a complexity level of variable-length coding without loss in coding efficiency relative to the use of arithmetic coding. For further detail on this aspect, the related contribution JCTVC-A032 was provided.
- **Variable block size prediction**: The size of the prediction blocks can adaptively be chosen by using a quadtree-based partitioning. Maximum and minimum admissible block size are not fixed, but are specified in the bitstream. For the submitted bitstreams a block size range from 4×4 to 64×64 was used.
- **Variable block size residual coding**: Analogous the block size used for DCT coding of the residual is also derived by using quadtree-based partitioning of the corresponding prediction block. For the transform, a block size range from 4×4 to 64×64 was used.
- **Merging of neighbouring prediction blocks**: In order to reduce the number of bits required for signaling the prediction parameters, neighbouring prediction blocks can be merged into one region, such that the prediction parameters need to be transmitted only once for the whole region. The skip and direct modes were replaced by this functionality.
- **Fractional sample interpolation filter using Maximal Order Minimum Support (MOMS)**: For interpolating the fractional sample positions for motion-compensated prediction, a fixed point implementation of the MOMS algorithm was used as a two-directional 1D IIR (1-tap) followed by 4-tap FIR filtering.
- **Adaptive in-loop filtering**: In addition to the deblocking filter, two 1-D Wiener filter were applied within the motion-compensated prediction-loop. These filters were applied to chosen regions of the deblocking filter output in horizontal and vertical direction, respectively.
- **AVC compliant high level syntax**: The NAL unit syntax and parameter sets (SPS, PPS) as specified in AVC were used.

The internal bit-depth handling used 14 bits of precision. The scheme used quadtree-based picture plane grouping, flexibly generalized, which can be done differently e.g. for luma and chroma (maximum 64x64 used in submission), nested but could be different for the transform and prediction. Generalized multi-hypothesis (could be more than 2) prediction was applied. "Interleaved" motion prediction and motion vector coding was included to utilize coherences between horiztonal/vertical directions, selecting the best prediction candidates from blocks that have the same x component.

Subjectively in the test results – overall this proposal seems to have been among the 5 best.

The software codebase was written from scratch, and was asserted to be modular and extensible.

The additional technical contribution JCTVC-A032 is closely-related to this proposal.

JCTVC-A117 [T. Chujoh, A. Tanizawa, T. Yamakage (Toshiba)] Video coding technology proposal by Toshiba

Presented Sunday morning.

This contribution presented a technology package of video coding tools in response to the Joint Call for Proposals on Video Compression Technology. The scheme described in the contribution is based on the standard AVC design with a variety of proposed enhancements, and is also enhanced in relation to the coding scheme submitted by the proponent for their prior response to the MPEG "Call for Evidence". The bit rate reduction of the proposal compared to the anchor under the "constraint set 1" coding condition was reportedly 28.7% on average (up to 45.1%). The bit rate reduction of the proposal compared to the anchor under the "constraint set 2" coding condition (Beta anchor) was reportedly 25.9% on average (up to 42.4%). Those measurements were initially computed slightly differently than requested, but were later refined slightly in an additional uploaded revision of the contribution.

Features:

- Multiple Macroblock based Motion Compensation (M3C) - Available block sizes are 4x4, 4x8, 8x4, 8x8, 8x16, 16x8, 16x16, 16x32, 32x16, 32x32, 32x64, 64x32 and 64x64.
- Transform sizes added for 16x16, 16x8, 8x16
- Quadtree adaptive loop filter (QALF), usage of circular-shape filters
- High accuracy interpolation filter (HAIF) – non-adaptive 8-tap filter for 1/4 pel position (asserted to work better when used together with QALF)
- Internal bit depth increase (IBDI)
- Subjectively adaptive quantization matrix selection (SAQMS)
- Bidirectional intra prediction (BIP) (VCEG-AG18)
- Directional unified transform (DUT) for intra
- Spatio-temporal direct selection (STDS) - STDS enables to use motion vector(s) from temporally adjacent (super) macroblock (TDS: Temporal Direct Selection) or spatially adjacent (super) macroblock (SDS: Spatially Direct Selection) as motion vector(s) for the current block.

Encoder and decoder complexity were reportedly several times higher than the JM reference.

JCTVC-A118 [F. Wu, X. Sun, J. Xu, Y. Zhou (Microsoft Research Asia), W. Ding, X. Peng, Z. Xiong (Univ. Sci. Tech. China)] Video coding technology proposal by Microsoft

Presented Sunday morning.

This contribution described the response from Microsoft Research Asia to the Joint Call for Proposals on video coding technology issued jointly by ISO/IEC and ITU-T.

Features:

- KTA 2.4 techniques
    - MDDT enabled
    - QALF enabled
    - Enhanced AIF enabled
    - RDOQ
    - Extended MB size
    - MV competition

- Line-based coding mode and sample-based coding mode (without transform) with Wiener directional filtering: Line by line prediction + 1D DCT; can also be column by column; prediction parameter (Wiener filter) estimated from training window in the past; selection from 21 pre-defined filters; alternatively template matching. 4 bit flags for signaling of: Hor/Vert; Wiener or predefined; prediction or template matching; Transform/No transform. For sample based coding only 2 flags H/V and Wiener/predefined.
- Content-adaptive de-blocking filter with orientation energy edge detection (OEED): Threshold adjustment such that in the no-edge case de-blocking becomes more likely

The primary benefit asserted for the deblocking filter was subjective rather than objective benefit. The line & sample based coding modes were reported to be primarily beneficial for intra coding.

JCTVC-A119 [K. Ugur (Nokia), K.R. Andersson (LM Ericsson), A. Fuldseth (Tandberg Telecom)] Video coding technology proposal by Tandberg, Nokia, Ericsson

Presented Sunday morning.

This contribution presented the Tandberg-Ericsson-Nokia Test Model (TENTM), which was reportedly designed to fulfill the requirements of the mobile, video-conferencing and broadcast industries.

TENTM is a design asserted to provide both high performance and low decoding complexity. It was argued that TENTM provides significant visual improvement over AVC (both High Profile and Baseline Profile) with decoder complexity lower than AVC Baseline Profile. These improvements can reportedly be achieved with significantly lower encoding complexity than for AVC (both High Profile and Baseline Profile) which is valuable for real-time communication and services on mobile devices. In order to have a clean design from the start, it was reported that TENTM is designed with a "back-to-basics" approach in mind. Several possible extensions could reportedly be added during the standardization process to improve the coding gain significantly, e.g. CABAC, additional reference frames, etc.

Encoder time measurements reportedly show that the complete CS1 test set (all sequences, 5 rate points) can be simulated in 5 ½ hours while the CS2 test set can be simulated in less than 4 hours. On the same computing platform, TENTM encoding is around 25 times faster than JM17.0 encoding the Alpha and Beta anchors and around 10 times faster for coding the Gamma anchor. TENTM encoding is reportedly significantly faster than JM and uses software that was written from scratch in a "clean" fashion, and various brute-force techniques such as frame-level multipass encoding; large number of reference frames etc. were reportedly avoided.

Decoder simulations reportedly show that the TENTM decoder runs more than twice as fast as the JM17.0 High Profile decoder on average. This is reportedly because TENTM decoder has less algorithmic complexity than AVC and was implemented in a clean fashion.

Subjectively in the test results – overall this proposal did particularly well when considering its relatively low encoding and decoding complexity.

The software development codebase was newly written from scratch

Features:

- Motion partitions 64x64, 32x32, 16x16, 16x8, 8x16, 8x8
- Modified skip mode with up to two motion vector candidates selectable by syntax in the bitstream
- Motion vectors are rounded to integer values for B skip and B direct (encoding and decoding of B pictures is faster than for "P pictures")
- Different coding of reference index (B pictures always referencing one temporally preceding and one temporally subsequent picture)
- Only 2 reference frames used for encoding each picture in low delay mode
- Directional interpolation filters (DIF) and separable interpolation filters (SIF), 1 bit for signaling

- For every motion vector in the "middle 9" fractional positions, signal which interpolation filter is applied
- Intra is always 16x16, 8x8, or 4x4
- Intra 16x16 with DC, vertical, horizontal, and planar prediction
- Intra 8x8 with 32 selectable directions
- Intra 4x4 with DC, vertical and horizontal
- For planar prediction, a quantized sample value is sent for the bottom right corner of the block and the rest of the prediction values are generated by bilinear interpolation
- For residual transform - when prediction block size is larger than 16x16, only one corresponding transform is considered, and only the lowest 8x8 region of coefficient values is represented (and therefore the other coefficients do not need to be computed in the encoder)
- For inter prediction modes, and additional residual transform mode is available, referred to as spatially-varying transform, in which one residual transform block is sent, which covers only a sub-area of the prediction block according to an encoded position indicator. (The possible positions are not exhaustively searched in the proposal's encoder.)
- Reduced-complexity deblocking – no 4x4 deblocking and less complex logic – uses a combination of strong and weak filters, with interpolative filtering if two macroblocks are coded in planar mode.
- Entropy coding is VLC-based, with context adaptivity improvement relative to AVC CAVLC – asserted to be both lower complexity and improved in coding efficiency relative to AVC.

The definition of "P picture" and "B pictures" in this context is somewhat narrower than in AVC.

Suggested extensions of the proposal by the proponent included CABAC, additional reference frames, additional motion partition sizes, improved MV coding, adaptive in-loop filtering, decoder-side MV derivation, and using even larger encoding partitions than 32x32.

The proponent emphasized low complexity as a goal of the work.

The contribution included syntax, semantics, detailed decoder description, and the complete software package for the proposal.

It was remarked by a participant that the reported rate variation measure (RVM) numbers were rather high for this proposal relative to those of other proposals. The proponent responded that there was a description in the proposal document (section 5.2) of a trick that could be used to reduce the bit rate fluctuation – but that the trick had not been used due to the desire to avoid schemes that might be interpreted as quantization variation in a manner not desirable for a CfP response (in relation to statements about rate control in the text of the CfP). Another participant indicated that the RVM of the proposal and other proposals may indicate too high a bit rate allocation to the initial I frame in the low delay case.

JCTVC-A120 [D. He, G. Korodi, G. Martin-Cocher, E.-h. Yang, X. Yu, J. Zan (RIM)] Video coding technology proposal by RIM

Presented Friday (16th).

This document describes a technology for video encoding and decoding, which was asserted to be designed primarily to address the following challenges in wireless video communications: 1) improved rate distortion performance to save bandwidth requirements; and 2) reduced decoding complexity to save power consumption for mobile devices.

In order to reduce decoding complexity and improve decoding throughput, the proposal uses the following three tools to reportedly reduce the complexity of entropy coding and in-loop filtering, two of the most computationally demanding components at the decoder.

- A binary variable-length-to-variable-length (V2V) entropy coding method. (See also JCTVC-A116 and JCTVC-A032 for descriptions of a conceptually similar technology.) In comparison to binary arithmetic coding (BAC) in the AVC standard, V2V provides competitive compression performance (reportedly well within 1% of that of BAC in all cases), reportedly at much lower decoding complexity (estimated at 1/2 of that of BAC in standalone tests in software implementation). Moreover, it was reportedly estimated that V2V can sustain very high throughput (more than 6 bits/clock), and is more power efficient than BAC in hardware implementation.
- A parallel processing framework in entropy coding, with a method balancing the computational load on any finite number of available entropy decoding units. By decoupling entropy coding and context modeling, the parallel processing framework can reportedly use any entropy coding methods, including BAC, V2V, and Huffman coding (VLC), together with any context models like the ones defined in the AVC standard or improved versions. In the case where it is coupled with V2V, the parallel framework is reportedly particularly attractive: for example in hardware implementation it reportedly provides the capability to double the throughput with a small increase in area cost.
- A method to perform deblocking only at the encoder. By exploiting the benefits of deblocking without repeating the process at the decoder, this method may reportedly reduce the decoding complexity by about 30% with little negative (and in some cases even positive) impact on rate distortion performance. However, this feature was not actually used in the test sequences submitted for subjective evaluation.

In order to improve rate distortion performance, the proposal also used the following two tools.

- A soft-decision quantization algorithm (an encoder-only optimization) to minimize the actual rate distortion cost. See ITU-T COM16-C305 (October 2009).
- An iterative coding framework to jointly optimize quantization, motion estimation, and mode selection.

The tools were integrated into the JM11.0 KTA2.6r1 software codebase. It was asserted that each of these tools may also be independently integrated into JM11.0 KTA2.6r1 or some other model with or without the others.

The coding efficiency of the proposed model was evaluated by the proponent against the existing AVC standard on the test sequences defined in the Joint Call for Proposals (CfP). Using a frame-level "rate control" scheme and the group of picture (GOP) structure IPPP without hierarchical P frames, the model was reportedly on average more than 1 dB better than the Gamma (low complexity Constrained Baseline) anchor in the CfP, and also better, albeit marginally, than the Beta (higher complexity High profile hierarchichal P) anchor, in terms of the peak signal-to-noise ratio (PSNR) values of luminance frames at the specified rates. The proponent indicated that both the Beta and Gamma anchors use more sophisticated macroblock level "rate control", and that the Beta anchor further benefits from a GOP structure that includes hierarchical P frames. For some submitted encodings, the bitstreams did not actually match the coding condition constraints for random access encoding – the actual submitted bitstreams used low-delay encoding without random access refresh. However, this deviation is likely to have harmed rather than helped the quality of this proposal in the subjective testing.

The entropy coding design was noted to be similar to that in JCTVC-A116 / JCTVC-A032.

JCTVC-A121 [M. Karczewicz, P. Chen, R. Joshi, X. Wang, W.-J. Chien, R. Panchal (Qualcomm)] Video coding technology proposal by Qualcomm

Presented Sunday.

This contribution described Qualcomm's proposal in response to the call for proposal (CFP) issued jointly by MPEG and VCEG. The proposal is based on JMKTA software with several enhancements and additions. The proposal contained various tools that have been adopted into the JMKTA software – namely, block sizes bigger than 16×16, mode dependent directional transform (MDDT) for intra-coding, luma high precision filtering, single pass switch interpolation filters with offsets (single pass SIFO), quadtree based adaptive loop filtering (QALF) and Internal bit-depth increase (IBDI). Several additional tools such as geometry motion partitioning, adaptive motion vector resolution, simplified bigger transforms, chroma high precision filtering and motion vector scaling had also been added.

For "constraint set 1", compared to the Alpha anchor, the average BD-rate reduction was reportedly 30.9% and for "constraint set 2", compared to Beta and Gamma anchors, the average BD-rate reductions were reportedly 33.0% and 48.6%, respectively. These values were computed somewhat differently than what was requested for CfP responses (using 4-reference points rather than 5-point integrations) – a later modified upload may provide the 5-point method numbers.

Some results were also presented for a low complexity version using VLCs instead of CABAC and disabling IBDI. Compared with JM16.2 High IPPP configuration, the low complexity version reportedly achieves average BD-rate reduction of 22.4%.

Features:

- Block sizes larger than 16×16
- Transforms of size 16×16, 16×8, and 8×16 (and smaller)
- 16x16 transform modified (LLM factorization)
- Mode dependent directional transform (MDDT) for intra-coding
- Luma high precision filtering (to 1/8 pel positioning precision)
- Single pass switched interpolation filters with offsets (single pass SIFO)
- Quadtree based adaptive loop filtering (modified, merge of QALF and post filter, up to 16 filters, diamond-shaped to reduce overhead and complexity)
- Internal bit-depth increase (IBDI).
- Motion vector competition.
- Geometry motion partitioning with OBMC-style weighting across the partition edge
- Adaptive motion vector resolution
- VLCs for a lower complexity version (somewhat different than CAVLC – not used for the subjectively tested encodings)
- Chroma high precision filtering
- Direct mode for P slices
- Motion vector scaling
- Changes to mode syntax for B slices

It was asserted that an important aspect of the proposal is that except for QALF, the rest of the algorithm is single-pass.

Subjectively in the test results – overall this proposal seems to have been among the 5 best.

The software was based on the JMKTA codebase.

JM 16.2 was used for the run-time speed comparison, but JM 17.0 was suggested to have about the same run time as JM 16.2.

The time spent for encoding or decoding was characterized as roughly 2-4x the time used for JM encoding or decoding.

JCTVC-A122 [A. Ichigaya, K. Iguchi, Y. Shishikui (NHK), S. Sekiguchi, K. Sugimoto, A. Minezawa (Mitsubishi Electric)] Video coding technology proposal by NHK and Mitsubishi

Presented Friday (16th).

This contribution presented specifications of a new video coding algorithm in response to the Joint Call for Proposals on Video Compression Technology. The proposed video coding algorithm is based on well-known macroblock based hybrid coding architectures with block motion compensation and orthogonal transforms with coefficient quantization, and additional new coding tools. Differences from AVC are to enable adaptation of macroblock size together with multi-level hierarchical motion partitioning, adaptive decision on image block coverage and transform basis type for transform coding, new intra coding exploiting global spatial correlation, and adaptive Wiener loop filtering. The proposed algorithm reportedly showed around 1 dB PSNR gain on average relative to high-complexity AVC High Profile, over a wide range of test sequences. More gain had been observed particularly for high-resolution video sources such as class A and B as reported in this contribution. The proposed architecture as asserted to have more functional extensibility than the fixed use of existing 16x16 macroblocks, and was thus proposed to be a starting point for further performance improvement, while maintaining product implementability. Technical changes relative to the AVC are listed below.

- Extension of macroblock size and ability for its adaptation at higher syntax level
- Inter prediction with hierarchical and non-rectangular shaped motion partitioning
- New intra coding with global planar prediction and iterative adjustment prediction
- Adaptive transform with multiple block sizes and basis functions
- Combined in-loop adaptive de-blocking and Wiener filtering
- CABAC design that accommodates extended macroblock size syntax

A question was asked regarding the relative complexity and compression performance of sometimes using DST versus sometimes just skipping the transform. It was remarked that various proposals have transform switching, and that this is a good category of algorithm concepts to study more deeply.

JCTVC-A123 [Y.-W. Chen, T.-W. Wang, C.-H. Chan, C.-L. Lee, C.-H. Wu, Y.-C. Tseng, W.-H. Peng, C.-J. Tsai, H.-M. Hang (NCTU)] Video coding technology proposal by NCTU

Presented Sunday 12:30pm.

This contribution proposed a Parametric Overlapped Block Motion Compensation (POBMC) technique to improve temporal prediction. It extends the notion of OBMC as in H.263 to accommodate the variable block-size motion segmentation of AVC. The approach solves for optimal OBMC weights using a closed-form formula involving only the distances between the predicted sample and its nearby block centers. The proposed scheme, when combined with EAIF, RDOQ, QALF, EMB, MDDT, and TMP-Skip, was reported to have an average BD-Rate saving of 22.0%, 21.9%, and 41.5% relative to Alpha, Beta, and Gamma anchors, respectively. The average BD-PSNRY gains were, reportedly, 0.9 dB, 0.9 dB, and 2.0 dB. Like multi-hypothesis motion compensation, the POBMC scheme reportedly has the side benefit of being error resilient, but incurs an increase in memory access bandwidth and computational complexity (by an amount characterized as moderate by the proponent).

Features:

- Parametric OBMC: Determines the weights used in overlap based on a distance weighting criterion (relative to distance to adjacent block centers). Extension to bi-prediction taking into account temporal distances. Combination not only with variable block size, but also with asymmetric and geometric partitions possible. It was reported that 6 hypotheses are used on average (only depends on block constellation).
- EAIF
- QALF

- EMB
- MDDT
- TMP-Skip

Regarding complexity – the implementation that was used was asserted to be non-optimized, such that better speed should be very feasible. Very high runtime ratios were reported (50-130x decoding time ratios).

It was remarked that ITU-T Rec. H.263 also has variable block sizes, and thus has a similar issue in regard to variable block size partitioning. In the H.263 case, larger blocks were treated as equivalent to a collection of smaller blocks with the same motion vectors in each smaller block as in the larger aggregate block.

A participant asked how much benefit there is to the parametric OBMC scheme relative to fixed weighting - e.g., in a similar manner as in H.263, but perhaps based on 4x4 as the basic block size. This question may benefit from further study.

It was also remarked that OBMC may have a greater subjective benefit than it does objectively.

For the OBMC weighting, 6 hypotheses were reportedly used on average – based on which MVs fall within a 32x32 region (only 3 MVs are used per prediction sample in H.263).

JCTVC-A124 [K. McCann (Zetacast/Samsung), W.-J. Han, I.-K. Kim, J.-H. Min, E. Alshina, A. Alshin, T. Lee, J. Chen, V, Seregin, S. Lee, Y.-M. Hong, M.-S. Cheon, N. Shlyakhov (Samsung)] Video coding technology proposal by Samsung (and BBC)

Presented Friday (16th).

This proposal is Samsung's response to the Call for Proposals (CfP) on video compression technology, jointly issued by ITU-T SG16 Q.6 (VCEG) and ISO/IEC JTC1/SC29/WG11 (MPEG). It was produced in collaboration with the British Broadcasting Corporation. The goal of this proposal was reportedly to provide a video compression technology which has significantly higher compression capability than the AVC standard, especially for high-definition (HD) video content. To achieve this goal, a number of new algorithmic tools were proposed covering several aspects of video compression technology. These include a general structure for representation of video content, inter/intra prediction, in-loop filtering, and entropy coding. When all the proposed algorithmic tools are used, the proposed video codec reportedly achieves approximately 40% bit rate savings for equal PSNR on average compared to AVC in both "Constraint Set 1" and "Constraint Set 2" configurations. The average decoding time for the proposed codec was measured to be between about 0.9 and 2.4 times that of JM17.0, depending on the computer hard disk drive configuration.

Highlighted features of proposed codec design are as follows.

- **Flexible size unit representation**: The proposal separately defines three block concepts: coding unit (CU), prediction unit (PU) and transform unit (TU). After the size of largest coding unit (LCU) and the hierarchical depth of CU have been defined, the overall structure of codec is characterized by the various sizes of CU, PU and TU in a recursive manner. This reportedly allows the proposed codec to be adapted for various kinds of content, applications, or devices that have different capabilities/resources.

- **Size-independent syntax representation**: While block level syntax such as coded block pattern and intra prediction mode are coded differently depending upon the block sizes in AVC, the proposed codec employs one common syntax representation for all CU sizes, which reportedly reduces complexity and improves clarity.

- **Support of large and asymmetric motion partitions**: Larger PUs than 16x16 are supported. Asymmetric motion partition (AMP) is also supported, reportedly to increase the performance for irregular image patterns (supporting 1/4 vs. 3/4 size).

- **Support of higher motion accuracy than 1/4 pel with new interpolation filter**: High accuracy motion (HAM) is supported with a new DCT-based interpolation filter (DIF). Motion vector refinement is introduced to obtain high accuracy such as 1/12 pixel.
- **Support of large integer transforms**: In addition to conventional 4x4 and 8x8 transform, fast integer realizations of 16x16, 32x32 and 64x64 transforms were proposed.
- **Rotational transform**: A new supplementary rotational transform (ROT) was proposed to encode high energy residual information more efficiently.
- **Logical transform**: Tree structure allowing extension into larger block sizes.
- **Modified motion vector prediction method**: Advanced motion vector prediction (AMVP) is utilized to find a motion vector predictor among the various PU combinations
- **In-loop filtering modifications**: Several in-loop filters are combined to reduce the reconstruction distortion. The AVC deblocking filter has been modified to make it suitable for the hierarchical CU/PU/TU structure. In addition, the CU-synchronized adaptive loop filter (ALF) minimizes the expected average distortion whilst the spatial filtering extreme correction (EXC) reduces the distortion in the specific regions which are important to visual perception. Also, content adaptive dynamic range (CADR) is performed to mitigate rounding effects and to increase the accuracy of intermediate calculation without increasing bit-depth.
- **Modified intra prediction methods**: To increase the performance of intra coding, four new intra tools were included: arbitrary directional intra (ADI), pixel based template matching (PTM), color component correlation based prediction (CCCP) and multi-parameter intra (MPI). Using these tools, prediction patterns can be provided which cannot be generated efficiently in the conventional way.
- **Entropy coding with explicit scan order signaling**: Syntax-based binary arithmetic coder (SBAC) is proposed. In order to increase the efficiency of the entropy coding of transform coefficients, an explicit scan order is signaled from amongst pre-defined scan orders (horizontal/vertical/diagonal).

The software codebase is C++ written substantially from scratch (not really using C++ features), apparently partly based on the JSVM reference software (the reference software for the SVC extensions to the AVC standard).

For Constraint Set 2 (low delay) encoding cases, the proponent chose between using the Hierarchical P versus IPPP coding structure by hand for some sequences.

The complexity was estimated as about 6x for encoding time on average relative to AVC JM.

Subjectively in the test results – overall this proposal seems to have been among the best few.

JCTVC-A125 [T. Davies (BBC)] Video coding technology proposal by BBC (and Samsung)

Presented Friday (16th).

This proposal was the BBC's response to the Call for Proposals (CfP) on video compression technology, jointly issued by ITU-T SG16 Q.6 (VCEG) and ISO/IEC JTC1/SC29/WG11 (MPEG). It was produced in collaboration with Samsung Electronics Co., Ltd. The goal of this proposal was reportedly to provide a video compression technology which has significantly higher compression capability than the AVC standard, especially for high-definition (HD) video content. A further goal was to obtain these gains with minimal increase in complexity over AVC. To achieve these goals, a number of new algorithmic tools were proposed covering several aspects of video compression technology. These include a general structure for representation of video content, inter/intra prediction, in-loop filtering, and entropy coding. When all the proposed algorithmic tools are used, the proposed video codec reportedly achieved approximately 30% bit rate saving on average for equal PSNR compared to AVC in both "Constraint Set 1" and "Constraint Set 2" configurations. Complexity is reported to be approximately equivalent to

AVC, with the average decoding time for the proposed codec varying between 0.6 and 1.25 times that of JM17.0, depending on the computer hard disk drive configuration.

The technology design for this proposal was generally similar to that in JCTVC-A124. This proposal represents a lower-complexity variation of the same basic design structure.

Complexity was estimated as about 3x for encoding time on average relative to the AVC JM.

Subjectively in the test results – overall this proposal seems to have been among the best few.

JCTVC-A126 [S. Mochizuki, K. Iwata (Renesas)] Video coding technology proposal by Renesas

Presentation Sunday p.m.

This contribution described the Renesas response to the Joint Call for Proposals (CfP) on Video Compression Technology. The proposal contained an intra prediction method in addition to other coding tools. Simulation results reportedly showed an average of 20.7% bit rate reduction relative to the Alpha anchor encodings for Constraint Set 1, and 11.8% bit rate reduction relative to the Beta anchor encodings for Constraint Set 2.

Features:

- Intra repetitive pixel replenishment (Intra RPR) based on template matching
- 2D-AIF (reference VCEG-Z17)
- Motion vector competition (reference VCEG-AC06)
- Extended block sizes up to 32x32 (reference VCEG-AJ23)

The concept of Intra RPR is to use a displacement vector to select a previously-decoded area within the same picture to use to form a prediction block. A method was described for filling in areas of the picture that have not yet been coded. The displacement vector is predicted using a decoder-side block matching search to determine a predicted displacement vector. A 1-bit flag is used for each intra NxN macroblock to identify whether or not to use the Intra RPR prediction scheme.

For I frames, the proponent indicated about a 3.7% bit rate savings for applying the Intra RPR technique.

A participant asked how the edges of the picture were handled – the response was that it was similar to handling of "unrestricted motion vector" operation – i.e., padding using the edge value.

A participant remarked about the effect on parallel processing, especially in the encoder, of needing to fully reconstruct the left neighbor area before encoding the current area. It was noted that the AVC anchor also has such a dependency.

It was remarked that this proposal is primarily emphasizing intra coding, while the manner in which the CfP responses were subjectively tested was not particularly friendly to the testing of intra coding techniques. It was estimated that 26% of the overall bit rate on average in the Alpha anchor encoding was being used for intra.

The decoding time was estimated at 7-9x JM 17 (but mostly not due to the Intra RPR scheme).

The software was based on a JMKTA codebase.

JCTVC-A127 [H.Y. Kim, S. Jeong, S.-C. Lim, J. Kim, H. Lee, J. Lee, S. Cho, J.S. Choi, J.W. Kim (ETRI)] Video coding technology proposal by ETRI

This contribution described the ETRI response to the Joint CfP on Video Compression Technology. The proposed technology employs some tools from KTA2.3 and the AVC High Profile. Based on these features, some intra coding and loop filter tools were also designed and integrated; a 32x32 extended block size was used for Intra-Slice coding and 4 mode and 9 mode directional intra prediction schemes were used with MDDT (Mode-Dependent Directional Transform) kernels for 32x32 and 16x16 partitions, respectively. For I_8x8 and I_16x16 prediction, the AVC directional prediction was extended in a recursive way (RIP: Recursive Intra Prediction) and adaptive low-pass filter (AFP: Adaptive Filtering

Process) was applied before and after the intra prediction stage. A simplified version of AVC deblocking filter (SDF: Simplified Deblocking Filter) was designed and an extended version of QALF (E-QALF: Enhanced QALF) was proposed.

Features:

- 32x32 extended block size is used for Intra-Slice coding
- MDDT (Mode-Dependent Directional Transform) kernels are proposed for 32x32 and 16x16 partitions (reference VCEG-AJ24)
- Extended Intra prediction 32x32 like AVC 16x16, and 16x16 with directions like AVC 8x8
- For I_8x8 and I_16x16 prediction, AVC's directional prediction is extended in a recursive way (RIP: Recursive Intra Prediction)
- Adaptive low-pass filter (AFP: Adaptive Filtering Process) is applied before and after the intra prediction stage
- Simplified version of AVC deblocking filter (SDF: Simplified Deblocking Filter) (reference VCEG-AJ17), only boundary samples q_0 and p_0 are used
- Extended version of QALF (E-QALF: Enhanced QALF) with 3 more symmetries (H/V/Diag)

Under the constraint set 1 (CS1) coding conditions, the average per-class BD-Rate savings against the Alpha anchor reportedly as ranging from a minimum of 23.5% for Class D to a maximum of 33.7% for Class B. Under the constraint set 2 (CS2) coding conditions, average BD-Rates against the Beta (and Gamma) anchor were reported as ranging from a minimum 10.9% (33.2%) for Class D to a maximum of 35.0% (-51.8%) for Class E.

The decoding times, relative to JM 16.2, reportedly ranged from 4.6x to 7.0x for CS1 and from 3.9x to 7.1x for CS2, without any non-automatic software optimization involved.

The codebase used was JMKTA software.

Subjectively in the test results – overall this proposal seems to have been among the 10 best.

3 Additional contributions

3.1 Guidance on working methods

JCTVC-A026 [D. Alfonso (STMicro)] Proposals for video coding complexity assessment

This contribution discussed some methods that were indicated to be commonly used to estimate the complexity of software applications, and proposed a methodology for the complexity assessment of video coding software systems based on the "Valgrind" tool suite.

STMicroelectronics submitted the following proposals for JCT-VC consideration:

- To consider complexity assessment during the standardization process of the new "High-Performance Video Coding" and to evaluate contributions in terms of both coding efficiency and complexity efficiency.
- To define a clear procedure for complexity assessment considering the present contribution as a starting point for further discussion.
- To specify the complexity assessment procedure in a document entitled e.g. "Recommended simulation common conditions for complexity efficiency experiments".

The group certainly agreed with the first suggestion. Regarding the other two suggestions – there was some concern expressed that it might be somewhat difficult to study the problem adequately and find a fully agreed specific method. Since complexity is a multi-dimensional concept, it is not possible to define the computational complexity of an application "per se"; it depends on the application, on the compiler technology, the CPU Instruction Set Architecture and/or custom silicon environment.

Further study of the proposal was encouraged.

3.2 Video coding technology proposals

JCTVC-A020 [X. Li (Santa Clara Univ.), L. Liu (Huawei), N. Ling (SCU), J. Zheng, P. Zhang (Hisilicon)] Predictive adaptive transform coefficients scan ordering for inter-frame coding

In earlier video coding designs, the quantized coefficients have typically been scanned in a zig-zag pattern. This scanning order may not always be optimal for entropy coding. To achieve better entropy coding gain in inter-frame coding, this contriution proposed a predictive adaptive scan ordering scheme for quantized transform coefficients and reportedly showed that additional inter-frame coding redundancy can be removed by the proposed method. The scanning orders are proposed to be dynamically updated based on the probabilistic distribution of quantized coefficients in previous frames.

Based on analysis, blocks of a frame are grouped by their inter prediction modes. A new scan order is generated for each different prediction mode. These new scan orders are then also applied to the next inter-predicted frame.

The coding efficiency benefit was reportedly 3.6% as tested.

It was remarked that there appears to be an error resilience issue with the use of the prediction of scan orders, in the event that data for some picture is lost.

It was also remarked that an alternative adaptive scan order scheme such as in JPEG XR (spatial statistics collection rather than inter-frame predictive scan ordering) might be an interesting alternative.

Further study of the proposal was encouraged.

JCTVC-A021 [J. Park, S. Park, B. Jeon (LG)] Coding tools using parametric representations to improve coding efficiency

This document presented two coding tools using parametric representations.

The first tool is an adaptive warped reference (AWR) method to handle complex motion in a video sequence. The AWR method generates warped reference pictures that compensate complex motion between a recently decoded reference picture and a current picture to be encoded. The motion is modeled as a parametric image transformation function such as a "homography transformation function". Then, the parameters of the transformation function are quantized and encoded in the bitstream so that a decoder can warp the previously decoded reference picture in the same way as the encoder did.

The proposed warping method may be conceptually similar to the perspective warp in MPEG-4 part 2, followed by 2D Keys cubic convolution interpolation (the same as Catmull-Rom interpolation) based on floating point computations. In experiment results, the average benefit of the warping technique appears to be negligible except for particular types of sequences, such as the Cactus (7%) and Jets (8%) sequences. For these benefit estimates, the reference anchor used was proposal number JCTVC-A110, rather than the AVC JM.

The second proposed tool was a parametric adaptive interpolation filter (PAIF) method that is an advanced AIF technique. The PAIF scheme represents an interpolation filter using a few parameters instead of many individual filter coefficients by approximating the interpolation filter with a parametric function. It was asserted that PAIF needs fewer bits than conventional AIFs to represent a filter and that its representation is closer to the optimal filter than those of conventional AIFs. In the proposed PAIF method, a parametric function and an offset value are used, which are computed for each reference frame.

The reported percentage bit rate savings for the PAIF scheme, tested on Class C and D was about 1% overall, with 9% benefit on one class D sequence (BQSquare).

These tools were used to further improve the LG proposal design (JCTVC-A110) that was submitted as a response to the CfP. However, the evaluation of the LG CfP response proposal was done without these tools because they were still under development during the evaluation period.

Further study of the proposal was encouraged.

JCTVC-A022 [L. Liu (Huawei)] Multiple predictor sets intra coding

To achieve better coding gain for intra (I) frames in AVC, multiple predictor sets for intra coding (MPSI) were proposed to improve the accuracy of intra prediction. A new predictor set was introduced with similar subsets as the original one in AVC, in which 8 modes are directional and 1 is non-directional. The same method used in AVC was used to predict the intra prediction mode of each current block.

The predictor set is determined by the statistics in a template area of previously decoded neighboring regions.

A flag at the macroblock level was proposed to select whether to apply the existing AVC intra prediction scheme or the modified one.

Experimental results reportedly showed that the proposed method achieves 3.1% average bit rate reduction for I frames for the "Constraint Set 1" and "Constraint Set 2" conditions with CABAC, and 3.9% average bit rate reduction for Constraint Set 2 with CAVLC. The technique is reportedly compatible with other KTA tools such as the Adaptive Loop Filter, and was asserted to provide more bit rate reduction when used together with such tools. The encoding time is increased substantially (about double) and the decoding time is also increased, although more modestly (about 25% - where the increase is primarily due to the template matching).

Related proposals include JCTVC-A105, JCTVC-A119, and JCTVC-A124.

Further study of the proposal was encouraged.

JCTVC-A025 [C. Lai, Y. Lin (Hisilicon & Huawei)] New intra prediction using the correlation between pixels and lines

This contribution presented a spatial prediction scheme for intra encoding using the correlation between lines and samples instead of blocks. Unlike block-based intra prediction, both line-based intra prediction and resample-based intra prediction were proposed to improve compression performance of intra encoding. Experimental results reportedly showed an average of about 4% bit rate reduction as compared to AVC High Profile in all intra picture coding (under test conditions otherwise similar to the CfP conditions).

Two techniques (also described in JCTVC-A111):

- Line-based and 2x8/8x2 intra prediction (see also JCTVC-A118), with nine selectable prediction directions (one direction selected for each line of each block or each 2x8 or 8x2 region), with reconstruction repeatedly for each line (or 2x8 or 8x2 region) before predicting the next line (or 2x8 or 8x2 region)
- Resample-based intra prediction (perhaps sort of similar in spirit to H.261 Annex D)

This contribution provided experiment results for these techniques individually, as opposed to having them packaged together with other techniques as found in JCTVC-A111.

Further study of the proposal was encouraged.

JCTVC-A027 [H. Zhu (Zhu)] Arithmetic coding based on probability-aggregation and delayed-subdivision

An arithmetic coder described as being parallel friendly was proposed in this contribution. One asserted shortcoming of the existing AVC CABAC design is the dependency on probability range computation. After each binary symbol is coded, the range variable is often renormalized. Because of this step, it was asserted to be necessary to decode all symbols one by one serially.

The proposal is motivated primarily by an improved ability to use parallelism for implementation. The proposed technique appears to perform about the same or somewhat worse, relative to the current AVC CABAC design.

Further study of the proposal was encouraged.

JCTVC-A028 [J. Zheng (Hisilicon & Huawei)] Adaptive frequency weighting quantization

In the AVC standard, a customization of quantization step sizes on a frequency basis is available in picture level using 8x8 and 4x4 quantization scaling matrices sent in the picture parameter set. However, different regions in a picture have different sorts of texture. This proposal considers a macroblock level quantization tool to allow parameterized frequency weighting controlled at the picture level and non–uniform quantization controlled at the macroblock level without macroblock-level signaling overhead. The technique is referred to as adaptive frequency weighting quantization (AFWQ). The quantization mode selection was proposed to be based on the block size, block type, prediction type, prediction direction, and/or such properties of neighbor blocks. Blocks are classified into three classes: flat, textured, and untextured.

It was remarked that the proposal is somewhat similar to the Toshiba proposal JCTVC-A117.

The average bit rate reduction for equal PSNR was reported to be in the range of 2-3%. RDOQ was reportedly set to 1 for these experiments.

Encoding and speed were reported to be approximately unaffected.

A participant asked whether this scheme had an effect on blocking artifacts, as the scheme causes variation of quantization fidelity across block edges.

Further study of the technique was encouraged.

JCTVC-A029 [X. Zheng (Hisilicon), H. Yu (Huawei)] Flexible macroblock partition for inter-frame coding

This contribution was uploaded late.

This contribution presents a macroblock partition technique for inter-frame coding by considering an object's boundary and contour. Unlike traditional block partitioning, the proposed technique can divide a macroblock into two triangles, or a triangle and a pentagon, or two unsymmetrical size rectangles. The proposed technique, which is called flexible macroblock partition (FMP), was also proposed in JCTVC-A111. This contribution provides some further information about the FMP technology.

A syntax indication is used to indicate when to apply the technique. It was estimated that in a P frame about 10% of the macroblocks use this technique. It was reported that the technique is applied more often at lower bit rates.

Approximately 2-4% gain was reported, averaging about 2.5% (using IPPP encoding, otherwise configured the same as the Beta anchor).

The proposed technique was only applied only using selection at the 16x16 syntax level. It was suggested that it may possibly work better with consideration of other block sizes.

Further study of the proposal was encouraged.

JCTVC-A030 [A. Tabatabai and T. Suzuki (Sony)] AVC based intra prediction for improved visual quality

In the current AVC intra coding framework, intra prediction is performed to reduce the correlation between the samples in the current block and those of reconstructed neighbors. DC prediction and eight directional prediction modes are defined. The prediction mode number is signaled to the decoder using predictive coding. The current intra prediction scheme was asserted to have two significant disadvantages: 1) that the 8 directional modes do not provide sufficient precision to cover arbitrary directional patterns; and 2) that the mode number prediction from neighbors is not accurate enough to exploit the geometric dependency between blocks. In this submission, it was proposed to extend AVC-based intra prediction for the next generation video coding standard, to improve both visual quality and objective coding performance. It was proposed to leverage the inter-block geometric dependency at the decoder side. More specifically, prediction direction detection was proposed to be performed at the decoder-side, in the reconstructed neighborhood of the current block to get an a priori prediction direction. The encoder would then send side information to signal to the decoder whether to use that prediction direction or the usual AVC based prediction direction. Since the prediction direction detection is conducted at the decoder side, a high direction resolution can reportedly be obtained without requiring additional overhead bits for signaling. Simulation results reportedly show that the new intra prediction method can provide about 4% (up to 10%) bit-rate reduction as compared to AVC intra prediction. (The initial uploaded contribution contained only a one-paragraph summary of the technology, with no test results or further detail; and a more complete description was provided later.)

Proposal contribution JCTVC-A114 (and possibly others) may be related.

Further study of the proposal was encouraged.

JCTVC-A032 [D. Marpe, H. Schwarz, T. Wiegand (Fraunhofer HHI)] Novel entropy coding concept

This contribution described an approach to entropy coding. The basic idea of the presented entropy coding concept is the usage of multiple parallel binary encoders/decoders that operate for fixed probability estimates. The entropy coding concept reportedly supports a high degree of decoder parallel processing and can reportedly be configured in a way that it operates at a complexity level of variable-length coding without any loss in coding efficiency relative to the use of arithmetic codes.

This contribution relates to proposal JCTVC-A116, but further extends the entropy coding material in that contribution and provides further information about the technique.

Contribution JCTVC-A120 (from RIM) appears similar. That contribution estimated a 3x throughput relative to CABAC.

The proposal includes the following concepts:

- Quantization of probability intervals
- Selection of a representation probability to identify the selection of a particular interval
- Variable-to-variable codes with codeword interleaving

It was noted that the context modeling is still sequential and basically the same as in AVC CABAC.

Further study of the proposal was encouraged.

3.3 Video source material for experimentation

JCTVC-A023 [S. Sakaida, Y. Shishikui, A. Ichigaya, Y. Matsuo, K. Iguchi, T. Toyoda (NHK)] 7680 × 4320 format test sequences for JCT-VC

This contribution described and introduced a set of 7680 × 4320 format video sequences that will be made available to the JCT-VC and its parent bodies by NHK. NHK proposed to adopt these sequences for developing and testing JCT-VC standards.

These sequences ("Nabuta festival" and "Steam Locmotive Train") were previously discussed in an MPEG contribution of the January 2010 MPEG meeting in Kyoto, but the usage conditions had been modified in the new contribution to better enable their use.

The sequences are 60 fps, progressive-scan, 4:2:0, 10 bits per sample.

The images were sampled using a Bayer-style "dual green" sampling method.

The modification of the usage conditions was welcomed, and the modified language appears adequate to allow them to be used in our work.

Participants who wanted a copy of these sequences were requested in the contribution to send email by the end of April to Shinichi Sakaida (sakaida.s-gq@nhk.or.jp).

3.4 Test model basis suggestion submitted during meeting

JCTVC-A033 [T. Davies (BBC), K. R. Andersson, R. Sjöberg (Ericsson), T. Wiegand, D. Marpe (Fraunhofer HHI), K. Ugur, J. Ridge (Nokia), M. Karczewicz, P. Chen (Qualcomm), G. Martin-Cocher (RIM), K. McCann, W.-J. Han (Samsung), G. Bjøntegaard, A. Fuldseth (Tandberg)] Suggestion for a Test Model

This document was submitted late – during the meeting – as a proposed initial Test Model design having some features from various proposals, following private discussions between the listed proponents during the JCT-VC meeting. There was no objection to the presentation of this late document. (Note that this document was not a report of a recognized break-out group activity of the meeting – it was private input from the listed authoring submitters.)

The document proposed a first suggested Test Model that was asserted to be able to provide a coding efficiency capability close to that of the best performing proposals in the CfP subjective testing and also a complexity point close to that of the lowest complexity submissions with good subjective testing results. It proposed to include the following design elements:

- Unit definition
  - Coding Tree Block (CTB)
  - Prediction unit (PU)
  - Transform unit (TU)
- Motion representation
  - Motion vector prediction for rectangular partitions
  - Motion vector prediction for geometric block partitions
  - Interpolation Methods
    - Single pass Switched Interpolation Filters with Offsets (single pass SIFO)
    - Choice of filter set and offsets
  - Adaptive motion vector resolution
- Intra-frame prediction
  - Adaptive reference sample smoothing
  - Planar prediction
  - Angular prediction
  - Arbitrary Directional Intra (ADI)
  - Combined Intra Prediction (CIP)
- Spatial transforms
  - Large transform (16x16, 32x32, 64x64)
  - Rotational transform (ROT)
  - Mode Dependent Directional Transforms (MDDT) for intra-prediction residuals
- Quantization – as in AVC
- Deblocking filter
  - Luma filtering

    - Chroma filtering
    - Intra planar mode filtering
- In-loop filtering
- Entropy Coding
    - Low complexity entropy coding with VLC codes
    - High coding efficiency entropy coding with V2V codes

4 Actions taken and future work planning

4.1 Informal naming

The group agreed to use "High Efficiency Video Coding" (HEVC) as the informal name of the new standardization initiative.

The following other candidate names had been discussed prior to reaching that consensus:

- HVC = high performance video coding
- NGVC = next-generation video coding
- EPVC = enhanced-performance video coding
- HPVC = high performance video coding
- JCV = joint collaborative video
- HCEV = high coding efficiency video
- HCVC = high compression video coding

4.2 Planning the video coding specification deliverable

It was discussed whether HEVC should be a new standard, or an extension of the AVC standard. This decision involves thinking of time frame, messaging, technology aspects, impact on system-level interfaces, etc. Possibly there could be multiple target output designs that might include different answers to that question. No conclusion was reached on this topic at the meeting.

4.3 Tentative conclusions from CfP proposal reviews

High-level noteworthy aspects from the review of the proposals and the outcome of the subjective tests are outlined as follows:

- Substantial progress in coding efficiency has clearly been demonstrated (relative to "anchor" AVC usage)
- There is no indication of a need to change the fundamental architecture of "conventional" video coding designs to achieve a substantial improvement – all proposals contained the same basic structure, which can be outlined as follows:
    - Block-based
    - Variable block sizes
    - Block motion compensation
    - Fractional-pel motion vectors
    - Spatial intra prediction
    - Spatial transform of residual difference

    - Integer-based transform designs
    - Arithmetic or VLC-based entropy coding
    - In-loop filtering to form final decoded picture
- Inclusion of support of larger block sizes in a highly variable (typically tree-structured) block segmentation approach is a major common theme, although large block sizes were not found in all proposals that did well subjectively (and objectively)
- Modified motion interpolation filtering is likely to be an element of the new design
- Modified in-loop picture filtering is likely to be an element of the new design
- Parallel processing has emerged as being increasingly important
- New entropy coding concepts seem to be appearing that could potentially be substantially more parallel-friendly than CABAC without sacrificing coding efficiency
- Techniques for reducing picture storage memory were in multiple proposals, providing potential memory bandwidth reduction (and other) benefits
- There are many individual tool variants that appear in proposals as good candidates for contributing tool features to an overall design
- The feasibility of a low complexity technology with enhanced subjective (and objective) quality appears to have been demonstrated
- Higher degrees of sophisticated inference processing on the decoder side (e.g., displacement estimation within the decoding process) are evident in various proposals relative to the designs in prior standards, and understanding the complexity/performance tradeoffs for such features seems particularly important

4.4 Generation of a Test Model under Consideration (TMuC)

After reviewing the proposals and test results, the group tried to determine how best to transition from the "competitive phase" of individual proposal development to the "collaborative phase" of working together on a single design. A main issue that needed to be discussed was how to come to the selection of a test model during the next period of meetings, including how to build the related software testing platform that would enable the group to conduct good core experiments, and how to conduct these experiments.

Various possible approaches were discussed on how to create a test model (e.g., basing it on a best-performing proposal in the subjective testing, basing it on a simplest proposal with good subjective quality, starting with a "least common denominator" of features found in most proposals, additionally include some other tools from the better subjectively-performing proposals, initially experimenting with various tools in different software environments, or selecting the test model based on what software appears to be the best starting point for software development).

The JCTVC-A033 contribution, received during the meeting, provided one concrete suggestion of an approach that was asserted to be able to provide both of the following capabilities:

- Having a good coding efficiency operating capability, expected to be comparable to that of the best-performing proposals in terms of subjective quality, and
- Also an operating mode with substantially reduced computational complexity comparable to that of the lowest-complexity proposals that showed good coding efficiency benefits in the subjective quality testing.

A break-out discussion was held, led by T.K. Tan and Thomas Wedi, to further discuss a possible approach along these lines. After further review of this approach by the JCT-VC as a whole, a "Test model under consideration" (TMuC) design was selected by consensus, with the common understanding that this is not yet an initial version of the draft standard, as no thorough testing has been performed for such a possible combination of tools. The inclusion of a technology in the TMuC document does not indicate a final adoption of the technology as an element of an approved test model or draft standard of the JCT-VC committee. Rather, it indicates a preliminary selection which may require further evaluation and justification to achieve that status. Moreover, the decisions about any inclusion of technology could only be made after verification using a software codebase which would enable such testing and better understanding of the performance of the various tools in a variety of combinations.

The TMuC includes some elements of the following proposals (listed here in document number order):

- JCTVC-A114 (from France Telecom, NTT, NTT DOCOMO, Panasonic and Technicolor)
- JCTVC-A116 (from HHI)
- JCTVC-A119 ("TENTM" from Tandberg, Ericsson, and Nokia)
- JCTVC-A120 (from RIM)
- JCTVC-A121 (from Qualcomm)
- JCTVC-A124 (from Samsung, with BBC)
- JCTVC-A125 (from BBC, with Samsung)

Some of those design elements are probably also found in some other proposals as well, as there was substantial similarity among many proposals.

An initial draft of the TMuC was produced during the meeting as JCTVC-A205 draft 0. An ad-hoc group (AHG) was established to further improve the editorial quality of the TMuC in the interim period until the next meeting.

The group discussed establishing a relative prioritization of the design features described in the TMuC. It was agreed that not all technical features should be considered equal priority, and an initial assignment of priorities to technical features was conducted as a group. The priority assigned to a technology feature indicates a combination of the priority for software development activity and the degree to which inclusion in the TMuC design is anticipated to need further evaluation of effectiveness.

The following aspects were considered "priority 1": coding tree blocks (CTB), prediction units (PU), transform units (TU), motion representation, motion vector prediction, scaling for prediction of MVs, MV competition signal on the motion partition level, using one dimension of MV to predict the other, single pass switched interpolation filters with offsets (single pass SIFO), adaptive motion vector resolution, intra-frame prediction, planar prediction, multidirectional intra prediction using up to 33 directions, combined intra prediction (CIP), spatial transforms, large transforms (16x16, 32x32, 64x64), mode dependent directional transforms for intra-prediction residuals, quantization – as in AVC, deblocking filter, luma & chroma filtering, planar mode filtering, in-loop filtering, entropy coding, low-complexity entropy coding with VLCs, and high coding efficiency entropy coding with V2V codes.

The following aspects were considered "priority 2": asymmetric partitions, non-rectangular partitions, motion vector prediction for non-rectangular partitions, adaptive reference sample smoothing, switched KLT for inter, and augmenting prediction and residual signals as input to the filter.

Although not formally considered part of the TMuC design, HHI & RIM committed to provide a conventional BAC entropy coder implementation for software integration, and this effort was assigned priority 2.

The following aspects were considered "priority 3": block based illumination compensation, edge detection based intra prediction.

Although agreed by consensus in group discussion, this assignment of priorities should be considered preliminary and subject to further review and consideration in AHG and JCT-VC activities. Also, in the event that there may be inconsistency between the technical features described in the TMuC document and those described in the above list, it should be expected for the TMuC document to take precedence.

4.5 Software development planning

A break-out discussion during the meeting (coordinated by Frank Bossen) was held on the software development subject. The topic was later additionally considered by the group as a whole.

The goal was agreed to create a first version of a software implementation of the TMuC and make it available before the next meeting. Some characteristics that were discussed regarding the desirability of various potential software codebases as starting points for collaborative development are listed below:

- Using well structured code (easily understandable flow, adequate data structures, easy to integrate new tools and replace tools, reasonable code size)
- Adequate documentation
- Highly configurable: easy to test individual tools, easy to define "low-complexity" and "high-performance" tool combinations
- Whether the software can be configured to operate as an AVC encoder/decoder
- Coding efficiency – we should be able to quickly reach performance levels demonstrated by top CfP responses
- Reasonable encoding and decoding speed, including fast setting that does not unduly penalize compression performance (i.e., ability to offer speed/coding efficiency trade-offs similar to those demonstrated in responses to CfP)
- Sizeable overlap with the technical content of the TMuC document such as to minimize the development effort (e.g., large block size support)
- Using a familiar programming language (e.g., selecting C or C++, perhaps without fancy object-oriented C++ feature usage, seems desirable)
- Multiple platform support
- The extent to which the software is already available for evaluation by the participants
- Whether participants already have some working-level familiarity with the software (e.g., if based on JM, JSVM, or JM-KTA codebases)

The proponents agreed to make available the complete software packages for the seven proposals that are partially included in the TMuC within 2 weeks after the meeting. The proposal packages for the proposals containing TMuC elements were also strongly encouraged to include the Config files for the CfP test set conditions (within 2 weeks). The available JM (e.g., version 17.0) and JMKTA codebases were also suggested as potential starting points for the software development effort.

It was agreed that arrangements should be made to establish an easily-accessed (e.g., public read access) software repository for the software development effort.

A software development ad hoc group (AHG) was set up to coordinate this process. The proposed timeline was as follows:

- 3 weeks after meeting: Complete a technical analysis of software.
- 8 weeks after meeting: Initial combination of software

It was noted that a suitable copyright disclaimer header text needs to be established for the reference software development effort. It was noted that the latest header formats approved by the MPEG parent body can be found in its N10693 (Maui 88th meeting) and N10791 (London 89th meeting) output documents (both of which are public documents) and that the header text used for the AVC (JM, JSVM, and JMVC) reference software may also provide a useful example.

4.6 Planning of Tool Experiments (TEs) and Core Experiments (CEs)

While the TMuC software is under development, it was considered desirable to also start further investigations and possible design harmonization of various types of tools that had been proposed. Such tool experiments (TE) were agreed, for first investigations, to possibly be based on multiple available starting codebases (only one for each experiment) and later to be continued as Core Experiments (CE) on the basis of TMuC software when it becomes available.

The following CE/TE processes were agreed:

- TE/CE definition: Multiple parties running the same experiment in a coordinated way designed to test a particular technology feature or set of features, each producing a report of what was done and what is suggested to be concluded.
- Participants in an experiment would consist of those who expresses an intent to participate verbally at the meeting or by email to the chairs and TE/CE coordinator within 2 weeks of the end of the meeting. Such participants must commit to providing a report of the outcome of their experiment participation at the next meeting. Participants must be among those qualified for participation in the JCT-VC (as per the ToR). The codebase used for such an experiment will be shared with all participants of that experiment.
- An experiment description will be written and agreed upon (including identification of the codebase) in draft form at the meeting and will be uploaded by the end of the meeting. The experiment coordinator, in consultation with the other participants, will finalize the description within 2 weeks after the meeting.
- A TE/CE is proposed by one or more experts, and it is approved by consensus, with a requirement that two or more independent experts will carry out the experiment. Experiments are designed to evaluate the potential for inclusion of a new technique or set of techniques. At the heart of the TE/CE process are multiple, independent, directly comparable experiments, performed to determine whether or not proposed algorithmic techniques have merits.
- An experiment must be completely and uniquely defined, so that the results are unambiguous. In addition to the specification of the algorithmic technique(s) to be evaluated, a TE/CE also specifies the parameters to be used (for example, software, configuration settings and video resolution), so that the results can be compared.

The experiment description document shall describe, precisely, for the corresponding TE/CE:

- The tool or combination of tools that will be tested. The description must specify the syntax, semantics, encoding and decoding processes.
- The test sequences and test points to be used in the experimentation
- The timeline and responsibilities
- The software & configuration that shall be used
- Criteria to evaluate the TE/CE outcome (e.g., compression and complexity analysis)

The interrelationship of different TEs/CEs must be considered, e.g. by using common test sequences and test points (whenever possible) to make results comparable.

The group established four "Tool Experiments" (TEs) to evaluate specific proposed coding tools. (The group thought it best not to refer to the TEs as "Core Experiments", since they are not yet being conducted relative to an adopted "Test Model".)

Four "Tool Experiments" were planned, as follows:

- JCTVC-A301 on Decoder-side MV derivation, coordinated by Mathias Wien of RWTH Aachen University (wien@ient.rwth-aachen.de) and Yi-Jen Chiu of Intel (yi-jen.chiu@intel.com).

- JCTVC-A302 on Internal Bit-Depth Increase (IBDI) and Memory Compression, coordinated by Takeshi Chujoh of Toshiba (takeshi.chujoh@toshiba.co.jp).
- JCTVC-A303 on Inter prediction (focused on adaptive warped reference prediction, adaptive global motion temporal prediction, and geometric block partitioning) global & warped motion, non-rectangular partitioning), coordinated by Andreas Krutz of Tech. Univ. Berlin (krutz@nue.tu-berlin.de).
- JCTVC-A304 on variable-length coding, coordinated by Xianglin Wang of Qualcomm (xianglin@qualcomm.com).

A preliminary draft of the plan for each Tool Experiment was approved at the meeting, and was made available on the group ftp/web site using the document numbers provided above. The experiment coordinator, in consultation with the other participants, will finalize the description within 2 weeks after the meeting.

4.7 Ad hoc groups formed

The *ad hoc* groups (AHGs) formed for carrying out work in particular subject areas until the next meeting are listed in the table below, along with mandates for the work to be conducted. The email reflector to be used for discussions of all of the listed AHGs is the JCT-VC reflector: jct-vc@lists.rwth-aachen.de. None of these AHGs were planned to hold meetings.

AHG Title and Email Reflector	Chairs	Mtg
JCT-VC project management (jct-vc@lists.rwth-aachen.de) • Coordinate overall JCT-VC efforts • Report on project status to JCT-VC reflector • Provide report to next meeting on project coordination status	Gary Sullivan (garysull@microsoft.com), Jens-Rainer Ohm (ohm@ient.rwth-aachen.de) [co-chairs]	N
Test Model under Consideration editing (jct-vc@lists.rwth-aachen.de) • Discuss JCTVC-A205 and perform editorial improvements as appropriate	K. McCann (ken@zetacast.com) [chair] M. Karczewicz, J. Ridge, S. Sekiguchi, T. Wiegand [vice chairs]	N
Software development and TMuC software technical evaluation (jct-vc@lists.rwth-aachen.de) • Study the available software packages in terms of suitability for software integration • Establish a work plan for the development of the common software implementation of TMuC according to the agreed priorities • Coordinate development of the software and its distribution to JCTVC members • Conduct experiments on the TMuC software to determine encoder settings • Provide performance information according to the feasible status	F. Bossen (bossen@docomolabs-usa.com) [chair] P. Chen, D. Flynn, H. Schwarz, K. Ugur [vice chairs]	N
Intra prediction (jct-vc@lists.rwth-aachen.de) • Study the enhanced schemes in intra-prediction including block sizes, directionality, resampling, line-based & 2x8/8x2, pre/post-filtering, and chroma prediction using luma. • To discuss the relationship and the evaluation procedure among the schemes studied in mandate 1 • Propose Core Experiments	C. Auyeung (cheung.auyeung@am.sony.com) [chair] S. Lei, K. Sugimoto, H. Yu [vice chairs]	N

Alternative transforms (jct-vc@lists.rwth-aachen.de) • To define and conduct experiments related to using alternative, adaptive, mode-dependent directional, and directional transforms for coding prediction residuals • To select a common codebase upon which these experiments will be performed • To define and conduct experiments related to transforms proposed for the CfP, including but not limited to a. The Orthogonal Mode-Dependent Directional Transform of JCTVC-A101 b. The Directional Unified Transform of JCTVC-A117 c. The Directional Transform of JCTVC-A107 d. The Directional Transform of JCTVC-A111 e. The Adaptive DCT/DST of JCTVC-A122 f. DDCT of JCTVC-A103 g. Alternate KLT of JCTVC-A114 • To evaluate and report the performance characteristics of these transforms, using a. Objective measures (BD-Rate, BD-PSNR) b. Subjective descriptions (i.e., what kinds of artifacts are produced by each transform, what kinds of textures/features these transforms work best) c. Complexity (computational, memory, encoder) • To report the results and conclusions of these experiments to the JCT	R. Cohen (cohen@merl.com), R. Joshi (rajanj@qualcomm.com) [co-chairs]	N
MV precision (jct-vc@lists.rwth-aachen.de) • Compare and summarize different ideas on motion vector precision in proposals to HEVC CfP • Compare and summarize different interpolation filtering schemes, necessary for fractional-pel motion vector precision • Raise and discuss various issues on motion vector precision, adaptive scheme, different interpolation filters, etc. • Discuss issues on how to evaluate different methods related to motion vector precision • Study and propose possible core experiment(s) on this topic	B. Jeon (bjeon2000@gmail.com) [chair] X. Wang, S. Wittmann, T. Suzuki [vice chairs]	N
In-loop filtering (jct-vc@lists.rwth-aachen.de) • To study enhancement schemes of in-loop filtering, including de-blocking/de-banding/de-noising filters, adaptive Wiener-based filters including variants with various inputs, combination of in-loop filters and noise aware loop filters • To discuss the relationship and the evaluation procedure among the schemes studied in mandate 1	T. Yamakage (tomoo.yamakage@toshiba.co.jp) [chair] Y.J. Chiu, M. Narroschke, X. Wang [vice chairs]	N

Large block structures (jct-vc@lists.rwth-aachen.de) • To compare and summarize different ideas on coding block structure in proposals to HEVC CfP. • To define and conduct experiments related to coding block structure. • To raise and discuss various issues on intra mode block structure for both luma and chroma components and inter mode block structure for both luma and chroma components. • To report the results and conclusions of these experiments to the JCT-VC.	K. Panusopone (krit@motorola.com) [chair] M. Budagavi, D. He [vice chairs]	N
Parallel entropy coding (jct-vc@lists.rwth-aachen.de) • Compare and summarize different ideas on parallel entropy coding in proposals to HEVC CfP. • Raise and discuss various issues on parallel entropy coding. • Discuss how to evaluate different methods related to parallel entropy coding.	M. Budagavi (madhukar@ti.com), A. Segall (asegall@sharplabs.com) [co-chairs]	N

4.8 Meeting resolutions conveyed to the WG 11 parent body

The following meeting resolutions were conveyed to the WG 11 parent body:

- The JCT-VC and the video subgroup recommend approval of the following documents

No.	Title	TBP	Available
	High Efficiency Video Coding		
JCTVC-A204 **WG 11 N11275**	**Report of Subjective Test Results from the Call for Proposals on High Efficiency Video Coding**	**Y**	**10/05/14**
JCTVC-A205 **WG 11 N11280**	**Test Model under Consideration for High Efficiency Video Coding**	**N**	**10/05/14**

- The JCT-VC and the video subgroup thank FUB, EPFL, and EBU for conducting the tests related to the CfP on High Efficiency Video Coding, and the following persons for their extraordinary efforts put into the test: Vittorio Baroncini, Licia Capodiferro, Luca Costantini, Cristina Delogu, Touradj Ebrahimi, Ulrich Engelke, Christine Gabriel, Lutz Goldmann, Ivan Ivanov, Adi Kouadio, Jong-Seok Lee, Federica Mangiatordi, Eugene Myakotnykh, Emiliano Pallotti, Andrew Perkis, Fitri Rahayu, Ulrich Reiter, Lionel Rhyn, Hamidreza Shirazi, Francesca De Simone, Paolo Sità, Christoph Steindl, Peter Vajda, Liyuan Xing, Ashkan Yazdani and Jungyong You.

- The JCT-VC and the video subgroup thank the following companies and organisations for submitting proposals in response to the CfP on High Efficiency Video Coding: BBC, ETRI, Fraunhofer HHI, Fujitsu, Hisilicon, Hitachi, Huawei, Intel, JVC, LG Electronics, LM Ericsson, MediaTek, MERCE, MERL, Microsoft Research Asia, Mitsubishi Electric, MIT, NCTU, NEC, NHK, Nokia, NTT, NTT DOCOMO Inc, France Telecom, Panasonic, Qualcomm, Renesas, RIM Ltd, RWTH Aachen University, Samsung Electronics, Sejong University, SHARP, SK Telecom, Sony, Sungkyunkwan University, Tandberg Telecom, Technicolor, Texas Instruments, Toshiba and University of Science and Technology of China.

- The JCT-VC and the video subgroup thank the following persons for the effort in evaluating data collected from the CfP results: Vittorio Baroncini, Stéphane Pateux, Rickard Sjöberg.

- The JCT-VC and the video subgroup thank NHK for offering new 8Kx4K test sequences for usage in standardization. It is appreciated that NHK has re-considered the usage conditions such that users simply need to observe an attached copyright declaration. It is emphasized that these test sequences belong to NHK and that users are required to observe the conditions stated in the declaration.

- The JCT-VC and the video subgroup suggest to use the name "High Efficiency Video Coding (HEVC)" for the new joint standardization project.

- The JCT-VC chairmen propose to hold the 2nd JCT-VC meeting during 21-28 July 2010 under ITU-T auspices in Geneva, CH. Further JCT-VC meetings are proposed to be held during 7-15 October 2010 under WG11 auspices in Guangzhou, CN, and during 21-28 January 2011 under WG 11 auspices in Korea.

- The JCT-VC provides the following list of JCT-VC ad hoc groups appointed to progress work in the interim period until the next JCT-VC meeting – as tabulated above in section 4.7.

4.9 Standardization timeline

The Joint CfP announced a tentative timeline including the following:

- Test model selection process begins 2010/04
- Test model selection by 2010/10
- Final standard approval by 2012/07

The test model selection process did begin at this meeting, with good progress shown in the form of the TMuC adoption (JCTVC-A205). No changes to this tentative timeline were planned at the meeting.

4.10 Future meeting plans

It was agreed to announce the following meeting dates for the next meeting:

- 21-28 July 2010 (Geneva, CH, under WP3/SG16 auspices)

Subsequent meetings are anticipated for approximately the following dates:

- 7-15 October 2010 (Guangzhou, CN, under SC29/WG11 auspices)
- 20-28 January 2011 (TBD, KR, under SC29/WG11 auspices)
- 15-23 March 2011 (Geneva, CH, under WP3/SG16 auspices)
- 16-22 July 2011 (Torino, IT, under SC29/WG11 auspices)

4.11 Closing remarks

Given the level of contributions and participation, the subjective test results indicating substantial technology advancement demonstrated by the proposals, and the positive spirit of the discussions, we can predict that this meeting of the JCT-VC has been only the first of a successful series of meetings for the new collaborative work between ITU-T and ISO/IEC JTC 1 on video coding. The JCT-VC appreciated the good working environment provided by its hosting parent body ISO/IEC JTC 1/SC 29/WG 11 (MPEG) and by the local host for the meeting, the Institut für Informationsverarbeitung of Leibniz Universität Hannover. The first meeting of the JCT-VC was closed at approximately 1:45 p.m. on Friday 23 April 2010.

JCT-VC Report Annex A – Document list

Documents of the first meeting of the Joint Collaborative Team on Video Coding (JCT-VC)

Dresden, Germany, 15-23 April, 2010

(Hyperlink base http://ftp3.itu.int/av-arch/jctvc-site/2010_04_A_Dresden/)

General Input Document	Category	Authors	Subject	Files
JCTVC-A020	proposal (2)	X. Li (Santa Clara Univ.) L. Liu (Huawei) N. Ling (Santa Clara Univ.) J. Zheng (Hisilicon) P. Zhang (Hisilicon)	Predictive adaptive transform coefficient scan ordering for inter-frame coding	archive document (r1)
JCTVC-A021	proposal (2)	J. Park (LG) S. Park (LG) B. Jeon (LG)	Coding tools using parametric representations to improve coding efficiency	archive document (r1) presentation (r2)
JCTVC-A022	proposal (2)	L. Liu (Huawei)	Multiple predictor sets intra coding	archive document presentation
JCTVC-A023	information	S. Sakaida (NHK) Y. Shishikui (NHK) A. Ichigaya (NHK) Y. Matsuo (NHK) K. Iguchi (NHK) T. Toyoda (NHK)	7680 × 4320 format test sequences for JCT-VC	archive document
JCTVC-A024	withdrawn		(Registration withdrawn – no document provided)	withdrawn
JCTVC-A025	proposal (2)	C. Lai (Hisilicon / Huawei) Y. Lin (Hisilicon / Huawei)	New intra prediction using the correlation between pixels and lines	archive document presentation
JCTVC-A026	proposal (2)	D. Alfonso (STMicro)	Proposals for video coding complexity assessment	archive document presentation

JCTVC-A027	proposal (2)	H. Zhu (Zhu)	Arithmetic coding based on probability aggregation and delayed subdivision	archive document
JCTVC-A028	proposal (2)	J. Zheng (Hisilicon / Huawei)	Adaptive frequency weighting quantization	archive document presentation (r1)
JCTVC-A029	proposal (2) late	X. Zheng (Hisilicon) H. Yu (Huawei)	Flexible macroblock partition for inter-frame coding	archive document (r1) presentation
JCTVC-A030	proposal (2)	A. Tabatabai (Sony) T. Suzuki (Sony)	AVC based intra prediction for improved visual quality	archive document (r1) presentation
JCTVC-A031	information (2)	S. Pateux (Orange - FT)	Tools for proposal evaluations	archive document (r1)
JCTVC-A032	proposal (2)	D. Marpe (Fraunhofer HHI) H. Schwarz (Fraunhofer HHI) T. Wiegand (Fraunhofer HHI)	Novel entropy coding concept	archive document presentation (r1)
JCTVC-A033	proposal (2) late	T. Davies (BBC) K. R. Andersson (Ericsson) R. Sjöberg (Ericsson) T. Wiegand (Fraunhofer HHI) D. Marpe (Fraunhofer HHI), K. Ugur (Nokia) J. Ridge (Nokia) M. Karczewicz (Qualcomm) P. Chen (Qualcomm) G. Martin-Cocher (RIM) K. McCann (Zetacast / Samsung) W.-J. Han (Samsung) G. Bjøntegaard (Tandberg) A. Fuldseth (Tandberg)	Suggestion for a Test Model	archive document (r1)
CfP Response Input Document	**Category**	**Authors**	**Subject**	**Files**
JCTVC-A101	CfP response proposal (2)	M. Budagavi (TI) V. Sze (MIT) M. U. Demircin (TI) S. Dikbas (TI) M. Zhou (TI) A. P. Chandrakasan (MIT)	Video coding technology proposal by Texas Instruments (and MIT)	archive document presentation

JCTVC-A102	CfP response proposal (2)	K. Nakamura (Hitachi) S. Saito (Hitachi) T. Murakami (Hitachi) Y. Komatsu (Hitachi) T. Yokoyama (Hitachi)	Video coding technology proposal by Hitachi	archive document presentation
JCTVC-A103	CfP response proposal (2)	T. Suzuki (Sony) A. Tabatabai (Sony)	Video coding technology proposal by Sony	archive document (r1) presentation
JCTVC-A104	CfP response proposal (2)	K. Chono (NEC) K. Senzaki (NEC) H. Aoki (NEC) J. Tajime (NEC) Y. Senda (NEC)	Video coding technology proposal by NEC	archive document (r1) presentation
JCTVC-A105	CfP response proposal (2)	A. Segall (Sharp) T. Yamamoto (Sharp) J. Zhao (Sharp) Y. Kitaura (Sharp) Y. Yasugi (Sharp) T. Ikai (Sharp)	Video coding technology proposal by Sharp	archive document (r1) presentation
JCTVC-A106	CfP response proposal (2)	Y.-J. Chiu (Intel) L. Xu (Intel) W. Zhang (Intel) H. Jiang (Intel)	Video coding technology proposal by Intel	archive document presentation
JCTVC-A107	CfP response proposal (2)	K. Sugimoto (Mitsubishi Electric) Y. Itani (Mitsubishi Electric) Y. Isu (Mitsubishi Electric) N. Hiwasa (Mitsubishi Electric) S. Sekiguchi (Mitsubishi Electric) R. A. Cohen (MERL) P. Wu (Mitsubishi Electric R&D Europe) N. Sprljan (Mitsubishi Electric R&D Europe)	Video coding technology proposal by Mitsubishi Electric	archive document presentation
JCTVC-A108	CfP response proposal (2)	S. Sakazume (JVC Kenwood) M. Ueda (JVC Kenwood) S. Fukushima (JVC Kenwood) H. Namamura (JVC Kenwood) K. Arakage (JVC Kenwood) T. Kumakura (JVC Kenwood)	Video coding technology proposal by JVC	archive document (r1) presentation

JCTVC-A109	CfP response proposal (2)	Y.-W. Huang (Mediatek) C.-M. Fu (Mediatek) Y.-P. Tsai (Mediatek) J.-L. Lin (Mediatek) Y. Chang (Mediatek) J.-H. Guo (Mediatek) C.-Y. Chen (Mediatek) S. Lei (Mediatek) X. Guo (Mediatek) Y. Gao (Mediatek) K. Zhang (Mediatek) J. An (Mediatek)	Video coding technology proposal by Mediatek	archive document (r2) presentation
JCTVC-A110	CfP response proposal (2)	B. Jeon (LG) S. Park (LG) J. Kim (LG) J. Park (LG)	Video coding technology proposal by LG Electronics	archive document (r1) presentation
JCTVC-A111	CfP response proposal (2)	H. Yang (Huawei) J. Fu (Huawei) S. Lin (Huawei) J. Song (Huawei) D. Wang (Huawei) M. Yang (Huawei) J. Zhou (Huawei) H. Yu (Huawei), C. Lai (Hisilicon) Y. Lin (Hisilicon) L. Liu (Hisilicon) J. Zheng (Hisilicon) X. Zheng (Hisilicon)	Video coding technology proposal by Huawei Technologies and Hisilicon Technologies	archive document (r1) presentation
JCTVC-A112	CfP response proposal (2)	S. Kamp (RWTH Aachen Univ.) M. Wien (RWTH Aachen Univ.)	Video coding technology proposal by RWTH Aachen University	archive document presentation
JCTVC-A113	CfP response proposal (2)	J. Lim (SK telecom) J. Song (SK telecom) H. Park (Sejong Univ.) C.-W. Seo (Sejong Univ.) D.-Y. Kim (Sejong Univ.) J. O. Lee (Sejong Univ.) M.-J. Kim (Sejong Univ.) S.-W. Hong (Sejong Univ.) M.-H. Jang (Sejong Univ.)	Video coding technology proposal by SK telecom, Sejong University and Sungkyunkwan University	archive document presentation

		H. K. Kim (Sejong Univ.) Y.-L. Lee (Sejong Univ.) J.-K. Han (Sejong Univ.) B. Jeon (Sungkyunkwan Univ.) J.-H. Moon (Sejong Univ.)		
JCTVC-A114	CfP response proposal (2)	I. Amonou (FT) N. Cammas (FT) G. Clare (FT) J. Jung (FT) L. Noblet (FT) S. Pateux (FT) S. Matsuo (NTT) S. Takamura (NTT) C. S. Boon (NTT DoCoMo) F. Bossen (NTT DoCoMo) A. Fujibayashi (NTT DoCoMo) S. Kanumuri (NTT DoCoMo) Y. Suzuki (NTT DoCoMo) J. Takiue (NTT DoCoMo) T. K. Tan (NTT DoCoMo) V. Drugeon (Panasonic) C. S. Lim (Panasonic) M. Narroschke (Panasonic) T. Nishi (Panasonic) H. Sasai (Panasonic) Y. Shibahara (Panasonic) K. Uchibayashi (Panasonic) T. Wedi (Panasonic) S. Wittmann (Panasonic) P. Bordes (Technicolor) C. Gomila (Technicolor) P. Guillotel (Technicolor) L. Guo (Technicolor) E. François (Technicolor) X. Lu (Technicolor) J. Sole (Technicolor) J. Vieron (Technicolor) Q. Xu (Technicolor) P. Yin (Technicolor) Y. Zheng (Technicolor)	Video coding technology proposal by France Telecom, NTT, NTT DoCoMo, Panasonic and Technicolor	archive document annex A annex B annex C appendix 1 presentation
JCTVC-A115	CfP response	K. Kazui (Fujitsu)	Video coding technology proposal by Fujitsu	archive

	proposal (2)	J. Koyama (Fujitsu) A. Nakagawa (Fujitsu)		document presentation
JCTVC-A116	CfP response proposal (2)	M. Winken (Fraunhofer HHI) S. Boße (Fraunhofer HHI) B. Bross (Fraunhofer HHI) P. Helle (Fraunhofer HHI) T. Hinz (Fraunhofer HHI) H. Kirchhoffer (Fraunhofer HHI) H. Lakshman (Fraunhofer HHI) D. Marpe (Fraunhofer HHI) S. Oudin (Fraunhofer HHI) M. Preiß (Fraunhofer HHI) H. Schwarz (Fraunhofer HHI) M. Siekmann (Fraunhofer HHI) K. Sühring (Fraunhofer HHI) T. Wiegand (Fraunhofer HHI)	Video coding technology proposal by Fraunhofer HHI	archive document presentation
JCTVC-A117	CfP response proposal (2)	T. Chujoh (Toshiba) A. Tanizawa (Toshiba) T. Yamakage (Toshiba)	Video coding technology proposal by Toshiba	archive document (r1) presentation (r1)
JCTVC-A118	CfP response proposal (2)	F. Wu (Microsoft Research Asia) X. Sun (Microsoft Research Asia) J. Xu (Microsoft Research Asia) Y. Zhou (Microsoft Research Asia) W. Ding (Univ. Sci. Tech. China) X. Peng (Univ. Sci. Tech. China) Z. Xiong (Univ. Sci. Tech. China)	Video coding technology proposal by Microsoft (and the University of Science and Technology of China)	archive document
JCTVC-A119	CfP response proposal (2)	K. Ugur (Nokia) K. R. Andersson (LM Ericsson) A. Fuldseth (Tandberg Telecom)	Video coding technology proposal by Tandberg, Nokia, and Ericsson	archive document appendix presentation
JCTVC-A120	CfP response proposal (2)	D. He (RIM) G. Korodi (RIM) G. Martin-Cocher (RIM) E.-h. Yang (RIM) X. Yu (RIM)	Video coding technology proposal by Research in Motion	archive document presentation (r1)

		J. Zan (RIM)		
JCTVC-A121	CfP response proposal (2)	M. Karczewicz (Qualcomm) P. Chen (Qualcomm) R. Joshi (Qualcomm) X. Wang (Qualcomm) W.-J. Chien (Qualcomm) R. Panchal (Qualcomm)	Video coding technology proposal by Qualcomm	archive document presentation
JCTVC-A122	CfP response proposal (2)	A. Ichigaya (NHK) K. Iguchi (NHK) Y. Shishikui (NHK) S. Sekiguchi (Mitsubishi Electric) K. Sugimoto (Mitsubishi Electric) A. Minezawa (Mitsubishi Electric)	Video coding technology proposal by NHK and Mitsubishi	archive document presentation
JCTVC-A123	CfP response proposal (2)	Y.-W. Chen (NCTU) T.-W. Wang (NCTU) C.-H. Chan (NCTU) C.-L. Lee (NCTU) C.-H. Wu (NCTU) Y.-C. Tseng (NCTU) W.-H. Peng (NCTU) C.-J. Tsai (NCTU) H.-M. Hang (NCTU)	Video coding technology proposal by National Chiao Tung University (NCTU)	archive document (r1) presentation (r1)
JCTVC-A124	CfP response proposal (2)	K. McCann (Zetacast / Samsung) W.-J. Han (Samsung) I.-K. Kim (Samsung) J.-H. Min (Samsung) E. Alshina (Samsung) A. Alshin (Samsung) T. Lee (Samsung) J. Chen (Samsung) V. Seregin (Samsung) S. Lee (Samsung) Y.-M. Hong (Samsung) M.-S. Cheon (Samsung) N. Shlyakhov (Samsung)	Video coding technology proposal by Samsung (and BBC)	archive document (r2) presentation
JCTVC-A125	CfP response proposal	T. Davies (BBC)	Video coding technology proposal by BBC (and Samsung)	archive document (r1)

	(2)			presentation
JCTVC-A126	CfP response proposal (2)	S. Mochizuki (Renesas) K. Iwata (Renesas)	Video coding technology proposal by Renesas	archive document (r1) presentation (r1)
JCTVC-A127	CfP response proposal (2)	H. Y. Kim (ETRI) S. Jeong (ETRI) S.-C. Lim (ETRI) J. Kim (ETRI) H. Lee (ETRI) J. Lee (ETRI) S. Cho (ETRI) J. S. Choi (ETRI) J. W. Kim (ETRI)	Video coding technology proposal by the Electronics and Telecommunications Research Institute (ETRI)	archive document (r2) presentation (r2)
Output Report Document	**Category**	**Authors**	**Subject**	**Files**
JCTVC-A200	meeting report	G. J. Sullivan (Microsoft) J.-R. Ohm (RWTH Aachen Univ.)	Meeting report of the first meeting of the Joint Collaborative Team on Video Coding (JCT-VC), Dresden, DE, 15-23 April, 2010	archive (this document)
JCTVC-A201	break-out report	K. Sühring (Fraunhofer HHI)	Results of break-out work on decoder speed measurement	archive document
JCTVC-A202	output study document	JCT-VC	Architectural outline of proposed High Efficiency Video Coding (HEVC) design elements	archive document
JCTVC-A203	output study document	JCT-VC	Table of proposal design elements for High Efficiency Video Coding (HEVC)	archive document
JCTVC-A204	subjective test report	JCT-VC	Report of subjective testing of responses to Joint Call for Proposals (CfP) on video coding technology for High Efficiency Video Coding (HEVC)	archive document
JCTVC-A205	output study document	JCT-VC	Test Model under Consideration (TMuC)	archive document (d2)
Tool Experiment Description Document	**Category**	**Authors**	**Subject**	**Files**
JCTVC-A301	tool experiment description	M. Wien (RWTH Aachen Univ.) Y.-J. Chiu (Intel Corp.)	Tool Experiment 1: Decoder-side motion vector derivation	archive document (r1)
JCTVC-A302	tool experiment	T. Chujoh (Toshiba)	Tool Experiment 2: Internal bit-depth increase (IBDI) and memory compression	archive document (r1)

	description			
JCTVC-A303	tool experiment description	A. Krutz (Tech. Univ. Berlin) A. Glantz (Tech. Univ. Berlin) T. Sikora (Tech. Univ. Berlin) J. Park (LG) E. François (Technicolor) P. Yin (Technicolor) P. Chen (Qualcomm) X. Zheng (Huawei) H. Yu (Huawei)	Tool Experiment 3: Inter prediction	archive document (r3)
JCTVC-A304	tool experiment description	X. Wang (Qualcomm)	Tool Experiment 4: Variable length coding	archive document (r1)

JCT-VC Report Annex B – Attendance

Attendance at the meeting was recorded by a sign-in sheet that was circulated among the participants during the meeting. The recorded participants were as follows:

1. Amon, Peter (Siemens)
2. Amonou, Isabelle (Orange Labs)
3. Andersson, Kenneth (Ericsson)
4. Aoki, Hirofumi (NEC)
5. Asai, Kohtaro (Mitsubishi Electric)
6. Auyeung, Cheung (Sony)
7. Bandoh, Yukihiro (NTT)
8. Bang, Gun (ETRI)
9. Barbarien, Joeri (Vrije Univ. Brussels)
10. Baroncini, Vittorio (FUB)
11. Bivolarsky, Lazar (Skype Technologies)
12. Bjøntegaard, Gisle (Tandberg)
13. Bossc, Sebastian (Fraunhofer HHI)
14. Bossen, Frank (DoCoMo USA Labs)
15. Bross, Benjamin (Fraunhofer HHI)
16. Budagavi, Madhukar (TI)
17. Chen, Peisong (Qualcomm)
18. Chen, Weizhong (Huawei)
19. Chen, Yi-Wen (NCTU/ITRI)
20. Chiu, Yi-Jen (Intel)
21. Choe, Yoonsik (Yonsei Univ.)
22. Choi, Jin Soo (ETRI)
23. Choi, Kiho (Hanyang Univ.)
24. Chono, Keiichi (NEC)
25. Chujoh, Takeshi (Toshiba)
26. Cohen, Robert (Mitsubishi Electric)
27. Davies, Thomas (BBC)
28. De Cock, Jan (Ghent Univ.)
29. De Petris, Gianluca (Telecom Italia)
30. Demircin, Mehmet Umut (TI)
31. Domanski, Marek (Poznań Univ. Tech.)
32. Drugeon, Virginie (Panasonic)
33. Duenas, Alberto (Cavium Networks)
34. Eleftheriadis, Alex (Vidyo)
35. Esche, Marko (Tech. Univ. Berlin)
36. Fernandes, Felix (Samsung)
37. François, Edouard (Technicolor)
38. Fu, Chih-Ming (MediaTek)
39. Fujibayashi, Akira (NTT DoCoMo)
40. Fukushima, Shigeru (JVC Kenwood)
41. Fuldseth, Arild (Tandberg)
42. Gabriullini, Andrea (BBC)
43. Glantz, Alexander (Tech. Univ. Berlin)
44. Guo, Xun (MediaTek)
45. Han, Jong-Ki (Sejong Univ.)
46. Han, Woo-Jim (Samsung)
47. He, Dake (RIM)
48. Helle, Philipp (Fraunhofer HHI)
49. Hinz, Tobias (Fraunhofer HHI)
50. Hong, Sung-Wook (Sejong Univ.)
51. Huang, Yu-Wen (MediaTek)
52. Ichigaya, Atsuro (NHK)
53. Iwata, Kenichi (Renesas)
54. Jacobs, Marc (Vrije Univ. Brussels)
55. Jang, Myoung-Hun (Sejong Univ.)
56. Jeon, Byeong Moon (LG)
57. Jeon, Byeungwoo (Sungkyunkwan Univ.)
58. Jeong, Seyoon (ETRI)
59. Joshi, Rajan L. (Qualcomm)
60. Jung, Joël (Orange Labs)
61. Jung, Seung Hoon (Galaxia Commun.)
62. Jung, Tae-Young (Hanyang Univ.)
63. Kamp, Steffen (RWTH Aachen Univ.)
64. Kanamuri, Sandeep (DoCoMo USA Labs)
65. Kang, Jung Won (ETRI)
66. Karczewicz, Marta (Qualcomm)
67. Kazui, Kimihiko (Fujitsu)
68. Kersouski, Domian (Poznań Univ. Tech.)
69. Kim, Haekwan (Sejong Univ.)
70. Kim, Hui Yong (ETRI)
71. Kim, Il-Koo (Samsung)
72. Kim, In Kwon (Galaxia Commun.)
73. Kim, Jae-Gon (Korea Aerosp. Univ.)
74. Kim, Jeong-Pil (Sejong Univ.)
75. Kim, Jungsun (LG)
76. Kim, Min-Jae (Sejong Univ.)
77. Kim, Seong Hoon (Galaxia Commun.)
78. Kim, Sung Jei (Yonsei Univ.)
79. Kim, Yong-Hwan (KETI)
80. Kirchhoffer, Heiner (Fraunhofer HHI)
81. Klomp, Sven (Leibniz Univ. Hannover)
82. Kondo, Kenji (Sony)
83. Konieczny, Jacek (Poznań Univ. Tech.)
84. Korodi, Gergely (RIM)
85. Kouadio, Adi (EBU)
86. Koyama, Jumpei (Fujitsu)
87. Krutz, Andreas (Tech. Univ. Berlin)
88. Lai, Changcai (Huawei)
89. Lainema, Jani (Nokia)
90. Lakshman, Haricharan (Fraunhofer HHI)
91. Laroche, Guillaume (Canon)
92. Lee, Hyuk (Hanyang Univ.)
93. Lee, Ju Ock (Sejong Univ.)
94. Lee, Sinwook (Hanyang Univ.)
95. Lee, Yung-Lyul (Sejong Univ.)

96. Lei, Shawmin (MediaTek)
97. Lim, Chongsoon (Panasonic)
98. Lim, Jeongyeon (SK Telecom)
99. Lim, Sung-Chang (ETRI)
100. Lin, Yongbing (Huawei)
101. List, Peter (Deutsche Telecom Labs)
102. Liu, Lingzhi (Huawei)
103. Liu, Yingjia (Huawei)
104. Luo, Zhong (Huawei)
105. Ma, Siwei (Peking Univ.)
106. Marpe, Detlev (Fraunhofer HHI)
107. Martin-Cocher, Gaëlle (RIM)
108. Matsuo, Shohei (NTT)
109. McCann, Ken (Zetacast / Samsung)
110. Mochizuki, Seiji (Renesas)
111. Moghe, Dhawal B. (CableLabs)
112. Moon, Joo-Hee (Sejong Univ.)
113. Munderloh, Marco (Univ. Hannover)
114. Murakami, Tokumichi (Mitsubishi Electric)
115. Nakamura, Katsuyuki (Hitachi)
116. Nishi, Takahiro (Panasonic)
117. Ohm, Jens-Rainer (RWTH Aachen Univ.)
118. Onno, Patrice (Canon)
119. Ostermann, Jörn (Univ. Hannover)
120. Panusopone, Krit (Motorola)
121. Park, Hyoungmee (Sejong Univ.)
122. Park, Jiho (KETI)
123. Park, Joonyoung (LG)
124. Park, Seungwook (LG)
125. Patëux, Stephane (Orange Labs)
126. Peng, Wen-Hsiao (NCTU/ITRI)
127. Ridge, Justin (Nokia)
128. Rusanovskyy, Dmytro (Nokia)
129. Sakazume, Satoru (JVC Kenwood)
130. Sampedro, Jesus (Polycom)
131. Schwarz, Heiko (Fraunhofer HHI)
132. Segall, Andrew (Sharp)
133. Sekiguchi, Shun-ichi (Mitsubishi Electric)
134. Seo, Chan-Won (Sejong Univ.)
135. Shen, Bazhong (Broadcom)
136. Shi, Il Hong (ETRI)
137. Shima, Masato (Canon)
138. Shimizu, Shinya (NTT)
139. Shishikui, Yoshiaki (NHK)
140. Siekmann, Mischa (Fraunhofer HHI)
141. Sikora, Thomas (Tech. Univ. Berlin)
142. Sjoberg, Rickard (Ericsson)
143. Sole, Joel (Technicolor)
144. Suehring, Karsten (Fraunhofer HHI)
145. Sugimoto, Kazuo (Mitsubishi Electric)
146. Suh, Jason (Samsung)
147. Sullivan, Gary (Microsoft)
148. Sun, Huifang (Mitsubishi Electric)
149. Suzuki, Teruhiko (Sony)
150. Suzuki, Yoshinori (NTT DoCoMo)
151. Takamura, Seishi (NTT)
152. Tan, Thiow Keng (NTT DoCoMo)
153. Tanizawa, Akiyuki (Toshiba)
154. Thoma, Herbert (Fraunhofer IIS)
155. Tonomura, Yoshide (NTT)
156. Tsai, Chun-Jen (NCTU/ITRI)
157. Ugur, Kemal (Nokia)
158. Wang, Dong (ZTE)
159. Wang, Tse-Wei (NCTU/ITRI)
160. Wang, Xianglin (Qualcomm)
161. Wang, Xing (H. K. Univ. Sci. Tech.)
162. Wedi, Thomas (Panasonic)
163. Wiegand, Thomas (Fraunhofer HHI)
164. Wien, Mathias (RWTH Aachen Univ.)
165. Winken, Martin (Fraunhofer HHI)
166. Wittmann, Steffen (Panasonic)
167. Won, Kwanghyun (Sungkyunkwan Univ.)
168. Wu, Ping (Mitsubishi Electric)
169. Xu, Jizheng (Microsoft)
170. Yamakage, Tomoo (Toshiba)
171. Yamamoto, Tomoyuki (Sharp)
172. Yang, Jungyoup (Sungkyunkwan Univ.)
173. Yea, Sehoon (LG)
174. Yeo, Chuohao (I2R)
175. Yi, Joo Yeung (KETI)
176. Yin, Peng (Technicolor)
177. Yong, Haitoo (Huawei)
178. Yong, Mingyuan (Huawei)
179. Yu, Haoping (Huawei)
180. Yu, Liu (ASTRI)
181. Yu, Lu (Zhejiang Univ.)
182. Yu, Wei-Ling (NCTU/ITRI)
183. Zhang, Cixun (Tech. Univ. Tampere)
184. Zhang, Li (Peking Univ.)
185. Zheng, Jianhua (Huawei)
186. Zheng, Xionzhen (Huawei)
187. Zhou, Minhua (TI)
188. Zou, Bill (DTS)