Advanced Multimedia Signal Processing
(#11: Intro. Of High Efficiency Video Coding (HEVC))

2017. Spring

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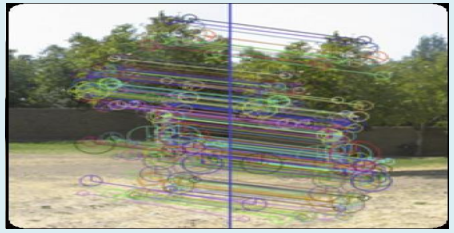
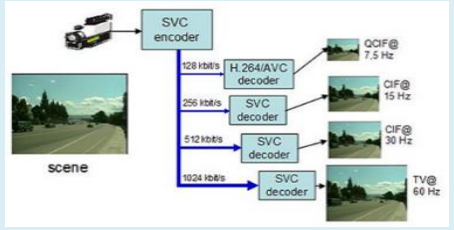
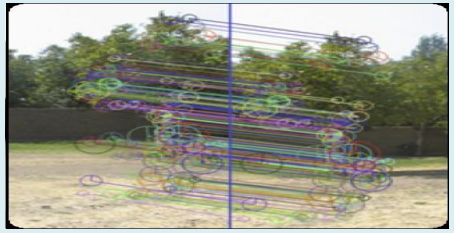
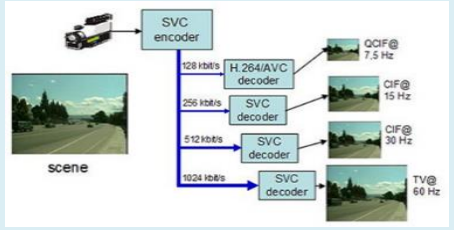




Contents

- UHD TV & Contents – Realistic media
- HEVC Technology (encoder)
- JSVM Software
- Summary





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- **HEVC Technology (encoder)**
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- **Summary**

UHD TV & Contents – Realistic media (1)

❖ Why ultra high quality media is needed?

- 3D / UHD media / realistic media
- Support HD media in mobile device

UHD TV & Contents – Realistic media (2)

- Realistic Media
  - Immersive
  - Reality
  - Movement (feel)

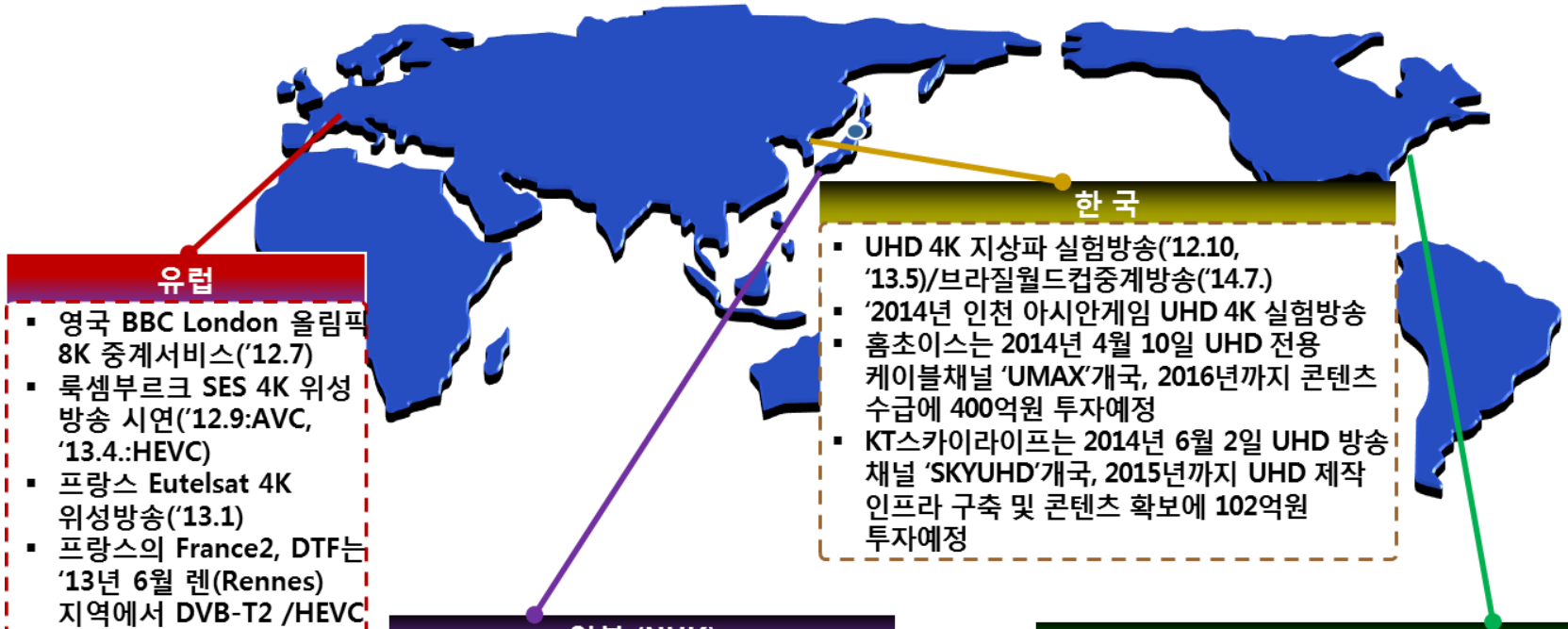
UHD TV & Contents – Realistic media (3)

❖ Data Size of UHD

규 격		데이터량
HD	1,920x1,080, YUV4:2:0, 8bits, 30fps	746Mbps
4K UHD	**3,840x2,160, YUV4:2:0, 8bits, 30fps**	**3Gbps(HDx4배)**
	3,840x2,160, YUV4:4:4, 12bits, 60fps	18Gbps(HDx24배)
8K UHD	7,680x4,320, YUV4:2:0, 8bits, 30fps	12Gbps(HDx16배)
	7,680x4,320, YUV4:4:4, 12bits, 60fps	**72Gbps(HDx96배)**

UHD TV & Contents – Realistic media (4)

UHDTV 국내외 방송서비스 현황 [4K >> 8K]



유럽

- 영국 BBC London 올림픽 8K 중계서비스('12.7)
- 룩셈부르크 SES 4K 위성방송 시연('12.9:AVC, '13.4.:HEVC)
- 프랑스 Eutelsat 4K 위성방송('13.1)
- 프랑스의 France2, DTF는 '13년 6월 렌(Rennes) 지역에서 DVB-T2 /HEVC 방식으로 지상파 실험방송 실시
- 영국의 BskyB, 독일의 Sky Deutshland 등 위성방송사는 '14년부터 위성을 통한 UHD방송 도입 계획 발표

한 국

- UHD 4K 지상파 실험방송('12.10, '13.5)/브라질월드컵중계방송('14.7.)
- '2014년 인천 아시안게임 UHD 4K 실험방송
- 홈초이스는 2014년 4월 10일 UHD 전용 케이블채널 'UMAX'개국, 2016년까지 콘텐츠 수급에 400억원 투자예정
- KT스카이라이프는 2014년 6월 2일 UHD 방송 채널 'SKYUHD'개국, 2015년까지 UHD 제작 인프라 구축 및 콘텐츠 확보에 102억원 투자예정

일본 (NHK)

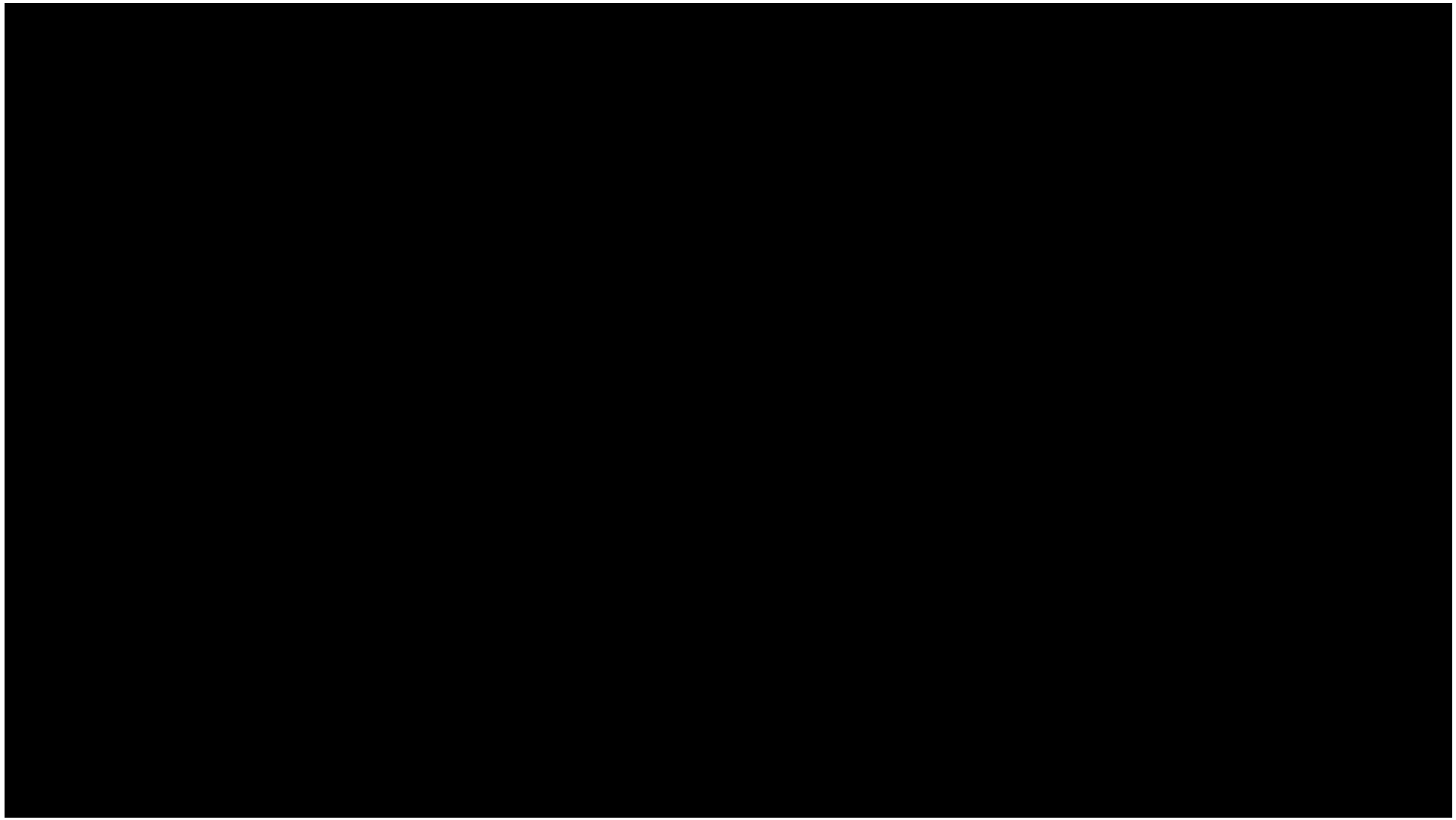
- London 올림픽 8K 중계서비스('12.7)
- 브라질 월드컵 4K 위성방송('14.7)
- '16년 리우 올림픽 8K 실험방송
- '20년 도쿄 올림픽에서 8K 본방송 송출을 계획 중

미 국

- 싱클레어 그룹과 삼성전자는 '14년 2월 라스베가스 지역에서 DVB-T2/HEVC 방식(4K, 60P)으로 지상파 실험방송 실시
- 위성방송사업자인 DirecTV는 UHD방송을 위한 위성추가발사('14년 중순) 및 본방송 계획('15년 상반기).
- Youtube는 '10년 4K영상 업로드, '12년 콘텐츠의 온디맨드 서비스를 시작
- OTT사업자인 Netflix는 '15년까지 4K VoD 서비스 실시 예정

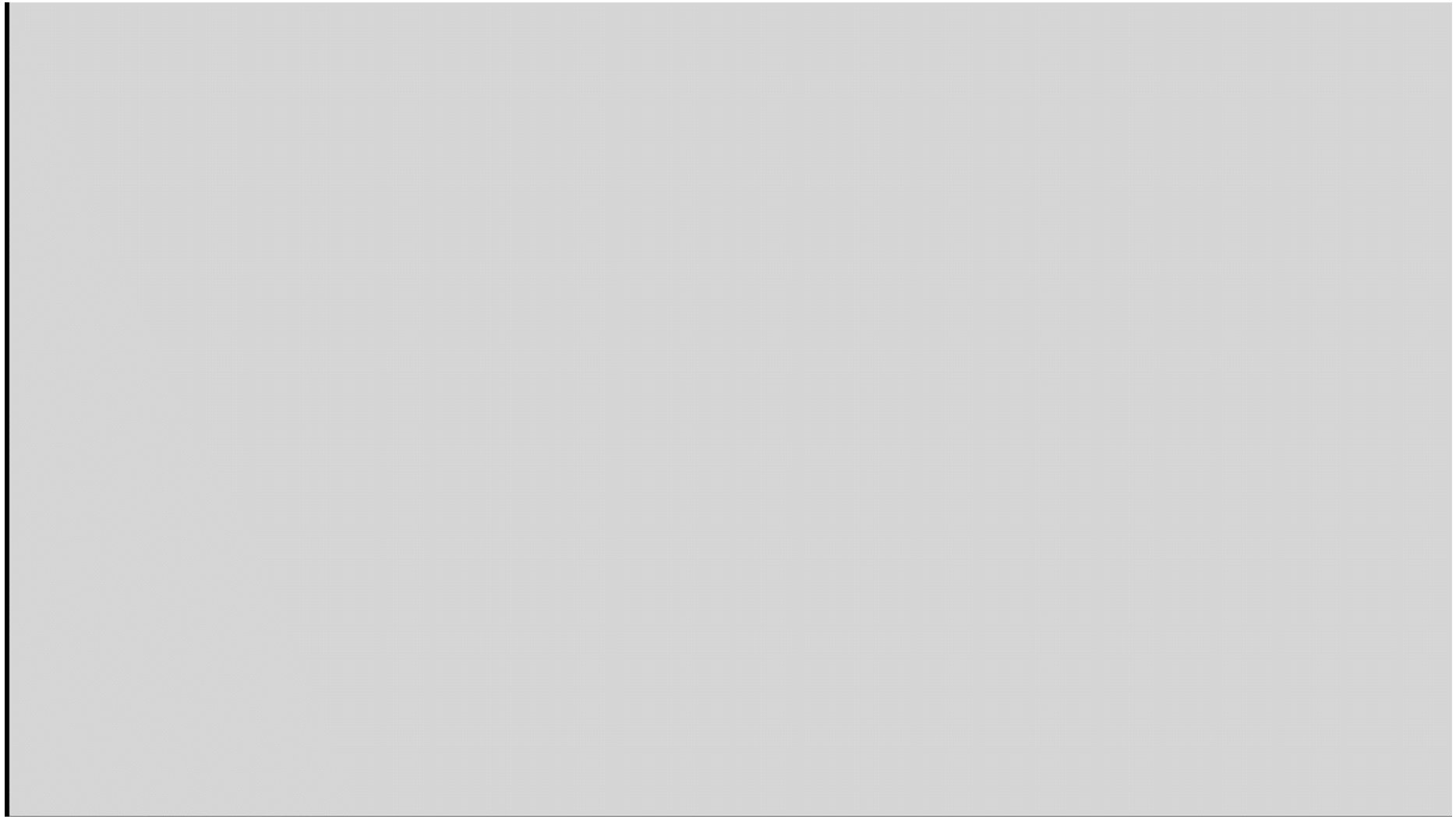
UHD TV & Contents – Realistic media (5)

❖ 4K vs. Full HD (HD)



UHD TV & Contents – Realistic media (7)

❖ 4K vs. Full HD (HD)



UHD TV & Contents – Realistic media (8)

❖ 4K vs. 8K

UHD TV & Contents – Realistic media (9)

Need for new video coding scheme (UHD): HEVC

MPEG-2 Video (ISO/IEC 13818-2) (ITU-T Rec. H.262)

- 1.5Mbps ~ 50Mbps range of video quality
- Being used in DTV/HDTV broadcasting, DVD
- Compression gain = 50:1

MPEG-4 AVC (ISO/IEC 14496-10) ITU-T Rec. H.264

- About 10kbps ~ 240Mbps, general high efficiency coding
- Compression gain = 100:1

MPEG-H HEVC (ISO/IEC 23008-2) (ITU-T Rec. H.265)

- Improve 2 times than H.264/AVC coding standard
- Ultra high efficiency in 128kbps~240Mbps of video
- Compression gain = 200:1

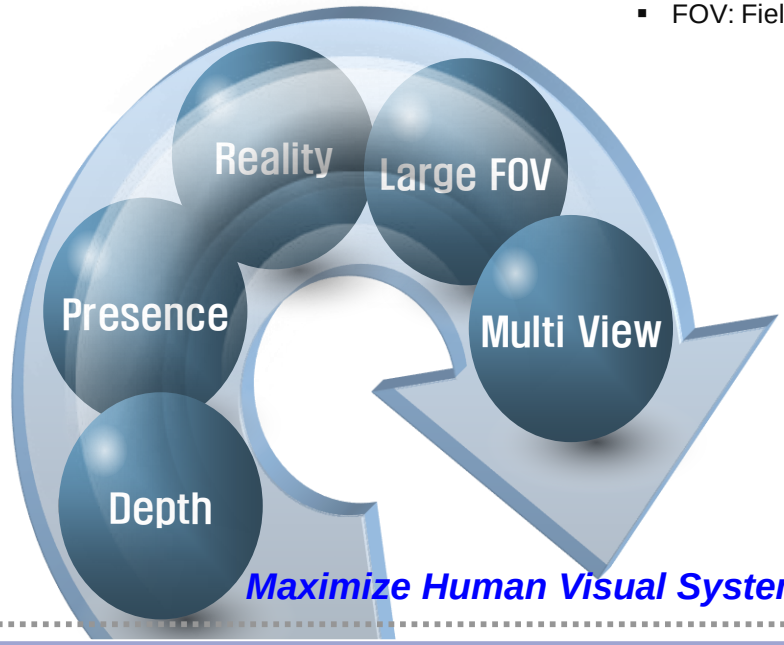
HEVC
High Effeciency Video Coding

ETRI, SONY, NOKIA, LG, SAMSUNG, QUALCOMM, Texas Instruments, Fraunhofer Heinrich-Hertz-Institut, Microsoft, BBC, MEDIATEK

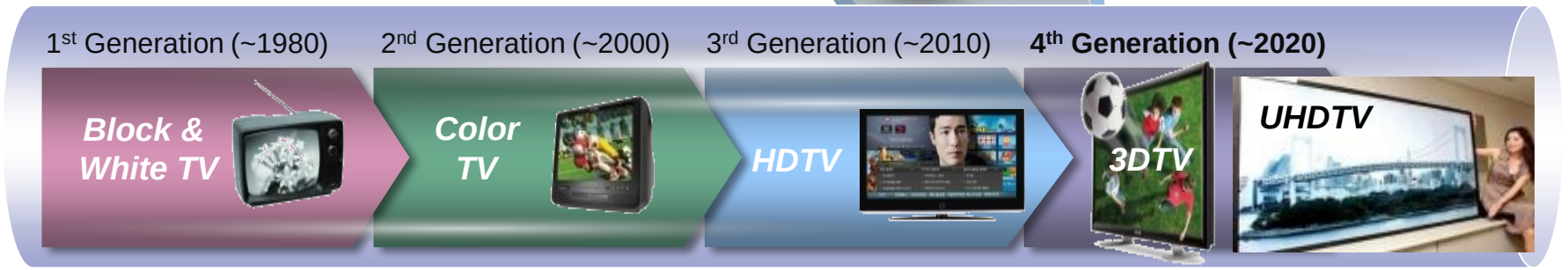
비디오 부호화 기술	표준 승인년도	압축률	HD video (1920x1080,60i,4:2:0)	4K-UHD Video (3840x2160,30p,4:2:0)	4K-UHD Video (3840x2160,60p,4:2:0)
MPEG-2	1994년	1/40~1/50	15~18 Mbps	60~72Mbps	**84~100Mbps**
H.264/AVC	2004년	1/80~1/100	7.5~9Mbps	30~36Mbps	**42~50Mbps**
H.265/HEVC	2013년	1/160~1/200	4~4.5Mbps	15~18Mbps	**21~25Mbps**

UHD TV & Contents – Realistic media (10)

- FOV: Field of View



Maximize Human Visual System (HVS)



UHD TV & Contents – Realistic media (11)

- Achieves 2x higher compression compared to H.264/AVC
- High throughput (Ultra-HD 8K @ 120fps) & low power
  - Implementation friendly features (e.g. built-in parallelism)
- Benefits include
  - Reduce the burden on global networks
  - Easier streaming of HD video to mobile devices
  - Account for advancing screen resolutions (e.g. Ultra-HD)

"HEVC will provide a flexible, reliable and robust solution, future-proofed to support the **next decade of video**"

- ITU-T Press Release (2013)

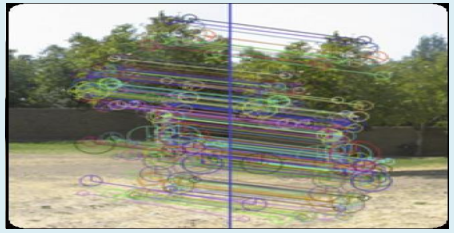
Samsung Galaxy S4

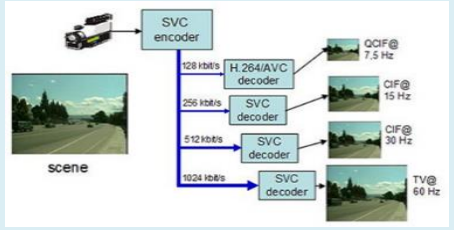
Netflix Ultra-HD 4K

Live delivery of French Open

ROLAND GARROS PARIS

Samsung TV Ultra-HD 4K





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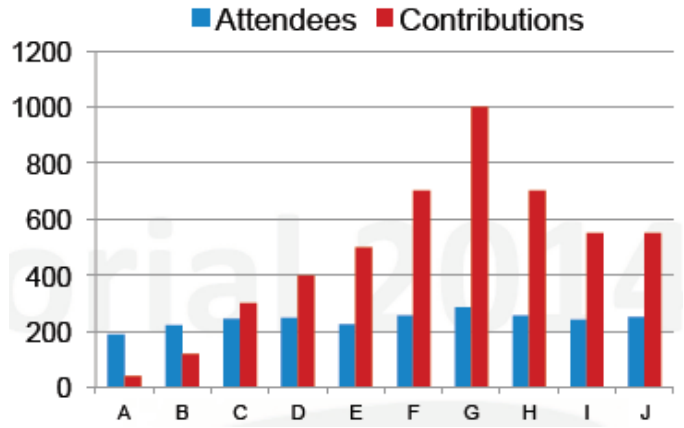
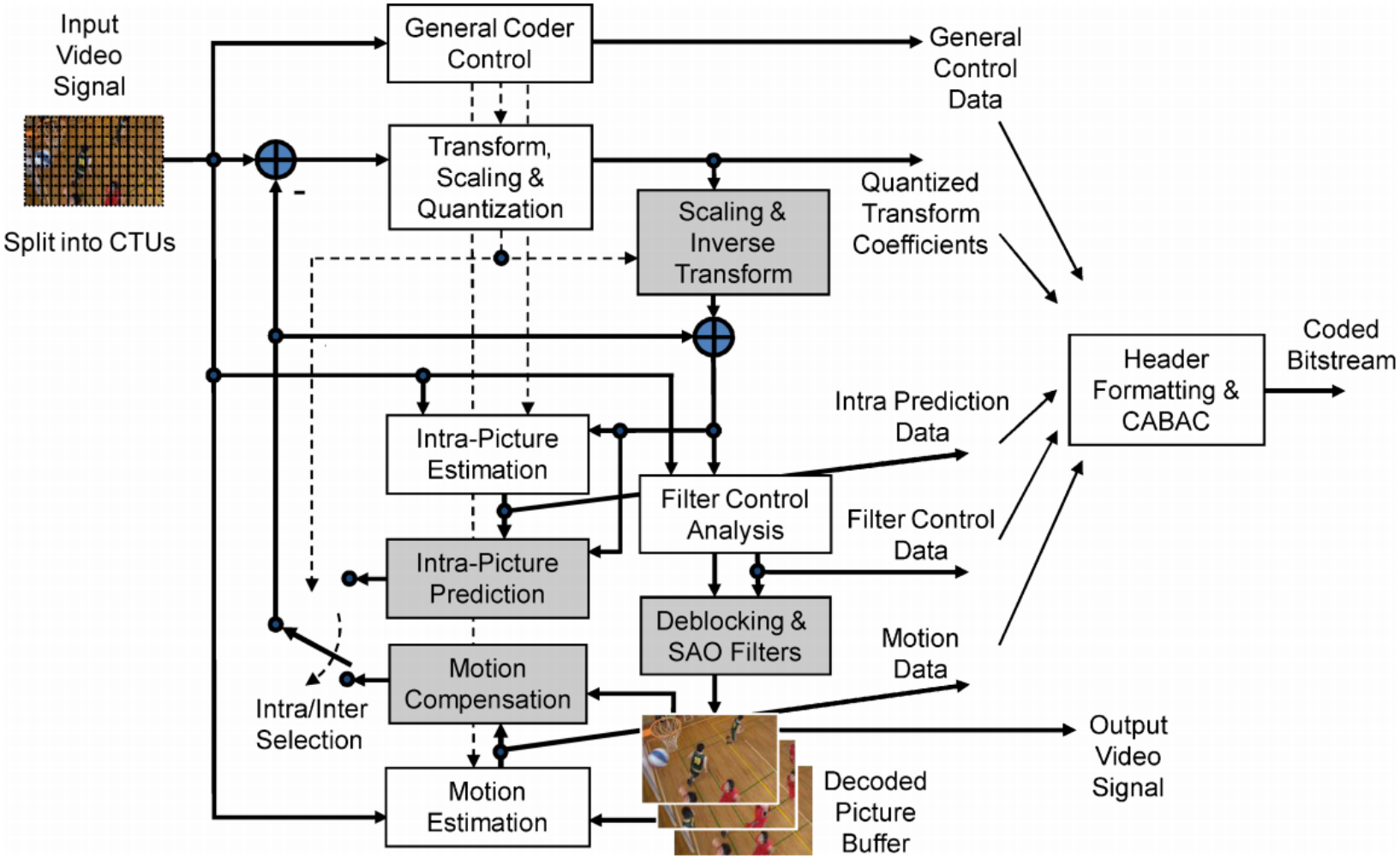
HEVC Technology (0)

- Activity in **JCT-VC** Committee
  - Chairs
    - G. J. Sullivan (Microsoft)
    - J. R. Ohm (Aachen University)
  - Meet Quarterly
    - 1st meeting (A) [January 2010]
    - …
    - 12st meeting (L) [January 2013]
  - ~250 attendees per meeting representing ~70 companies
  - Several hundred contributions per meeting
  - Each meeting is around 9-10 days (14+ hours/day)
  - Multiple parallel tracks



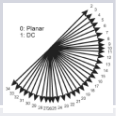
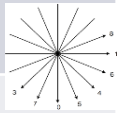
HEVC Technology (1)

HEVC (High Efficiency Video Coding)



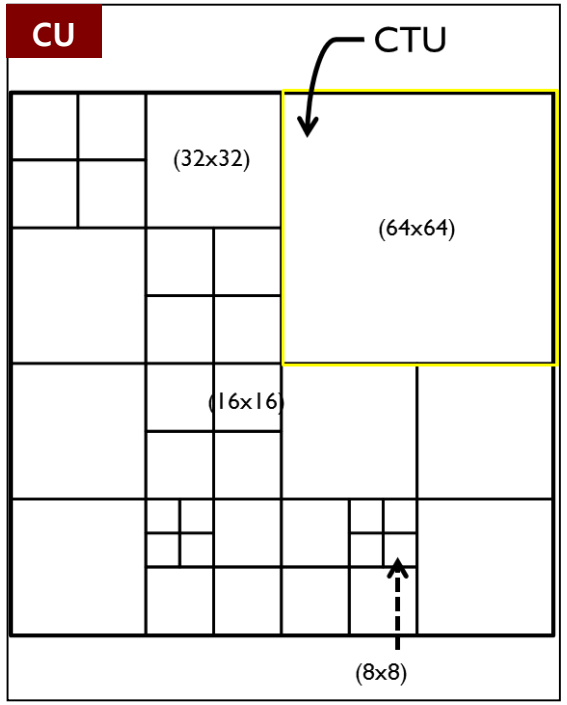
HEVC Technology (2)

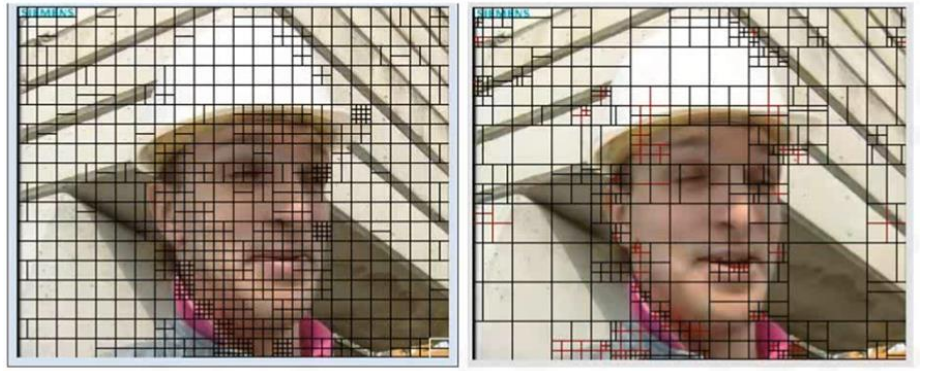
Coding Tools bet. HEVC and H.264/AVC

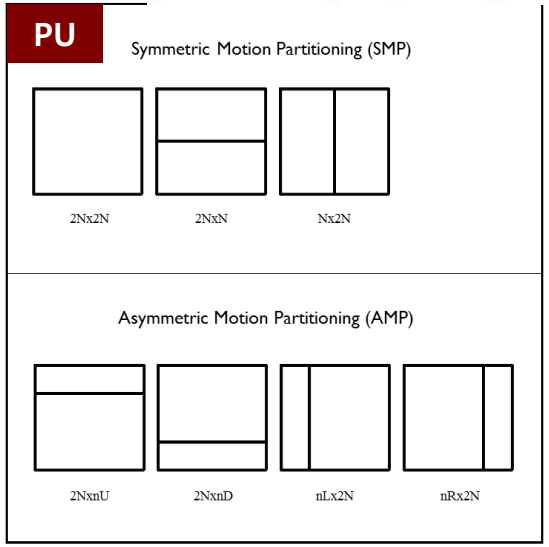
	HEVC	H.264
Block Structure (Unit Partition)	• Coding Unit (CU) (64x64~8x8) • Prediction Unit (PU) • Transform Unit (TU) (32x32~4x4)	• Macroblock (MB) (16x16 fixed) • Transform: 16x16, 8x8, 4x4
Inter Prediction	• Advanced Motion Vector Prediction (AMVP), MERGE • 2Nx2N, Nx2N, 2NxN, AMP	• Spatial Motion Vector Prediction (Median) • 16x16, 16x8, 8x16, P8x8
Interpolation	• DCT-based interpolation - Half-pel: 8-tap - Quarter-pel: 7-tap 	• Half-pel: 6-tap FIR • Quarter-pel: bi-linear after Half-pel interpolation 
Intra Prediction	• 35 modes	• 4 modes
In-Loop Filtering	• Simplified Deblocking Filter (8x8)	• Deblocking Filter (4x4)
Entropy Coding	• Simplified CABAC	• CABAC • CAVLC

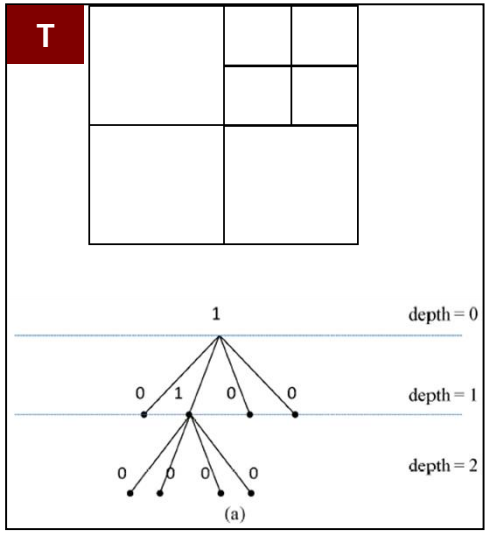
HEVC Technology (3)

HEVC Block Structure





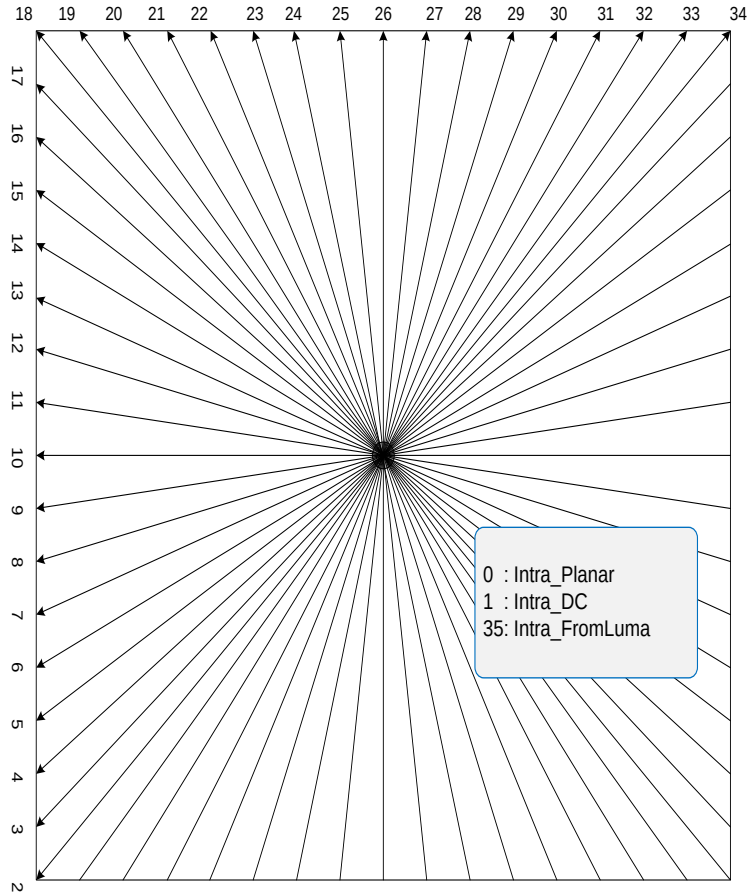


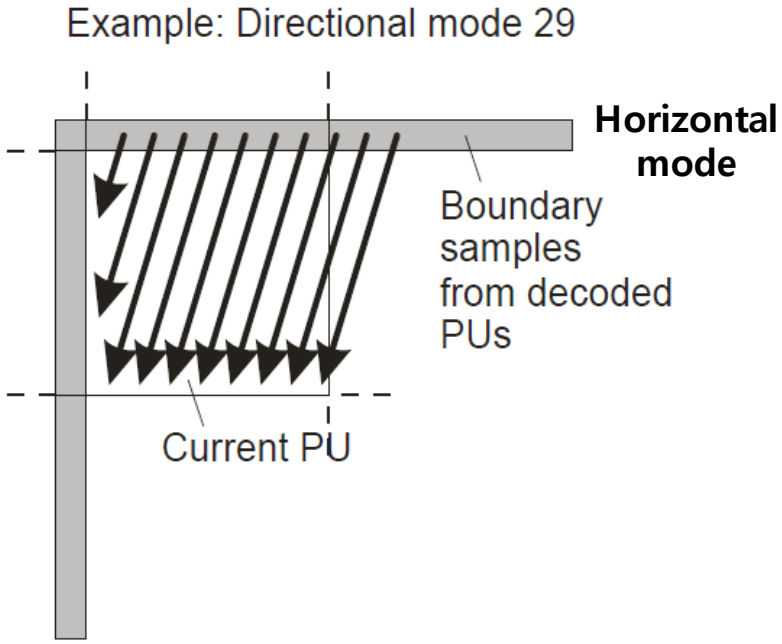


HEVC Technology (4): Intra Prediction

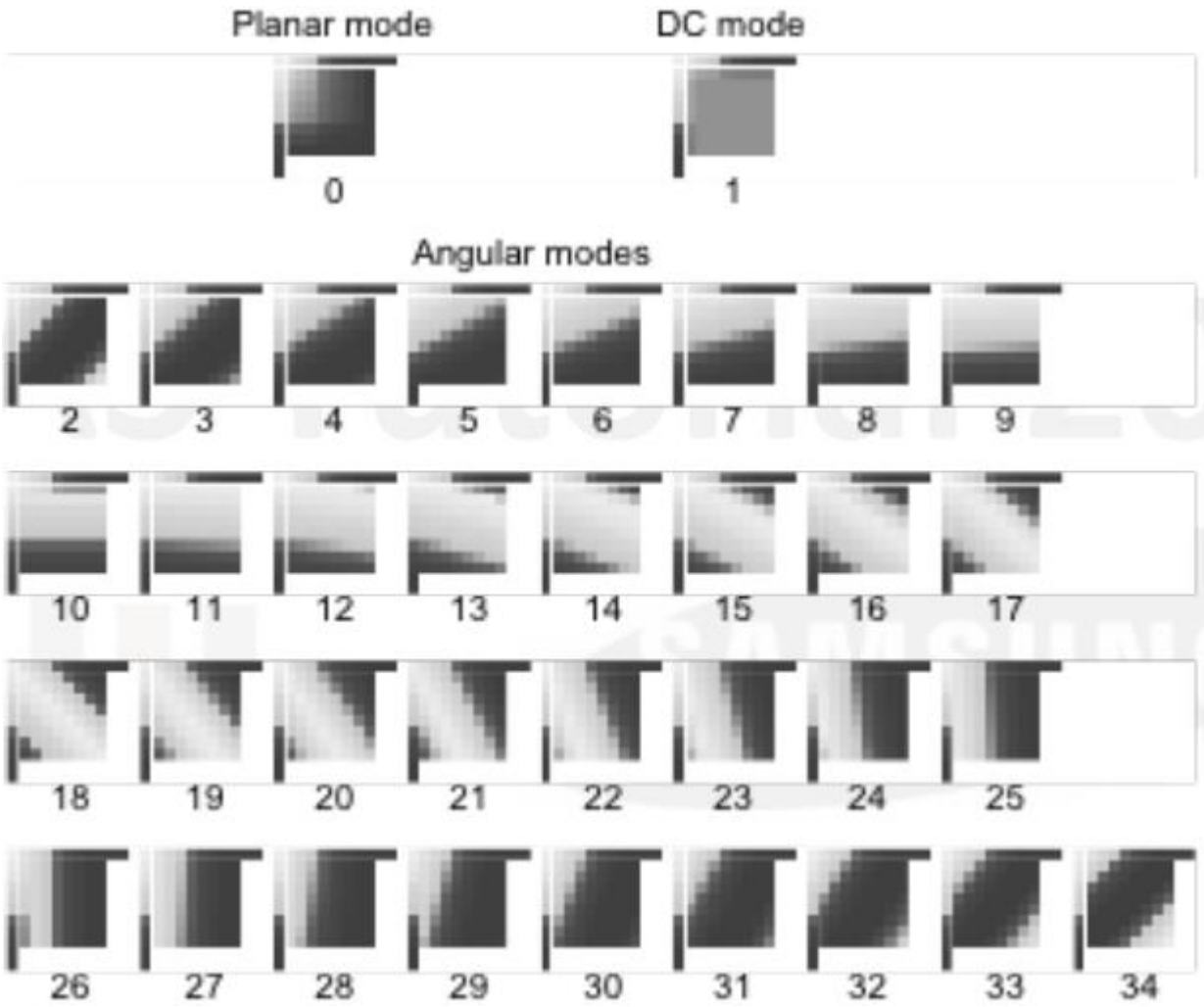
- Four square Types
  - **32x32, 16x16, 8x8, 4x4**
- 35 directional modes

Vertical mode





HEVC Technology (4): Intra Prediction



[J. Lainema, W.-J. Han, "Intra Prediction in HEVC," *High Efficiency Video Coding (HEVC): Algorithms and Architectures*, Springer, 2014.]

❖ Reference Sample Smoothing

- Smooth out neighboring pixels (i.e., reference samples) before using them for prediction
- Reduce contouring artifacts caused by edges in the reference sample arrays
- Two modes
  - Three-tap smoothing filter (a)
  - Strong intra smoothing with corner reference pixel (b)

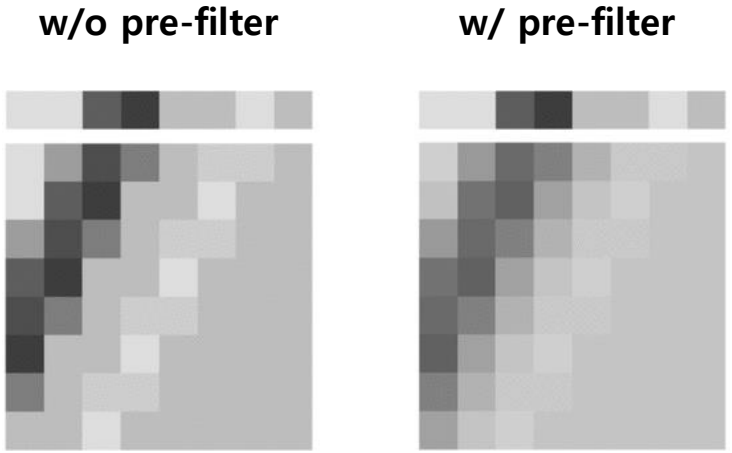
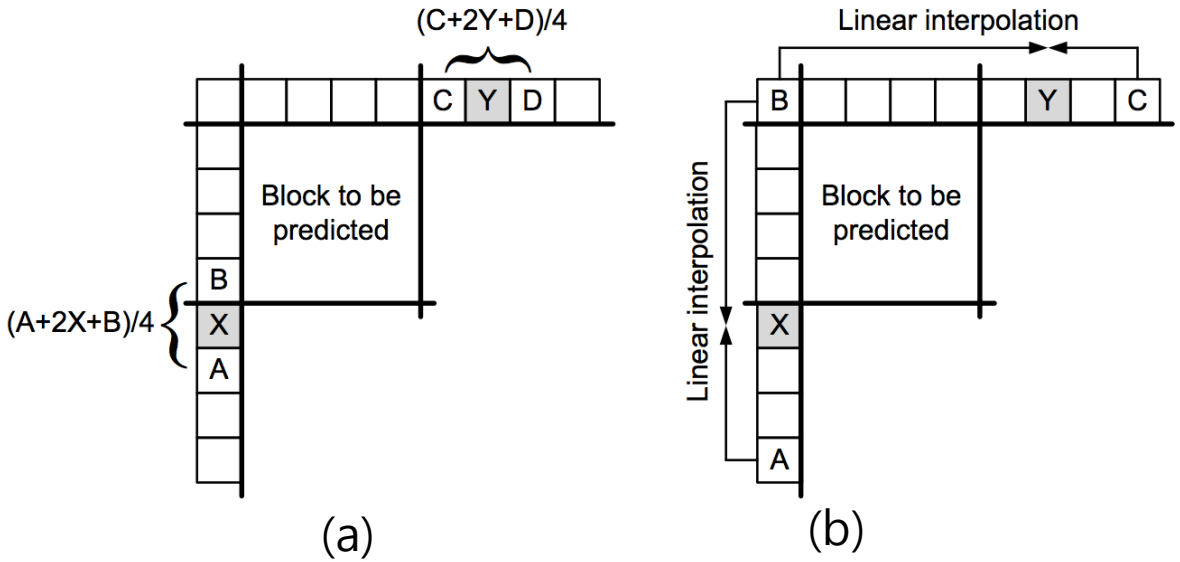


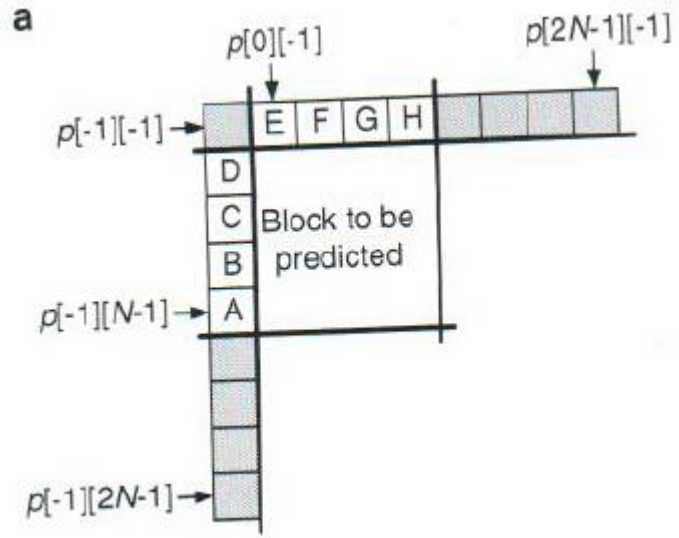
Image source: M. Wien, TCSVT, July 2003



[J. Lainema, W.-J. Han, "Intra Prediction in HEVC," *High Efficiency Video Coding (HEVC): Algorithms and Architectures*, Springer, 2014.]

❖ Boundary Smoothing

- Intra prediction may introduce discontinuities along block boundaries
- **Applied to only DC prediction, horizontal prediction(26) and vertical prediction(10) under condition of Block size<32x32.**



Vertical prediction

$P[0][y] = p[0][y]+((p[-1][y]-p[-1][-1])>>1)$, for y=0,.....,N-1

Horizontal prediction

$P[x][0] = p[x][0]+((p[x][-1]-p[-1][-1])>>1)$, for x=0,.....,N-1

DC prediction

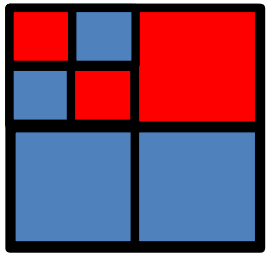
- P[0][0] = three-tap filter [1 2 1]/4 ((p[-1][0]+2*dcVal + p[0][-1])>>2)
- Other boundaries = two-tap filter [3 1]/4 ((p[x][0] = p[x][-1]+3*dcVal +2)>>2 for x=1,...,N-1)

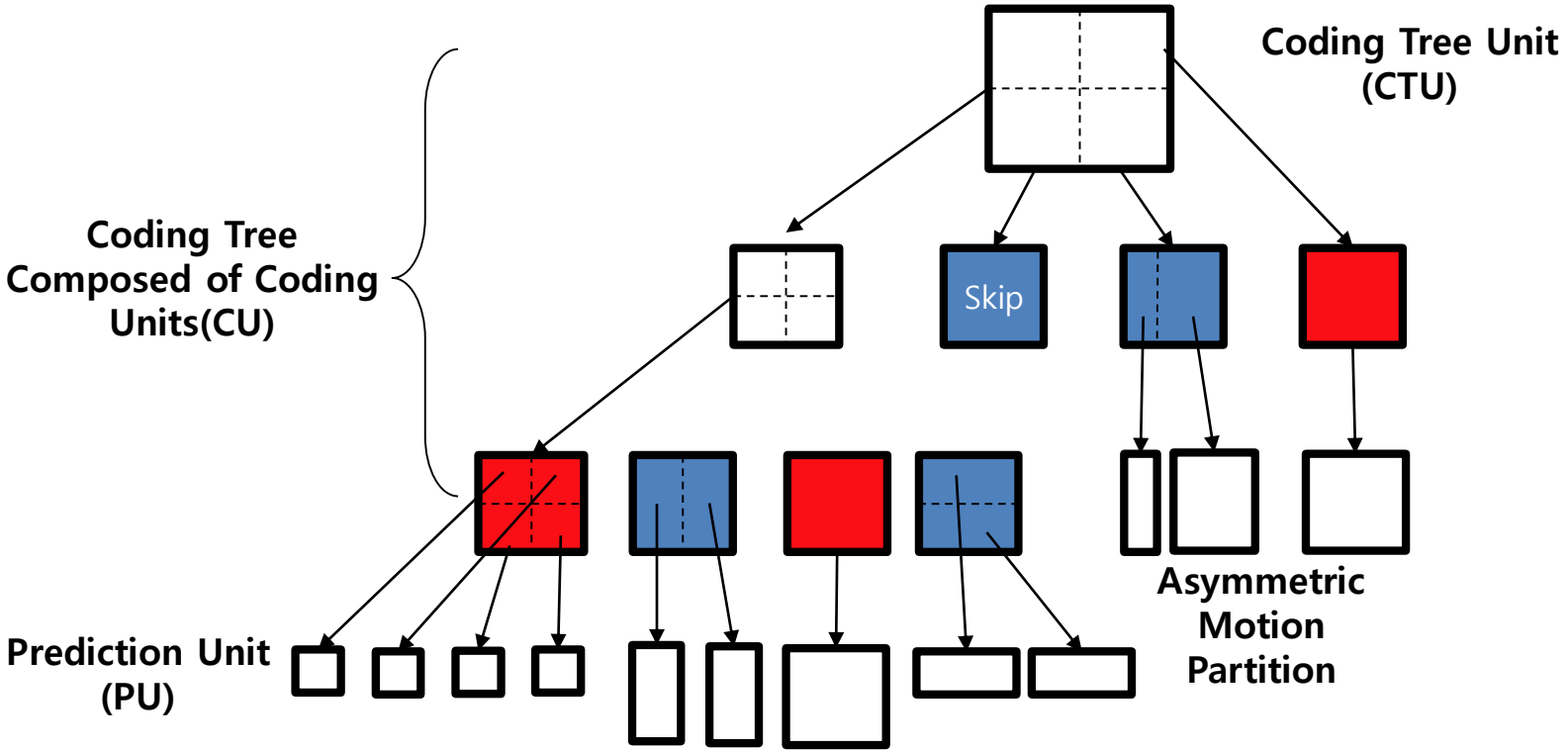
[J. Lainema, W.-J. Han, "Intra Prediction in HEVC," *High Efficiency Video Coding (HEVC): Algorithms and Architectures*, Springer, 2014.]

HEVC Technology (5): Inter Prediction

❖ Flexible Coding Block Structure

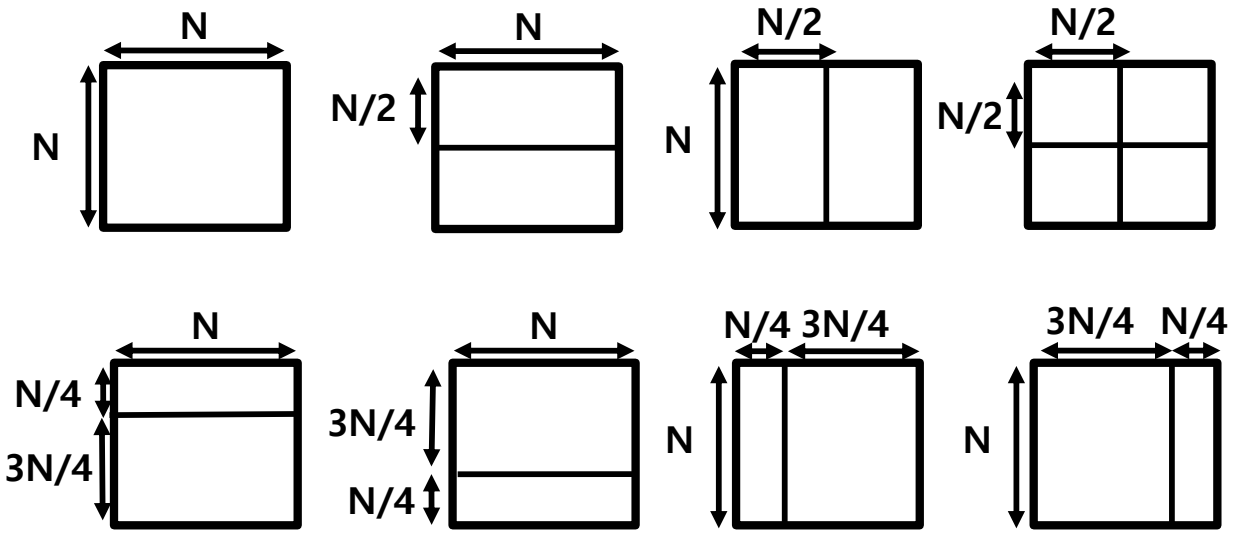
- Better adaptation to different video content
- **Coding tree unit (CTU)** divided into **Coding Units (CU)** with Quad tree
- Coding units divided into **prediction units (PU)**
- **PU** have different **motion data** or prediction modes





HEVC Technology (6): Inter Prediction

- Prediction Units (PUs) (* note: no 4x4 PU)
  - square PU
  - non-square PU

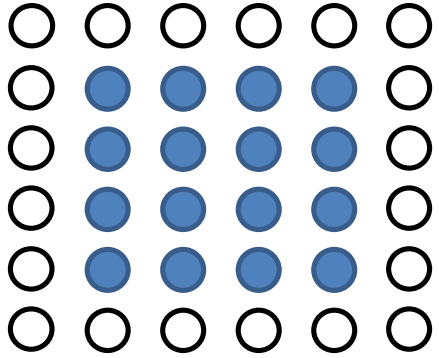


Eight methods of partitioning
For inter-coded CU

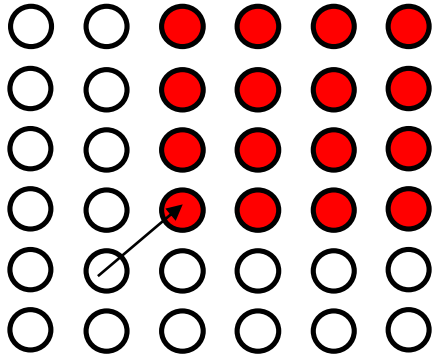
HEVC Technology (7): Inter Prediction – Motion vector estimation

❖ Motion vectors

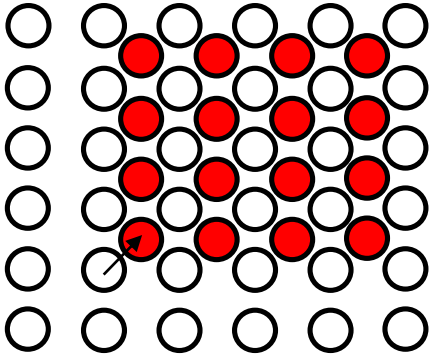
- up to ¼ pixel accuracy (interpolation required).



4x4 block in current frame



Reference block in Previous frame vector (1,-1)



Reference block in previous frame vector (0.5,-0.5)

❖ Luma component uses 8/7-tap and chroma components use 4-tap

- Different coefficients for ¼ and ½ positions

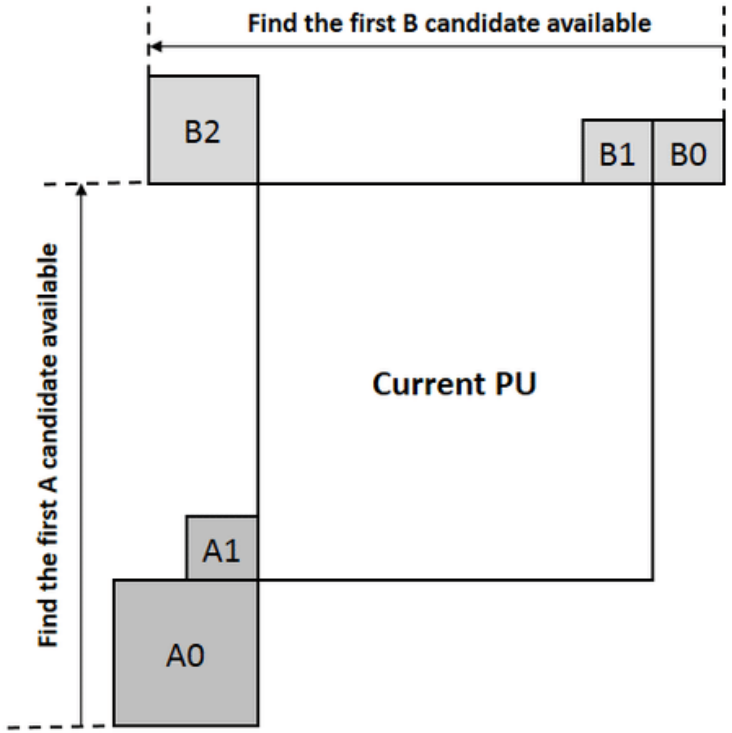
Comparison: In H.264/AVC, luma uses 6-tap filter, and chroma uses bilinear filter

❖ Restriction: can be only **uni-prediction** on smallest PU sizes

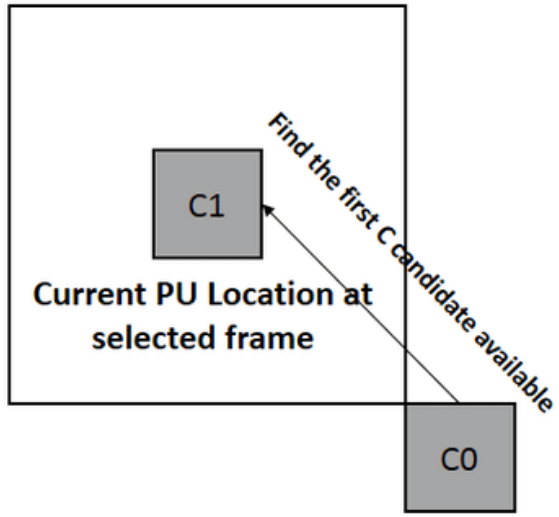
❖ Advance Motion Vector Prediction (AMVP)

- Five spatial neighboring: **Spatial candidate MVPs**
- Two collocated blocks: **Temporal candidate MVPs** when both spatial candidate MVPs are not available or they are identical.
- **Zero motion vector** when the spatial, temporal, or both candidates are not available.

In H.264/AVC, Motion vector prediction?



(a) AMVP Spatial Candidates



(b) AMVP Temporal Candidates

HEVC Technology (9): Inter Prediction – Advance Motion Vector Prediction (AMVP)

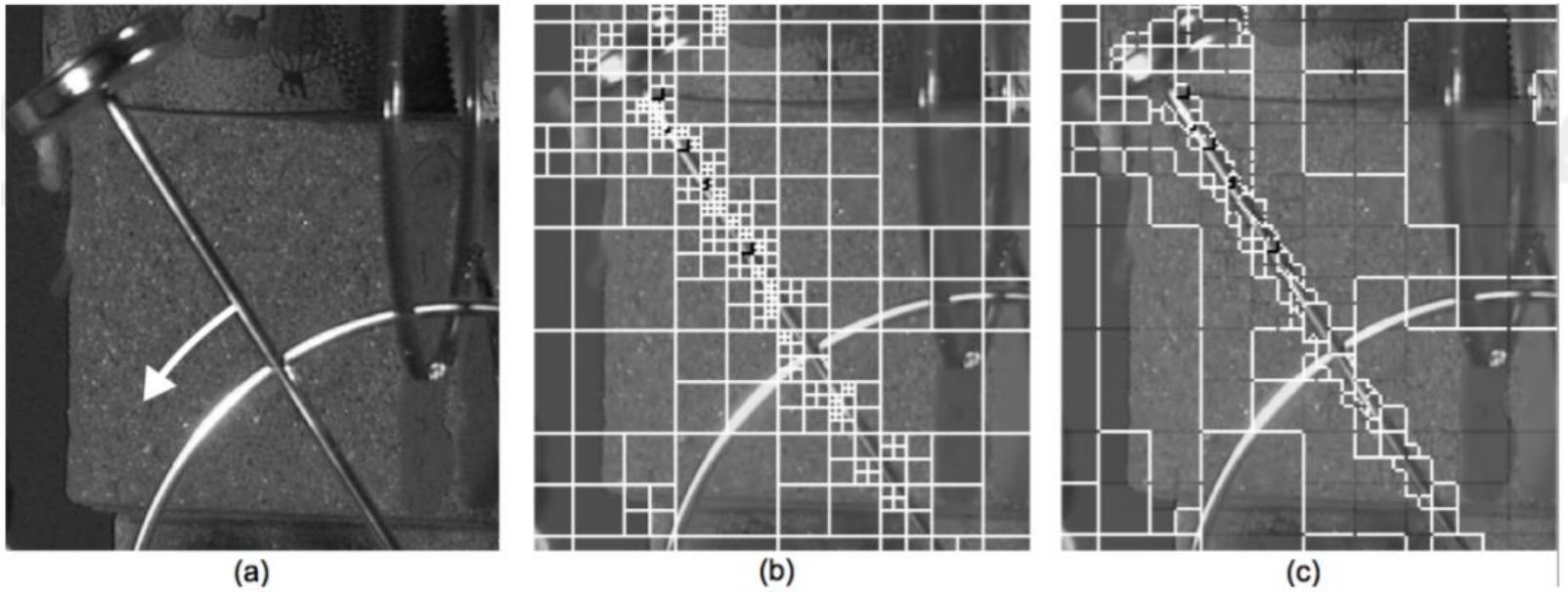
❖ AMVP Motion Data Signaling

- Motion vector difference $(\Delta x,\ \Delta y)$
- Corresponding reference picture index: Δt

HEVC Technology (10): Inter Prediction-Merge Mode

❖ CTU (quad structure) is very efficient, but it causes over-segmenting image.
-> potentially leading to ***redundant signal bits*** and ***ineffective borders***.

How to solve this problem?



→ **Solution: Block merging (merge mode)**

HEVC Technology (11): Inter Prediction-Merge Mode

- **Merge mode**: For a sub-block, allow to explicitly ***reuse the exact same motion parameters contained in neighboring blocks***.
  - **A list of candidate motion parameter** tuples by picking from neighboring blocks.
  - Actually, **an index** is signaled which identifies the candidate to be used.
- Merge Candidate List Construction (like AMVP)
  - Up to **four spatial merge candidate** from five spatial neighboring
  - **One temporal merge candidate** from two temporal, collocated blocks
  - **Additional merge candidate** including combined bi-predictive candidate and zero motion vector candidates (**for uni-, and bi-predictive slice**)

- In PU level,

Usually 5 merge candidate lists { merge_flag = 1
merge_idx (refer to motion data)

HEVC Technology (12): Inter Prediction-Merge Mode/Skip Mode

- A crucial application of block merging concept: **Skip mode**

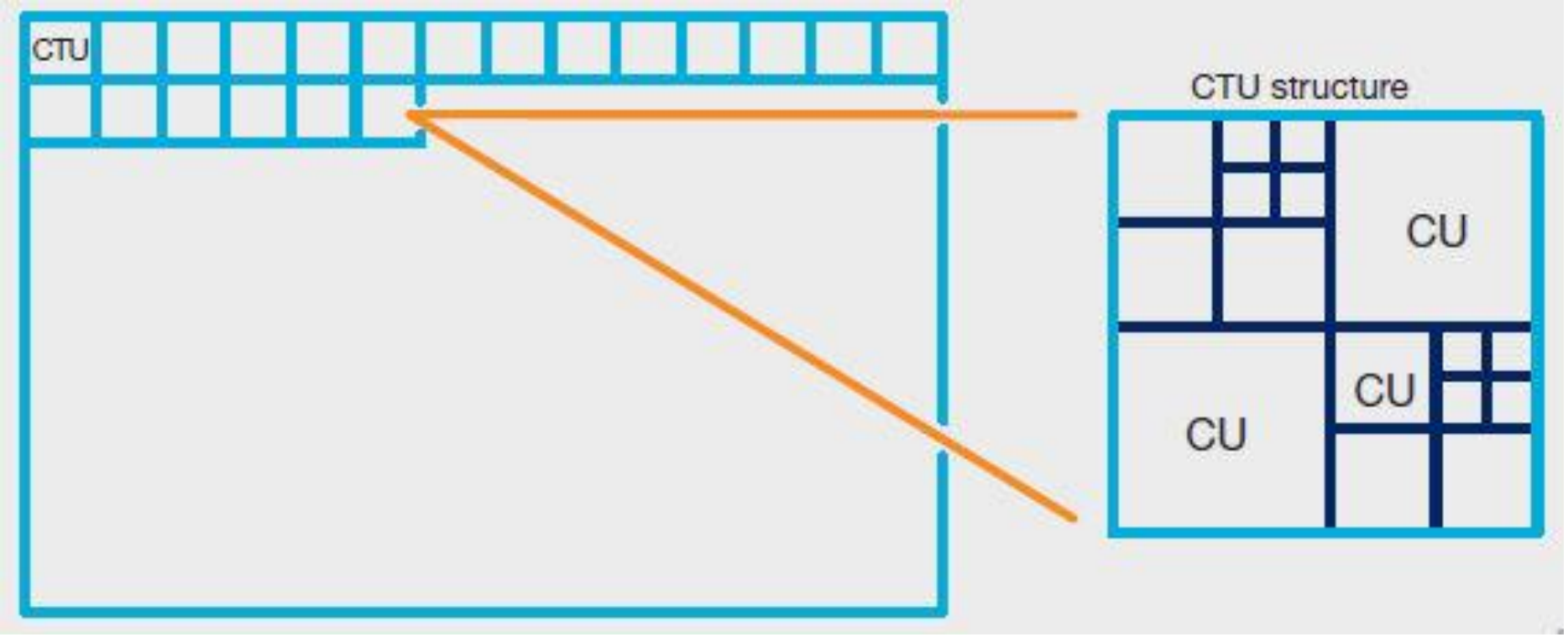
(condition)

- **The CU contains one PU (2Nx2N).**
- **The merge mode is used to derive the motion data (when merge_flag=1).**
- **No residual data is present in the bit stream.**

- **Performance Improvement**
  - **About 6% ~ 8.0% of bit saving in the average value**
  - **Up to 20% bit-saving in Class E (small size of resolution)**

HEVC Technology (13): Processing Order

❖ In a frame:



HEVC Technology (14): Processing Order

❖ In CTU partitioning:

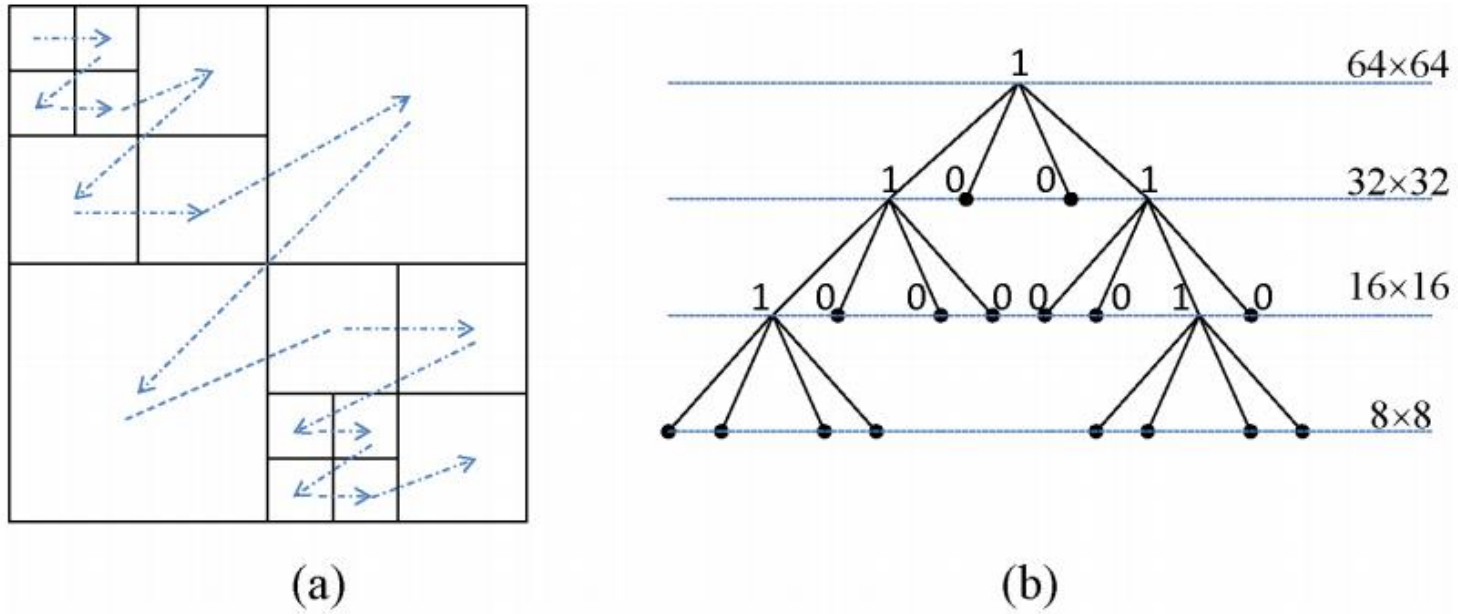


Fig. 2. Example of CTU partitioning and processing order when size of CTU is equal to 64 × 64 and minimum CU size is equal to 8 × 8. (a) CTU partitioning. (b) Corresponding coding tree structure.

HEVC Technology (15): Partitioning

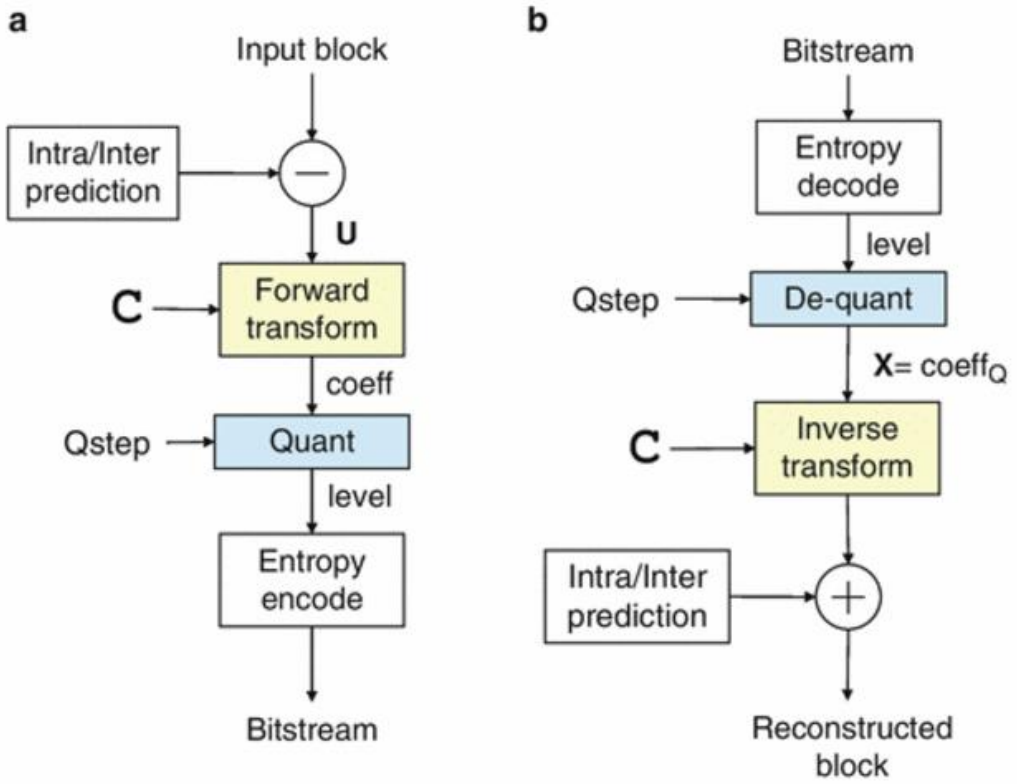
❖ Partitioning: H.264/AVC vs. HEVC

H.264

HEVC

HEVC Technology (16): Transformation

- Transformation
  - Residual (spatial domain)→ spatial **frequency** representation



Encoding Decoding

HEVC Technology (17): Transformation

❖ In HEVC,

- HEVC supports 4x4, 8x8, 16x16, 32x32 integer transforms
- **Core transformation**: **finite precision approximation to the inverse discrete cosine transform (IDCT)** for all transform sizes (not defined forward transforms, but inverse transform was defined)

Integer transform

4x4 or 8x8	16x16 or 32x32
H.264/AVC integer transform	Approx. of fast IDCT

- Achieves 5 to 10% increase in coding efficiency
- Increased complexity compared to H.264/AVC
  - 8x more computations per coefficient
  - 16x larger transpose memory

HEVC Technology (18): Quantization

- Quantization matrix (Q-matrix) design
  - Default matrices: 4x4, 8x8

Default 4x4 for IntraLuma, IntraCb, IntraCr, InterLuma, InterCb, InterCr

16	16	16	16
16	16	16	16
16	16	16	16
16	16	16	16

(Flat matrix)

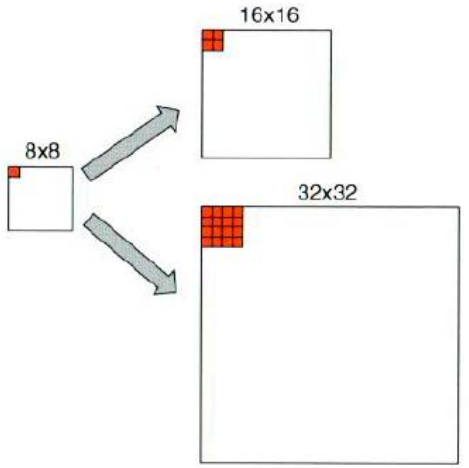
Default 8x8 for IntraLuma, IntraCb, IntraCr

16	16	16	16	17	18	21	24
16	16	16	16	17	19	22	25
16	16	17	18	20	22	25	29
16	16	18	21	24	27	31	36
17	17	20	24	30	35	41	47
18	19	22	27	35	44	54	65
21	22	25	31	41	54	70	88
24	25	29	36	47	65	88	115

Default 8x8 for InterLuma, InterCb, InterCr

16	16	16	16	17	18	20	24
16	16	16	17	18	20	24	25
16	16	17	18	20	24	25	28
16	17	18	20	24	25	28	33
17	18	20	24	25	28	33	41
18	20	24	25	28	33	41	54
20	24	25	28	33	41	54	71
24	25	28	33	41	54	71	91

  - Expand to 16x16 and 32x32 from 8x8 Q-matrix



HEVC Technology (19): Quantization

❖ 20 quantization matrices as block size and type

- Luma: Inter 4x4 ~ 32x32
  Intra 4x4 ~ 32x32
- Cb : Inter 4x4 ~ 16x16
  Intra 4x4 ~ 16x16
- Cr : Inter 4x4 ~ 16x16
  Intra 4x4 ~ 16x16

❖ Quantization size for different coding tree unit sizes

diff_cu_qp_delta_depth	For 64x64 CTU	For 32x32 CTU	For 32x32 CTU
0	64x64	32x32	16x16
1	32x32	16x16	8x8
2	16x16	8x8	-
3	8x8	-	-

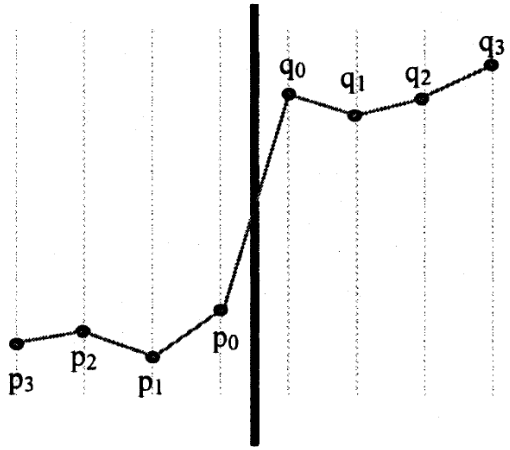
HEVC Technology (20): In-Loop Deblocking Filter

❖ Removes blocking artifacts due to block based processing

- Computationally intensive in H.264/AVC

w/o deblocking

w/ deblocking



- In **H.264/AVC**, performed on **every 4x4 block edge**
  - Each macroblock has 128 pixel edges, 32 edge calculations
  - Each 4x4 depends on neighboring 4x4
- In **HEVC**, performed on **every 8x8 block edge**
  - Each 16x16 CTU has 64 pixel edges, 8 edge calculations
  - All 8x8 are independent (can be processed in parallel)

HEVC Technology (21): In-Loop Deblocking Filter

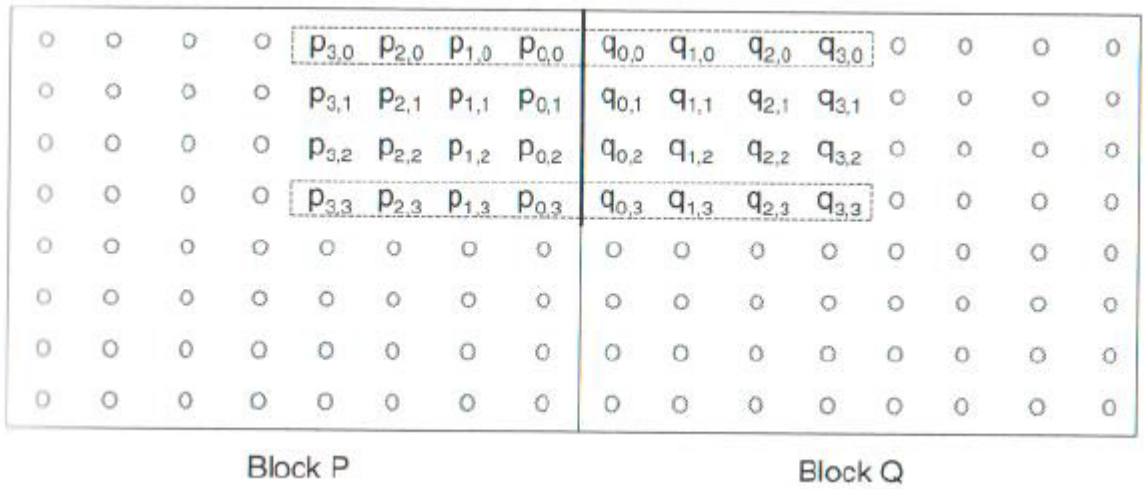
❖ **Boundary Strength (Bs)**-based Filter Decision

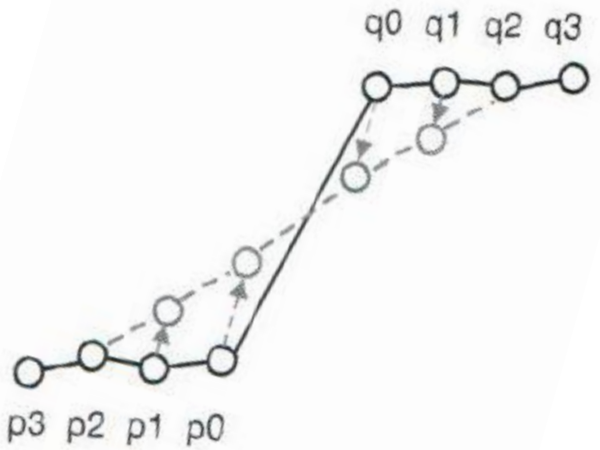
Conditions	Bs
At least one of the blocks is Intra	2
At least one of the blocks has non-zero coded residual coefficient and boundary is a transform boundary	1
Absolute differences between corresponding spatial motion vector components of the two blocks are >= 1 in units of integer pixels	1
Motion-compensated prediction for the two blocks refers to different reference pictures or the number of motion vectors is different for the two blocks	1
Otherwise	0

HEVC Technology (22): In-Loop Deblocking Filter

❖ **Two Filtering Modes (using Bs and some conditions)**

- **Normal filtering modes: p1, p0, q0, q1 계산 후 생성**
- **Strong filtering modes: p2, p1, p0, q0, q1, q2 계산 후 생성**





[Example of normal mode]

- **Chroma boundary deblocking (only for Bs=2)**

HEVC Technology (23): In-Loop Deblocking Filter

- Result of adaptive delocking filtering

Sequence *KristenAndSara*, Low Delay, QP37: (**a**) deblocking turned off, (**b**) deblocking turned on

HEVC Technology (24): Sample Adaptive Offset (SAO)

❖ **Problem: ringing effect (Gibs phenomenon) in edge**

- ➢The dotted curve -original samples
- ➢The solid curve - reconstructed samples by discarding high frequencies of the original samples

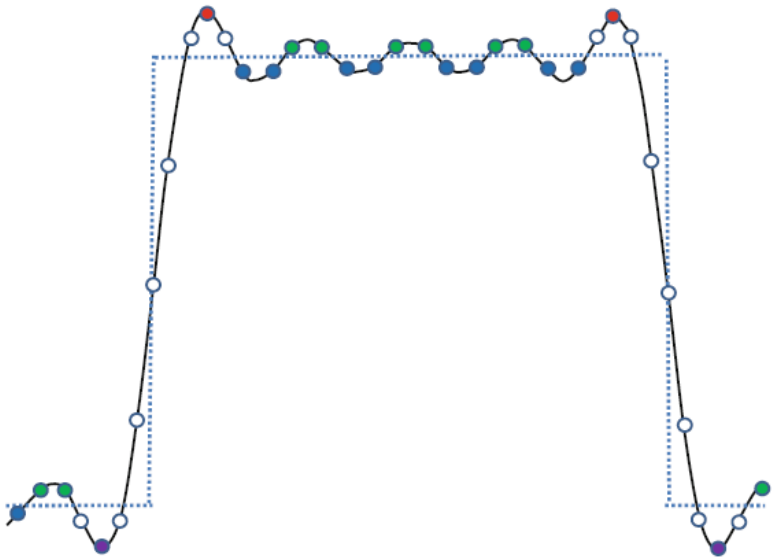


Fig. 4. Gibbs phenomenon where the dotted curve is the original samples and the solid curve is the reconstructed samples.

solution → SAO in HEVC standard

HEVC Technology (25): Sample Adaptive Offset (SAO)

Original Image

SAO=Off

SAO=On

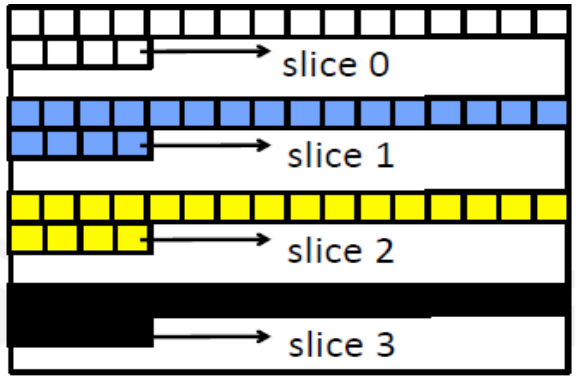
HEVC Technology (26): Entropy Coding

- HEVC uses Context Adaptive Binary Arithmetic Coding (CABAC)
  - 10 to 15% higher coding efficiency compared to CAVLC

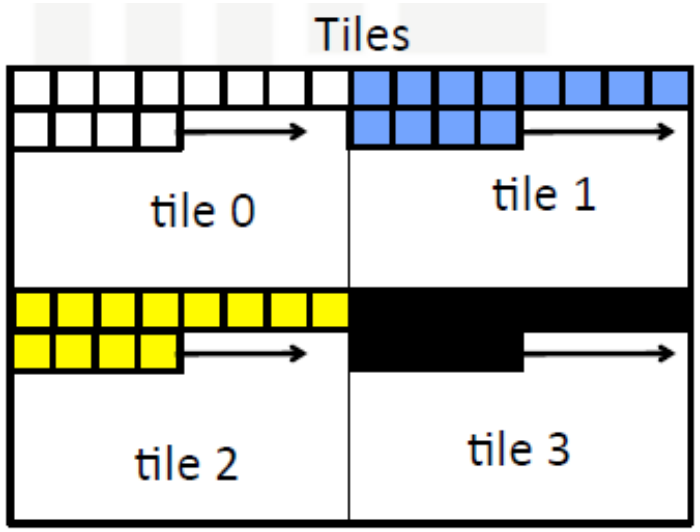
HEVC Technology (27): High Level Parallel Tools (Multi-Core)

❖ Multi-slices

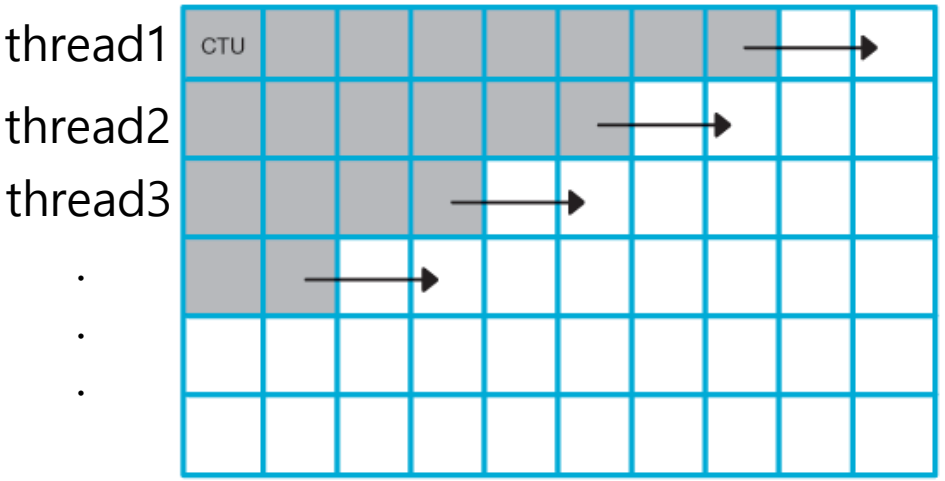
Slices
(also in H.264/AVC)



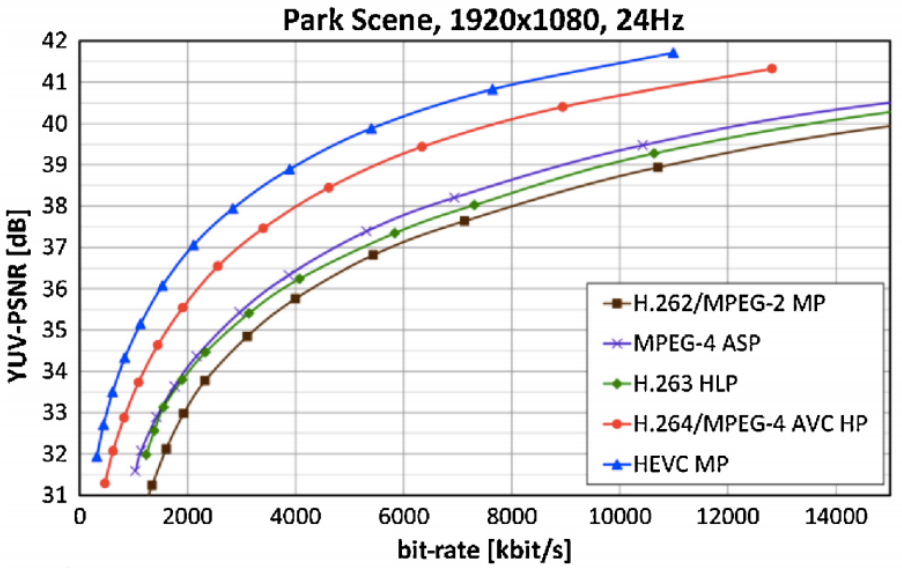
❖ In HEVC standard,



Wavefront parallel processing



HEVC Technology (28): Performance



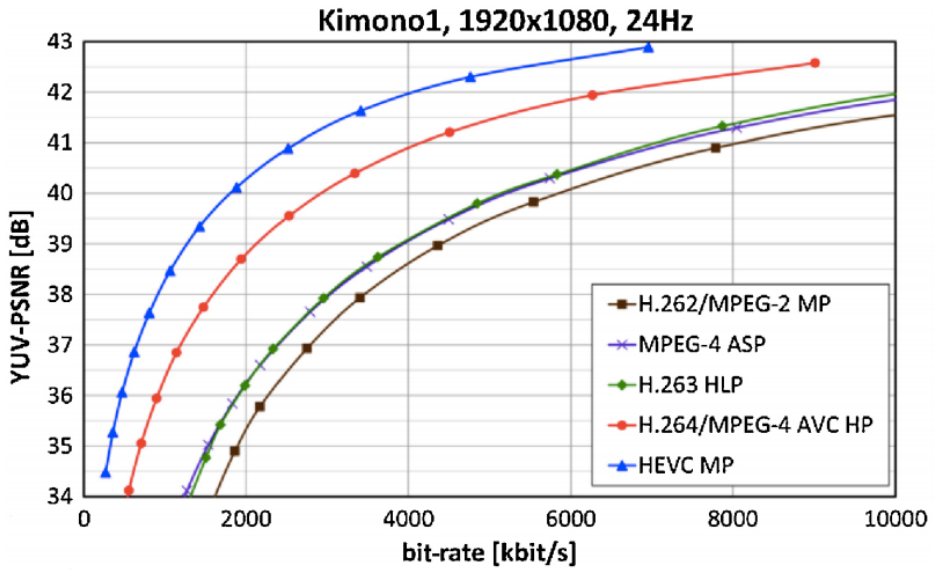


TABLE VI

AVERAGE BIT-RATE SAVINGS FOR EQUAL PSNR FOR ENTERTAINMENT APPLICATIONS

Encoding	Bit-Rate Savings Relative to			
	H.264/MPEG-4 AVC HP	MPEG-4 ASP	H.263 HLP	MPEG-2/ H.262 MP
HEVC MP	35.4%	63.7%	65.1%	70.8%
H.264/MPEG-4 AVC HP	–	44.5%	46.6%	55.4%
MPEG-4 ASP	–	–	3.9%	19.7%
H.263 HLP	–	–	–	16.2%

J. R. Ohm et al., Comparision of the Coding efficiency of Video Coding Standards-Including High Efficiency Video Coding (HEVC)," IEEE Transactions on Circuits and Systems for Video Technology, 2012

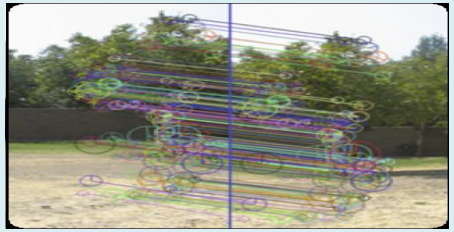
HEVC Technology (29): Performance

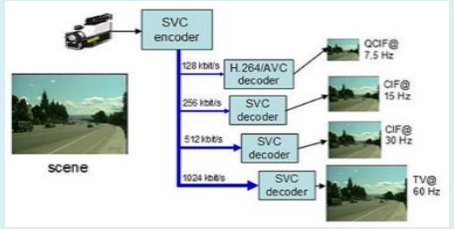
HEVC vs H.264/AVC at Same PSNR

HEVC Technology (29): Performance

HEVC vs H.264/AVC at Same Bitrate

Original	HEVC	AVC/H.264
원본(1920x1080, 50fps, 4:2:0)	HM 4.0@6.1Mbps, Y PSNR: 36.2	JM 18@6.1Mbps, Y PSNR: 34.4





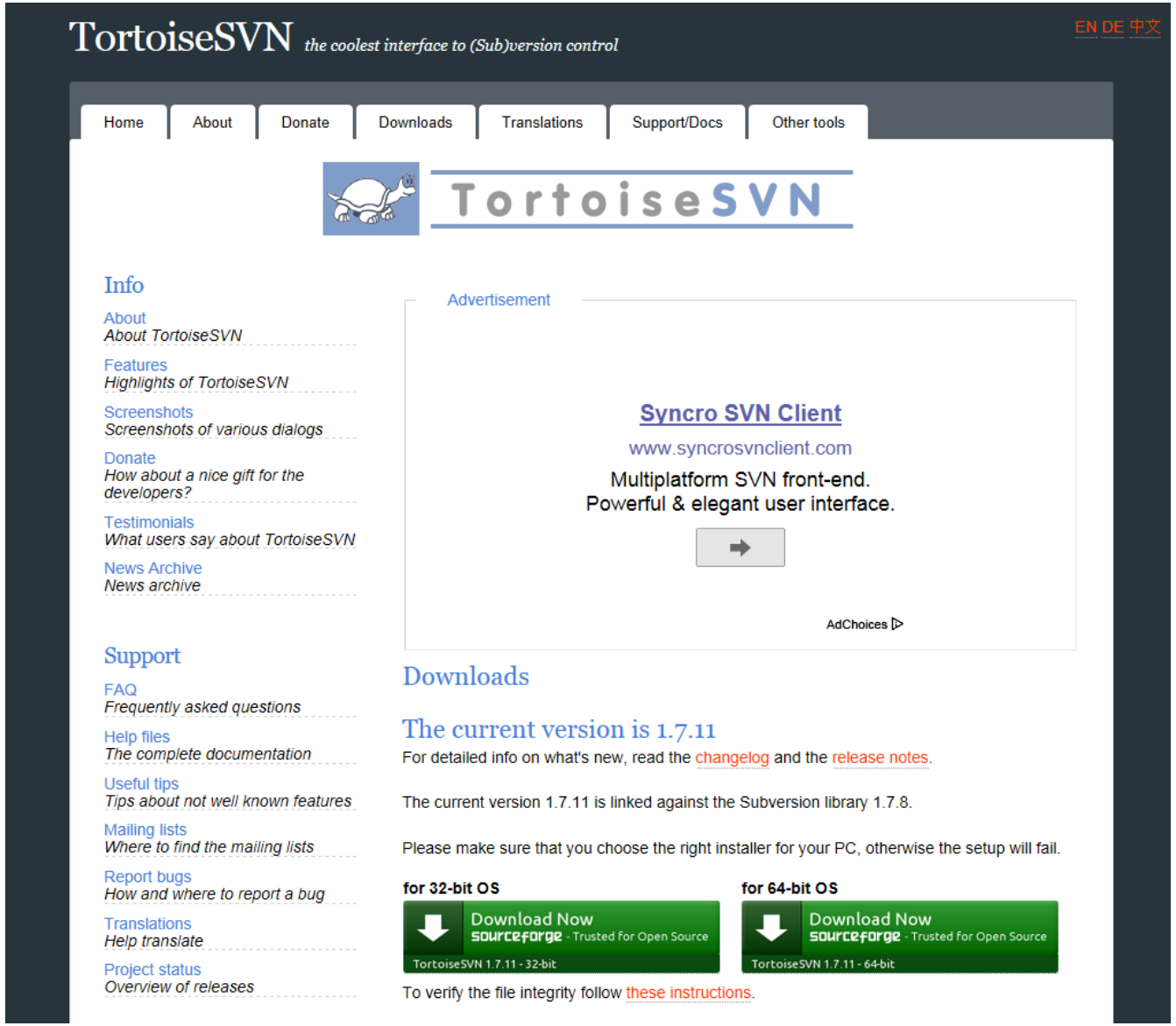
Contents

- UHD TV & Contents – Realistic media
- HEVC Technology (encoder)
- HM Reference Software
- Summary

HM Reference Software(1)

❖ How to get?

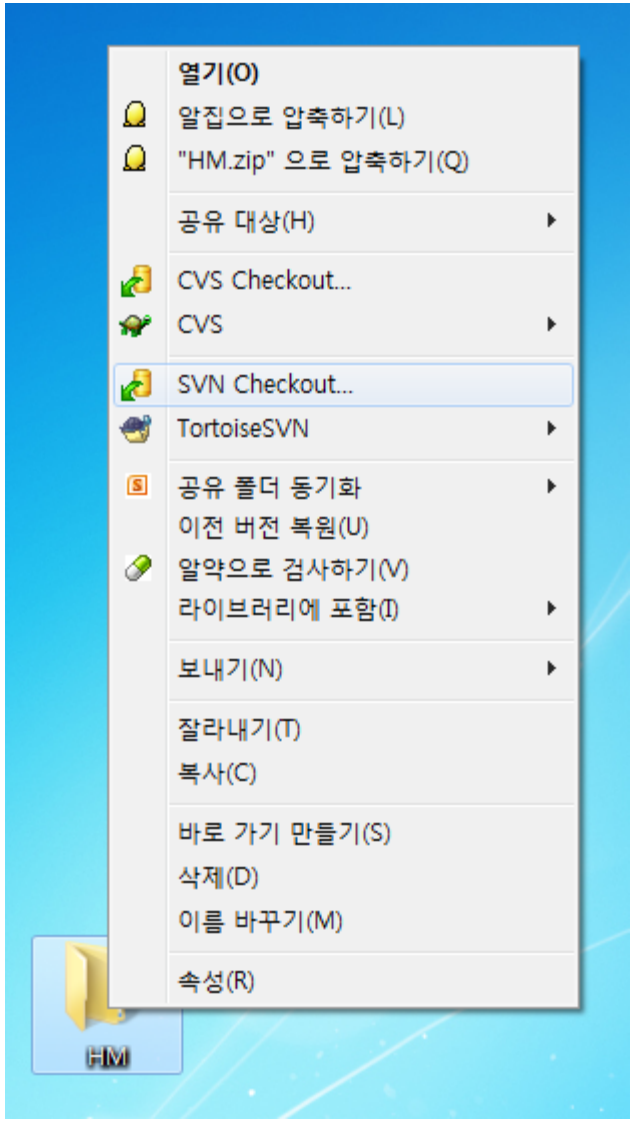
- SVN 다운로드



HM Reference Software(2)

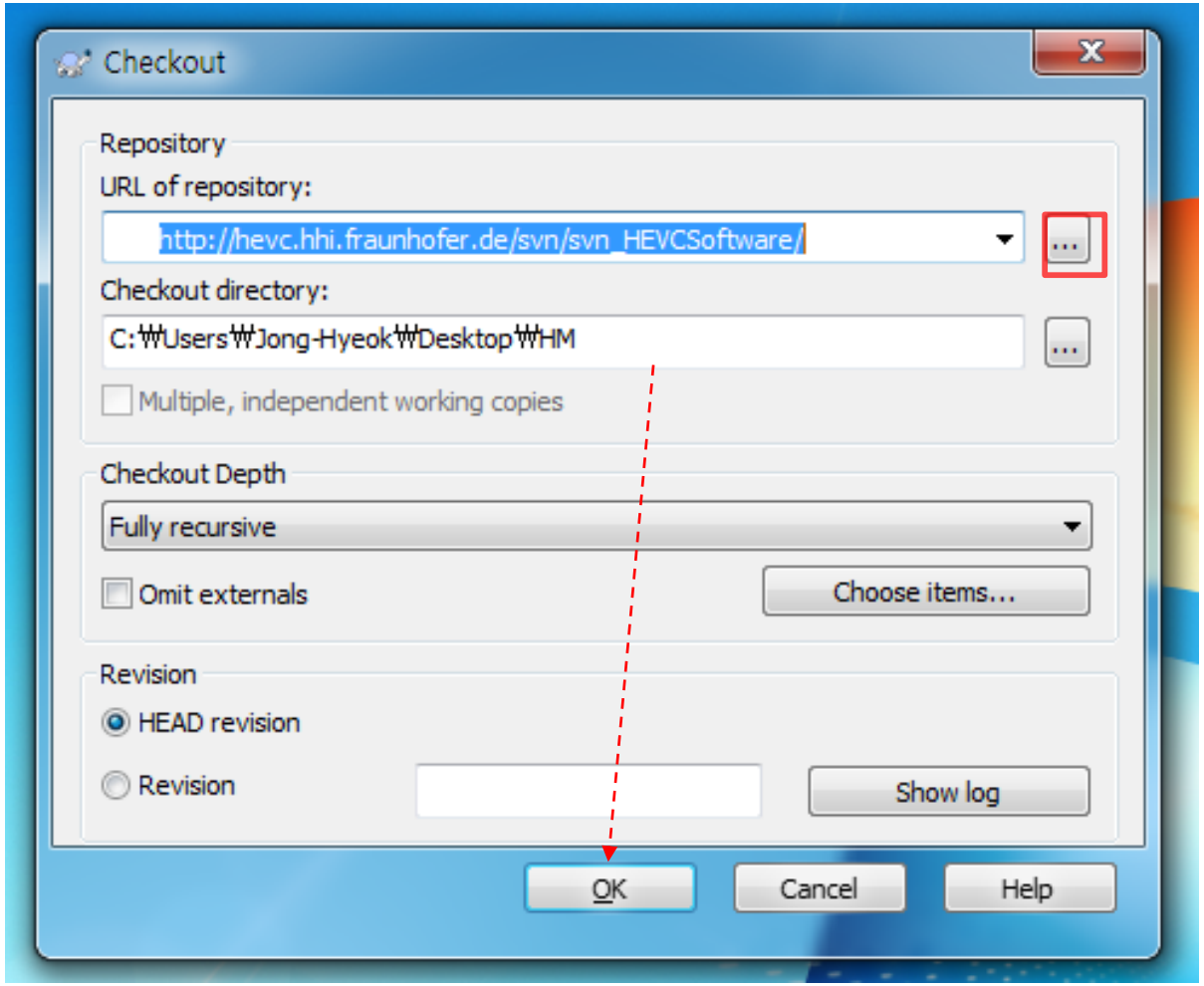
❖ TortoiseSVN 설치 후 적당한 디렉토리 생성

❖ SVN Checkout 클릭

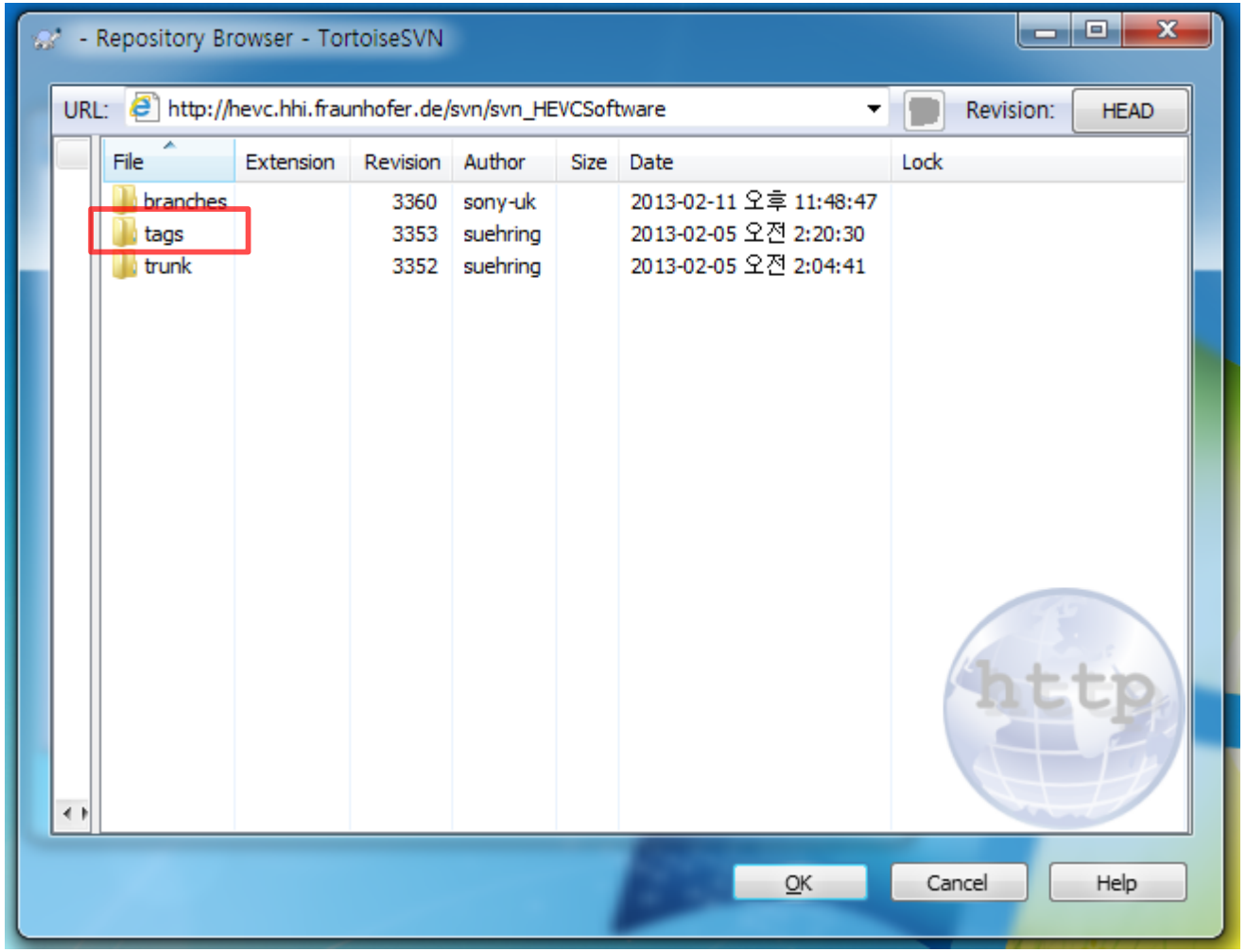


HM Reference Software(3)

http://hevc.hhi.fraunhofer.de/svn/svn_HEVCSoftware/

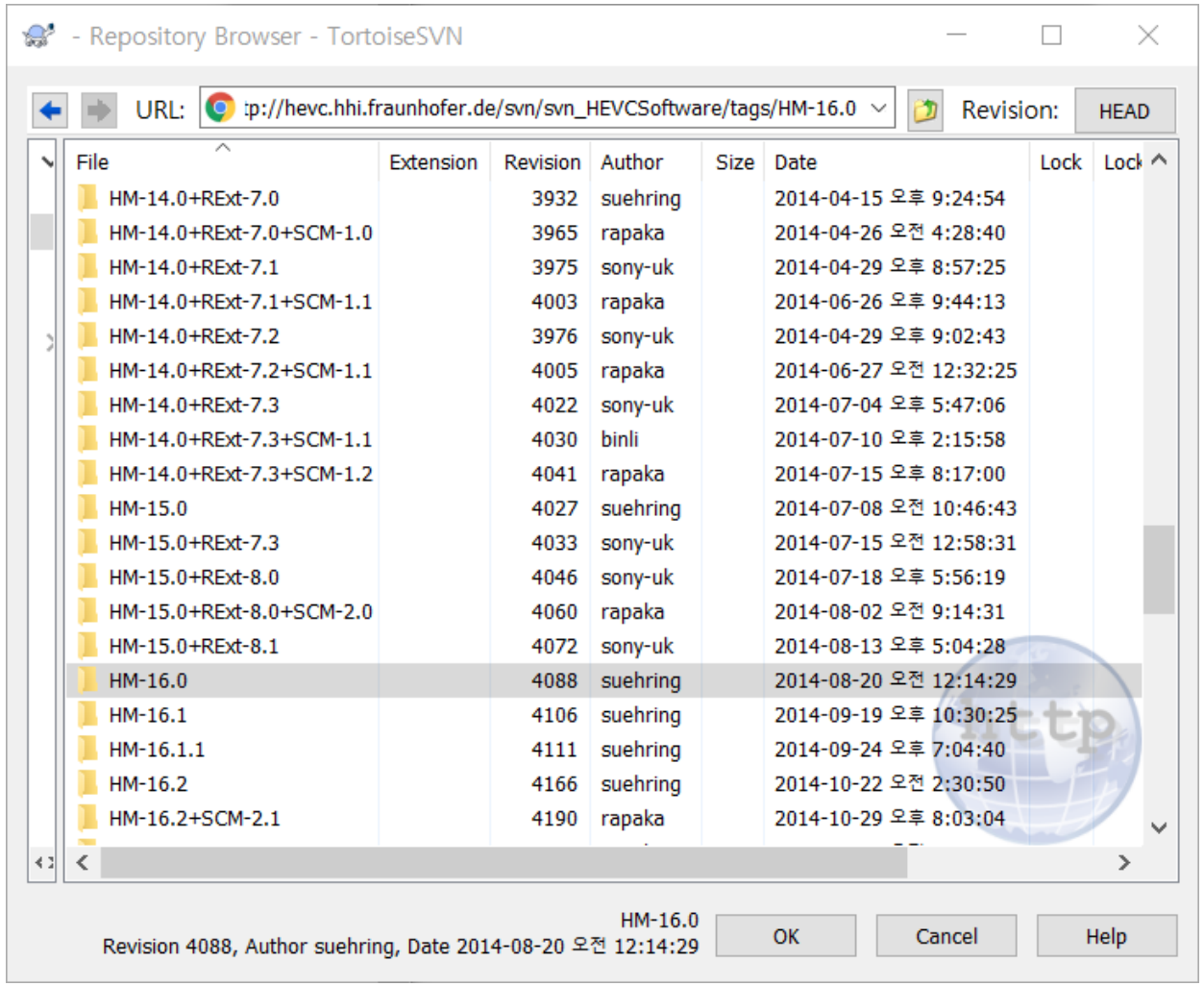


HM Reference Software(4)



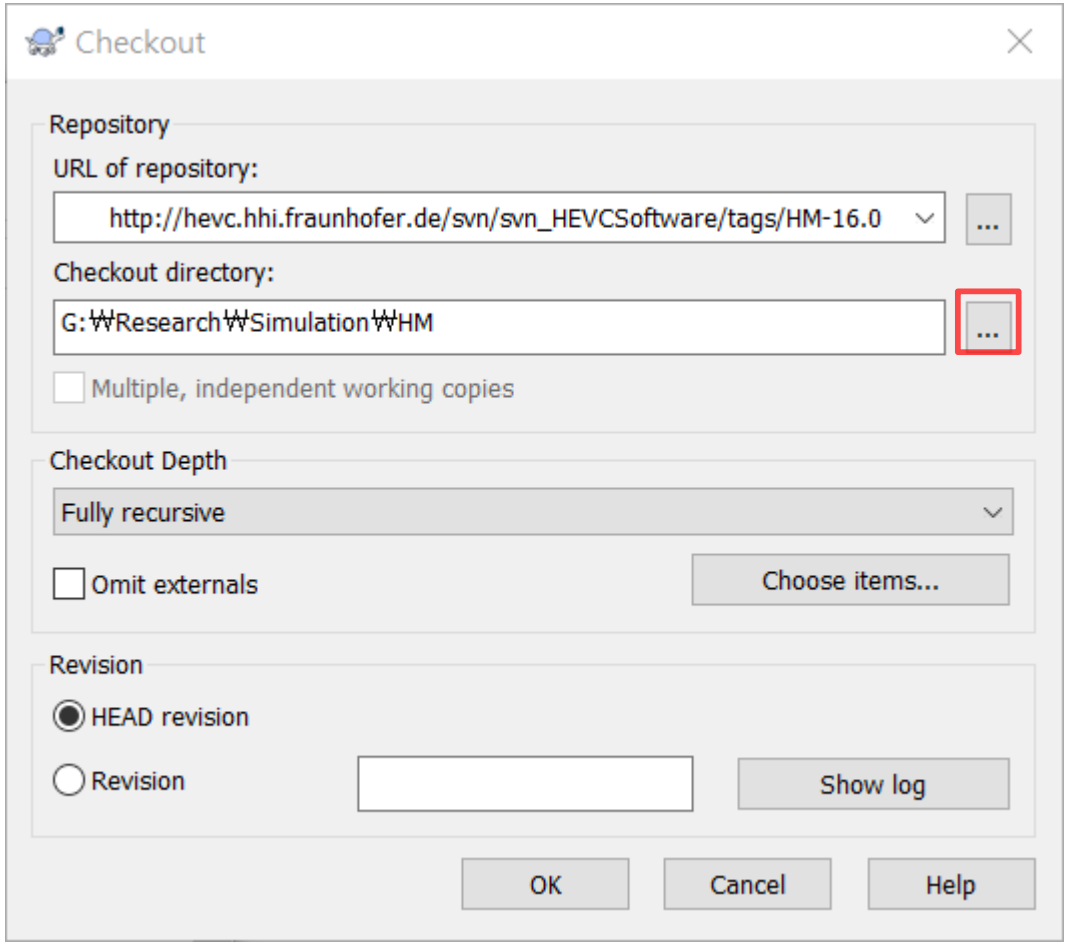
HM Reference Software(5)

- Select version…!!!



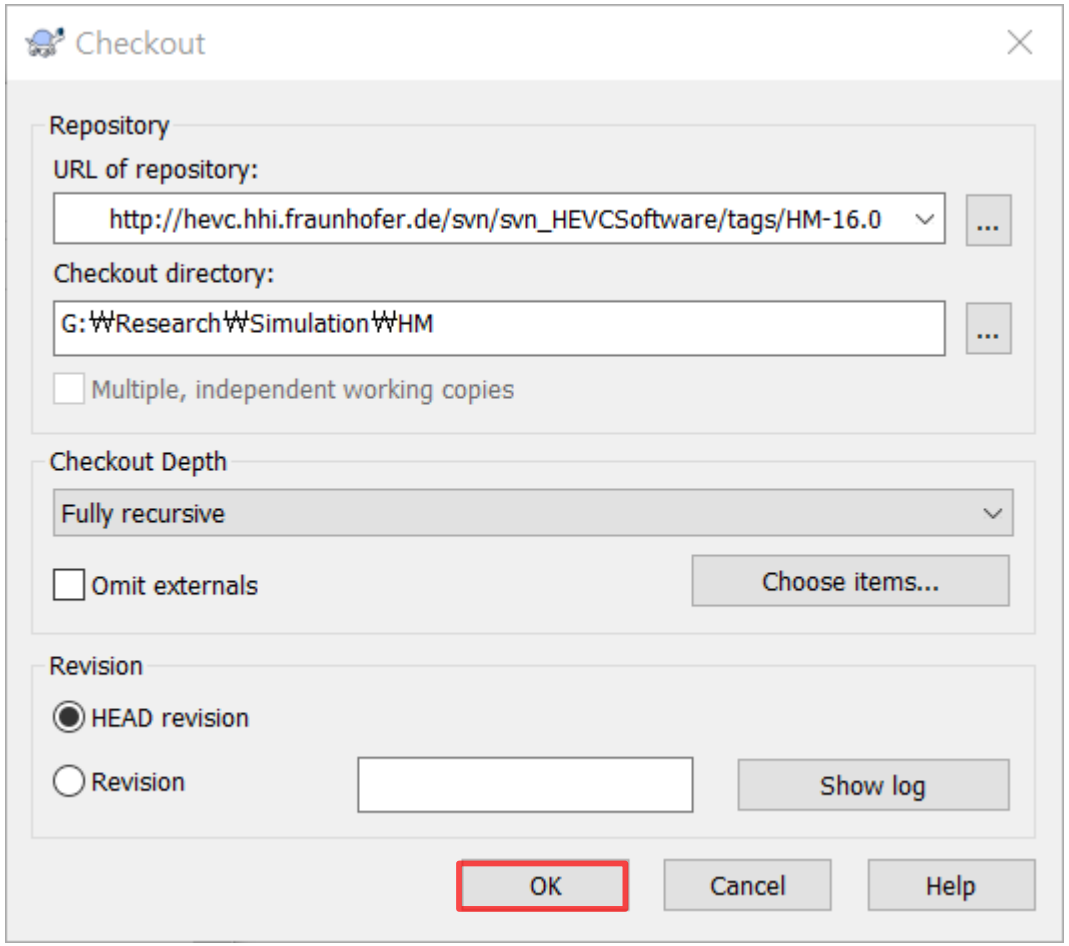
HM Reference Software(6)

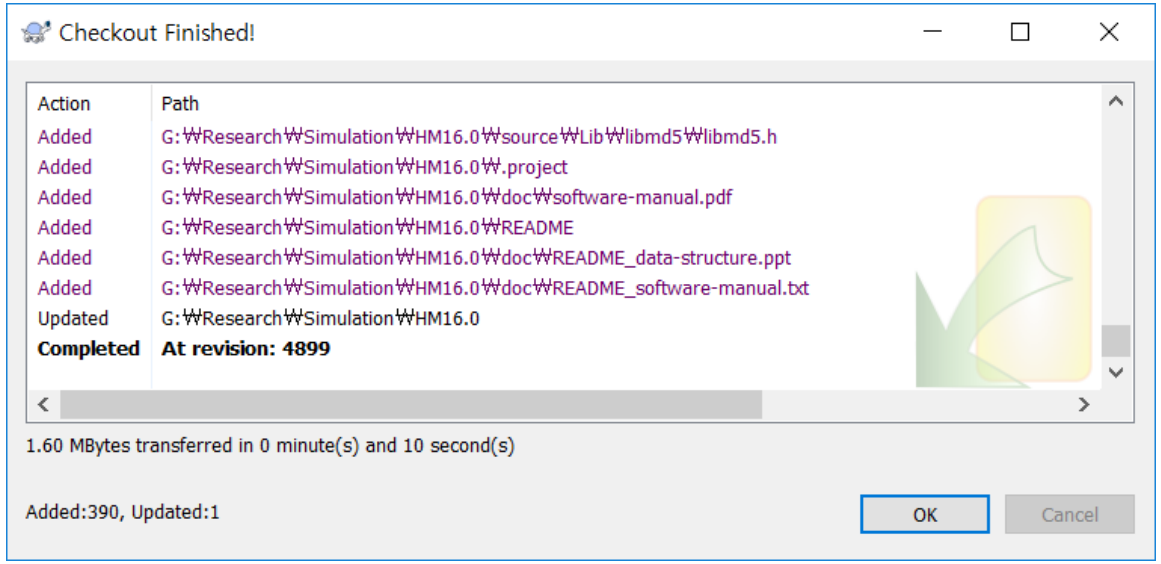
- Specify Download folder…!!!



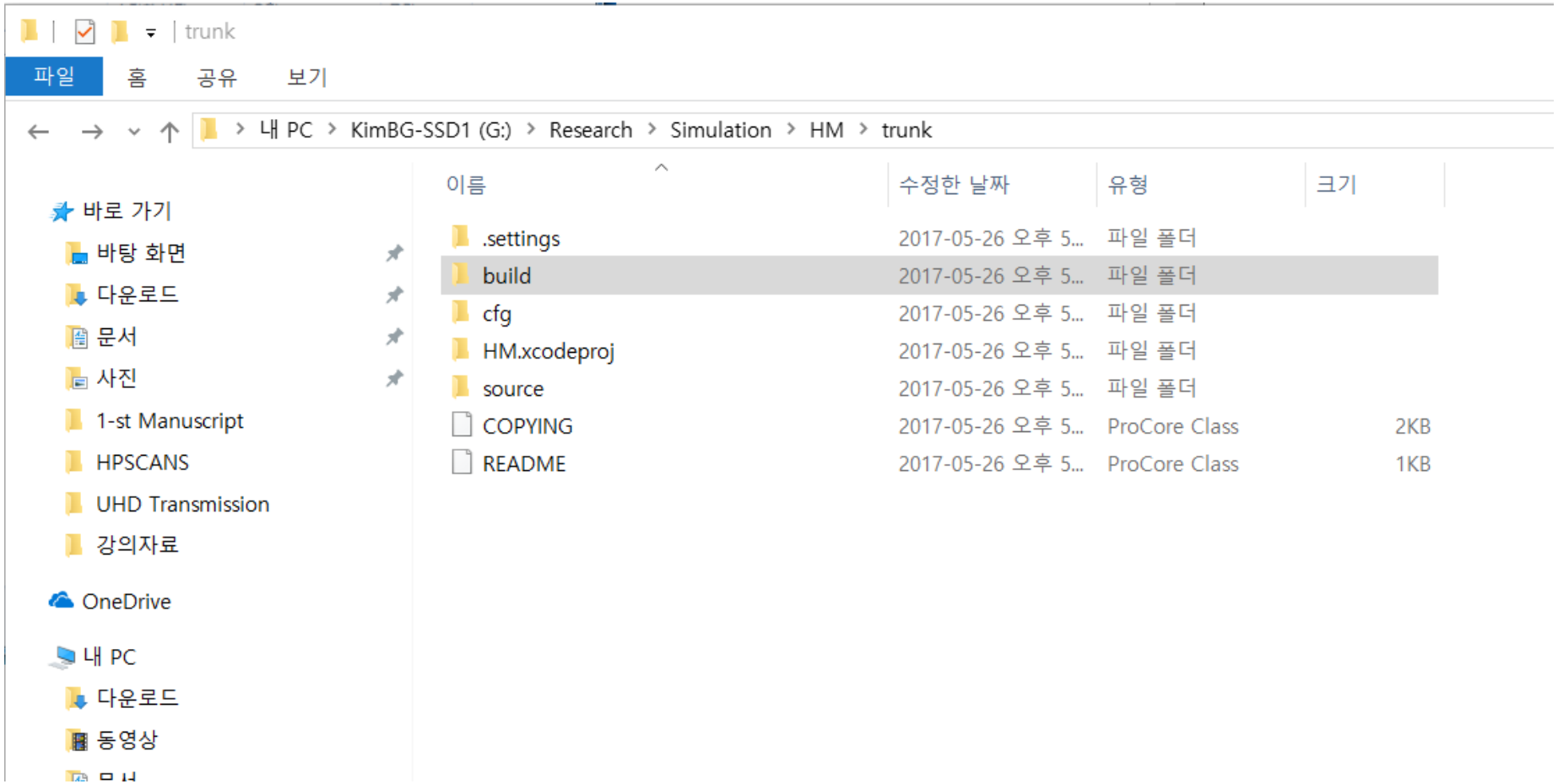
HM Reference Software(7)

- Press "OK" button…..!





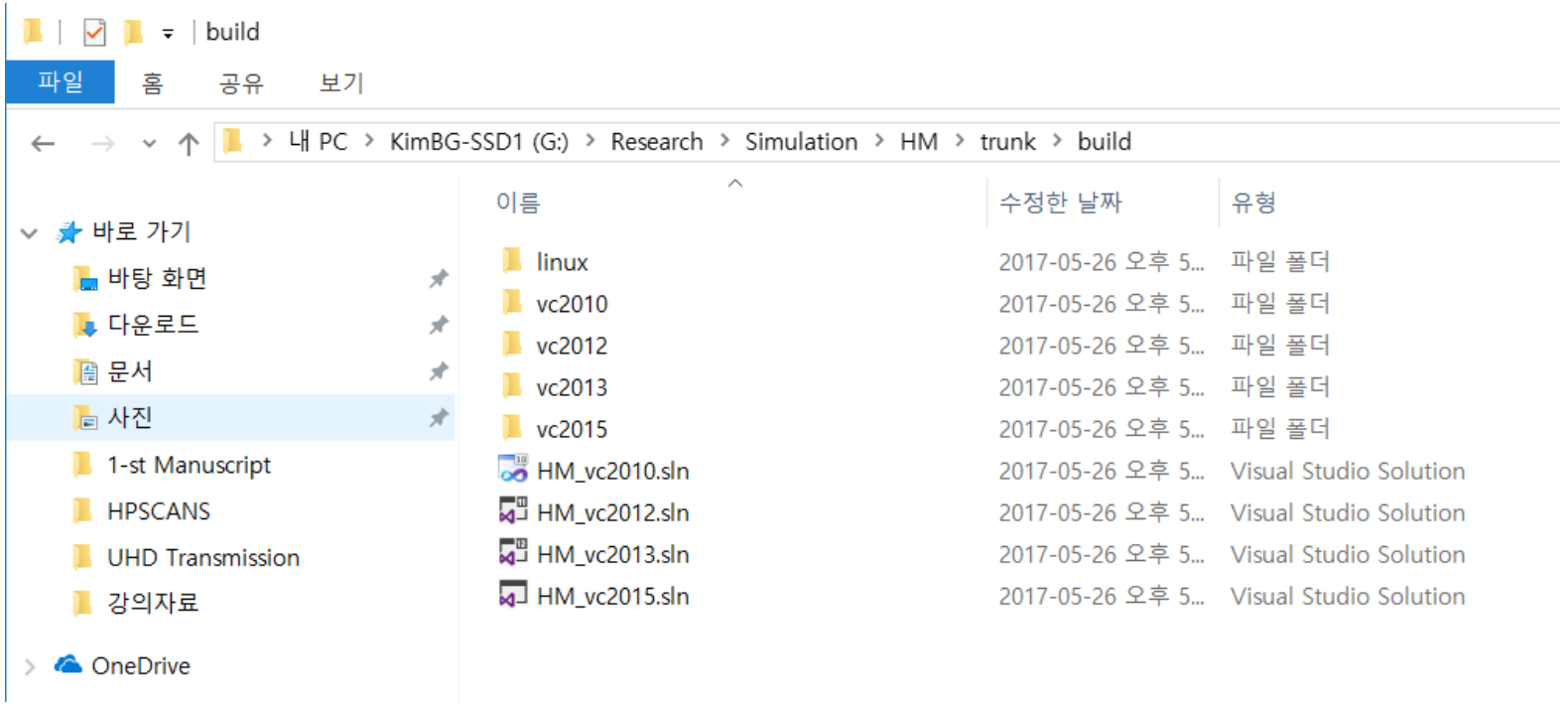
HM Reference Software(8)



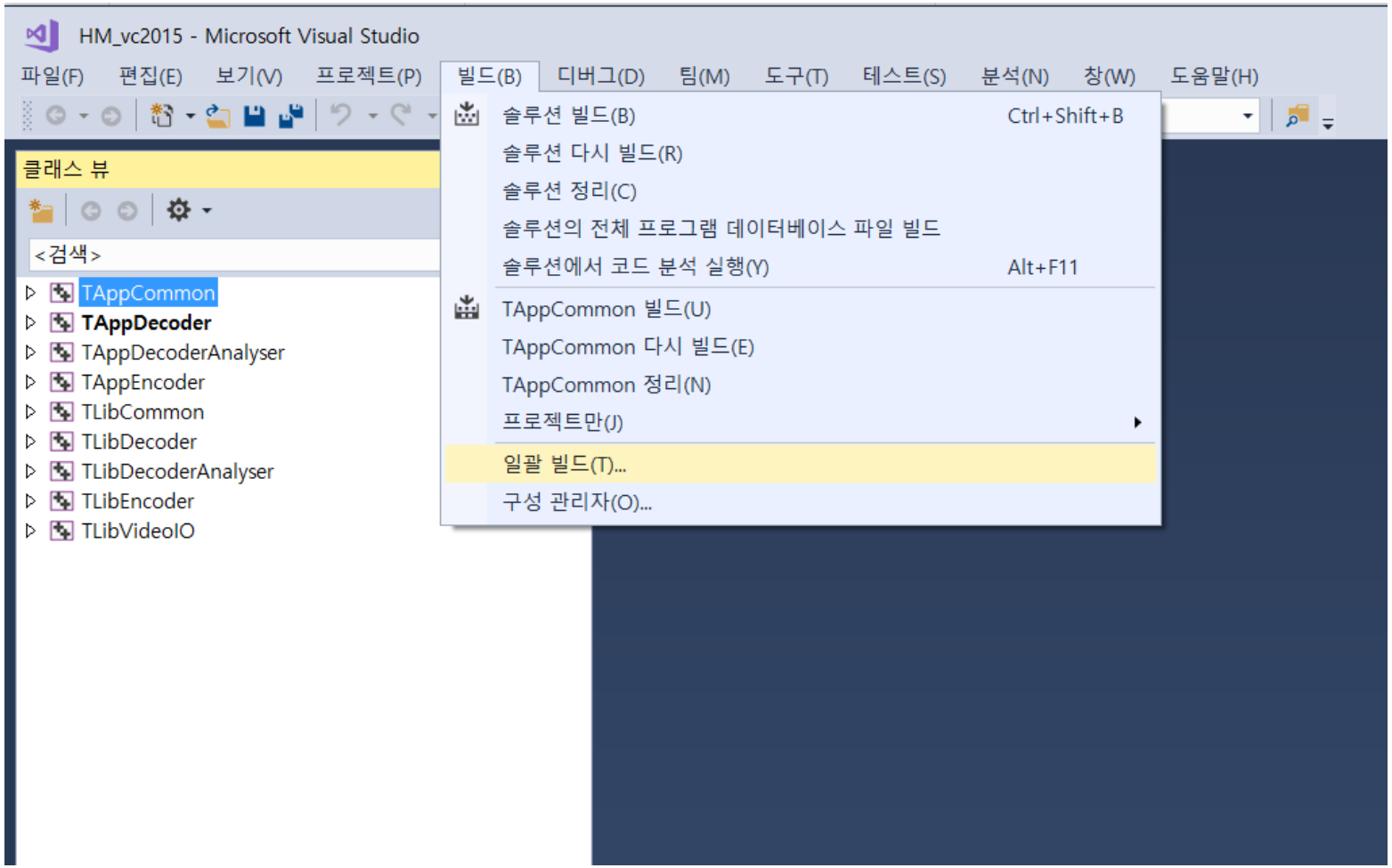
Go to “build” folder..!!!

HM Reference Software(8-1)

- In “build” folder, open project as your VS version.

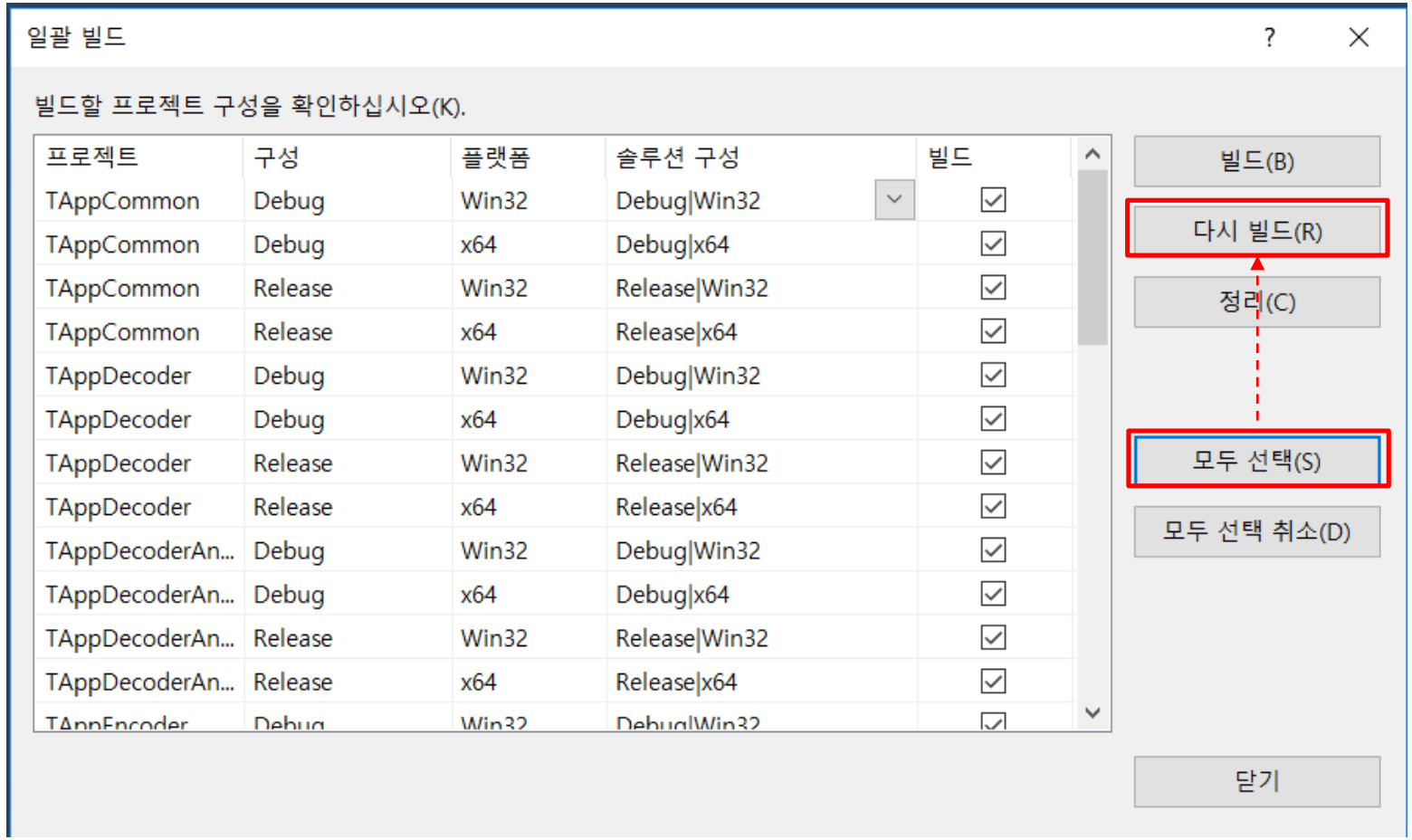


HM Reference Software(8-2)



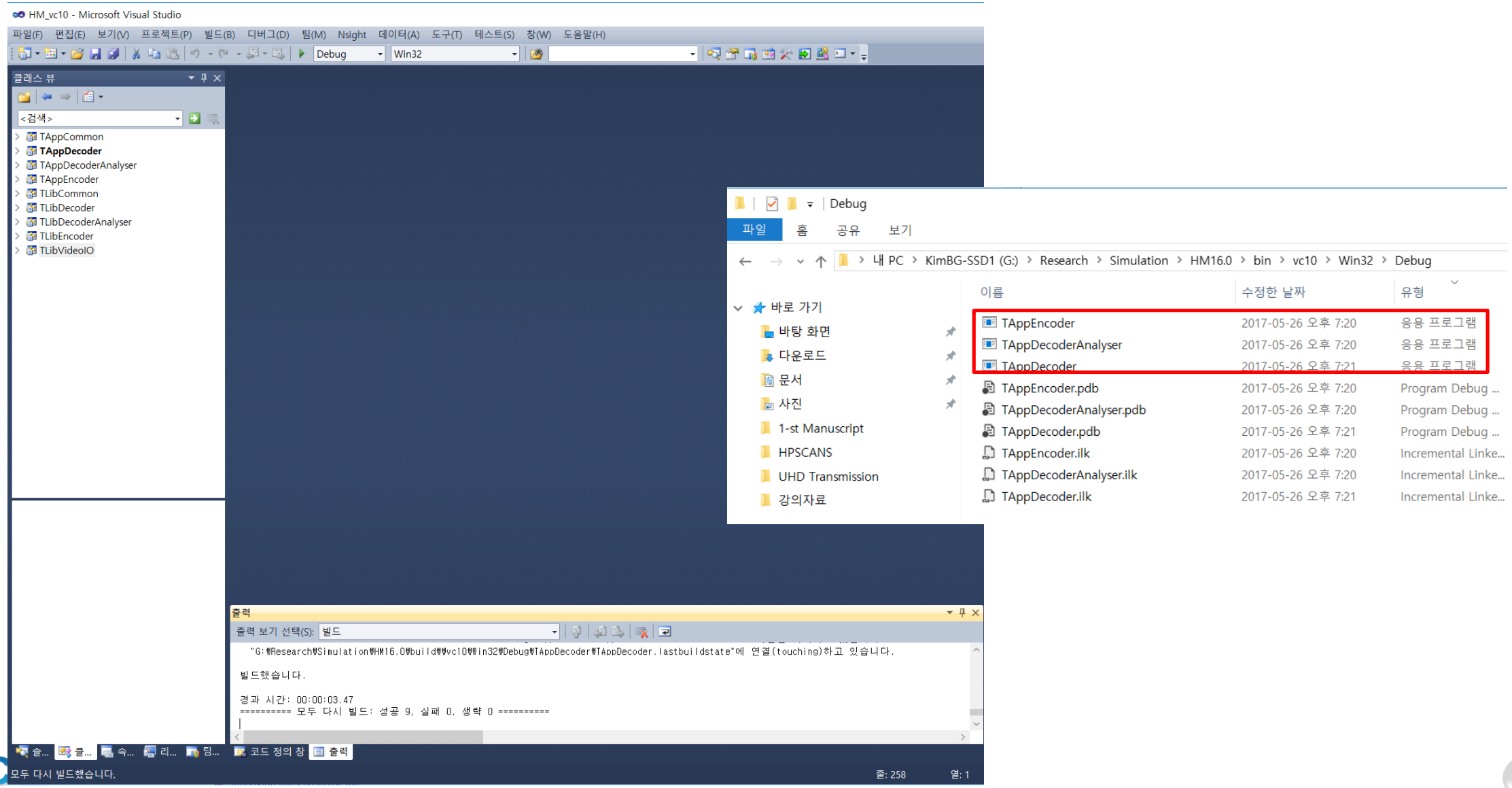
HM Reference Software(8-3)

- "모두 선택(select all)" 후 "다시 빌드(build again)"



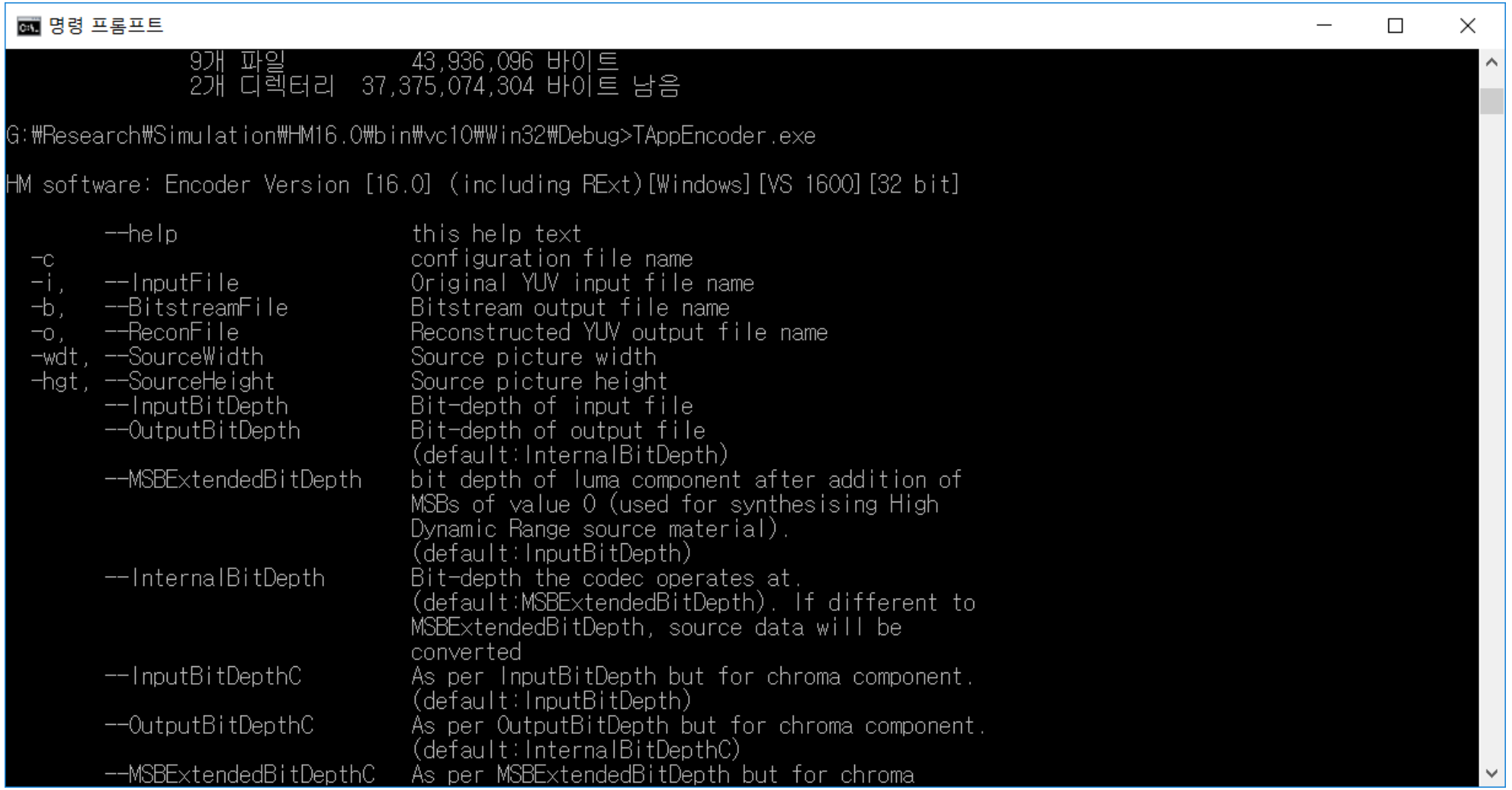
HM Reference Software(8-4)

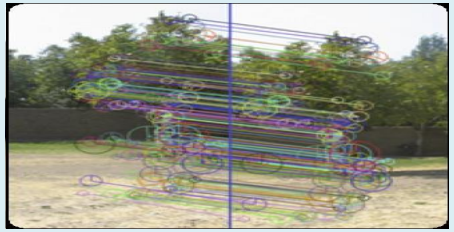
- Successful to build….!!!!

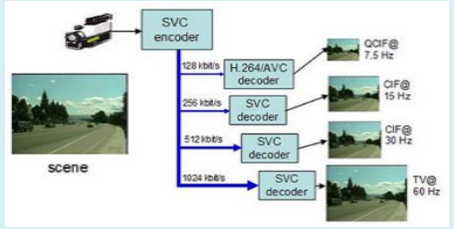


HM Reference Software(8-5)

- HEVC Encoder test…..!!!!: TAppEncoder.exe







Contents

Summary

- Realistic media and contents
  - Ultra Hi-definition (UHD) Video
- HEVC Video standard
  - Block type
  - Mode selection
  - Transform and so on.
- HEVC reference SW
  - How to get?
  - Starting to compile.

VICL
Visual Information Computing Lab

Thank you for your attention.!!!
QnA

http://vicl.sookmyung.ac.kr