# *Green* HEVC Encoding - How To Be Both Coding Efficient And Energy Efficient

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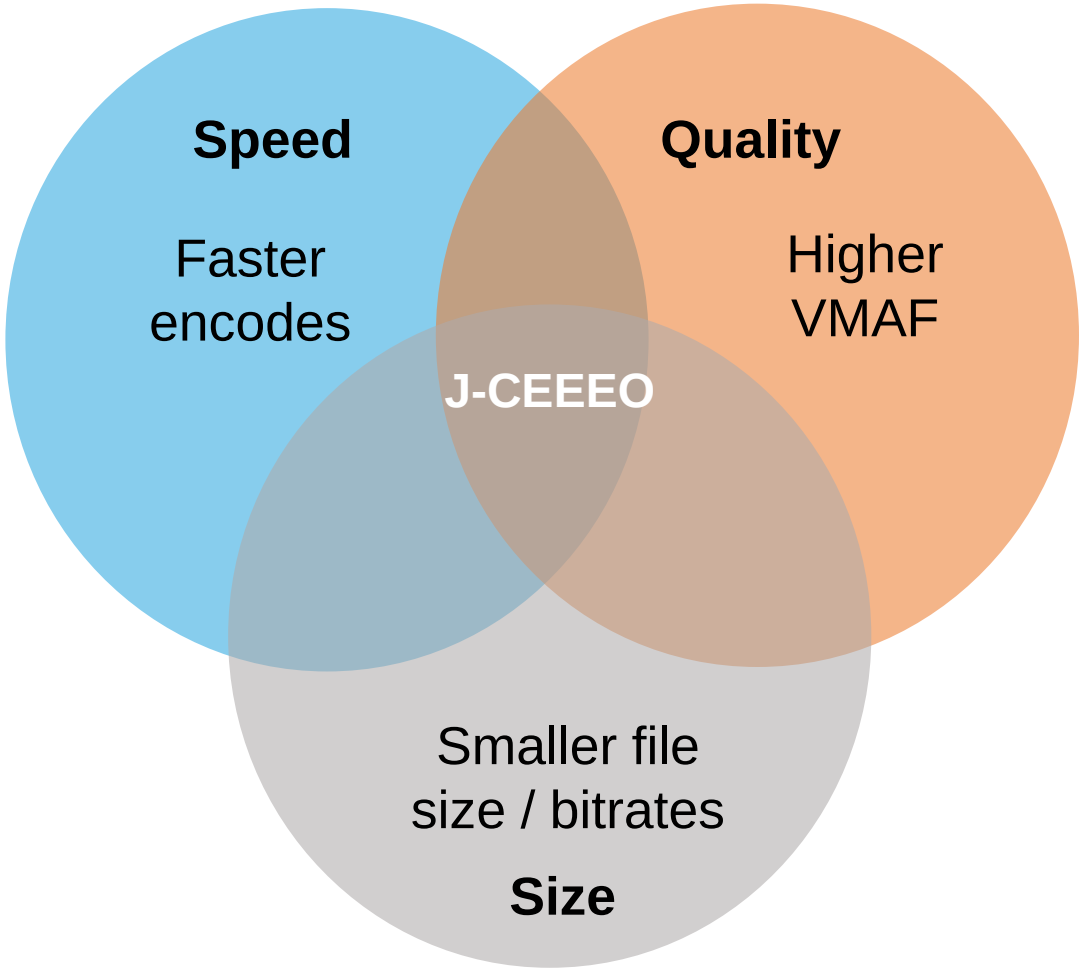
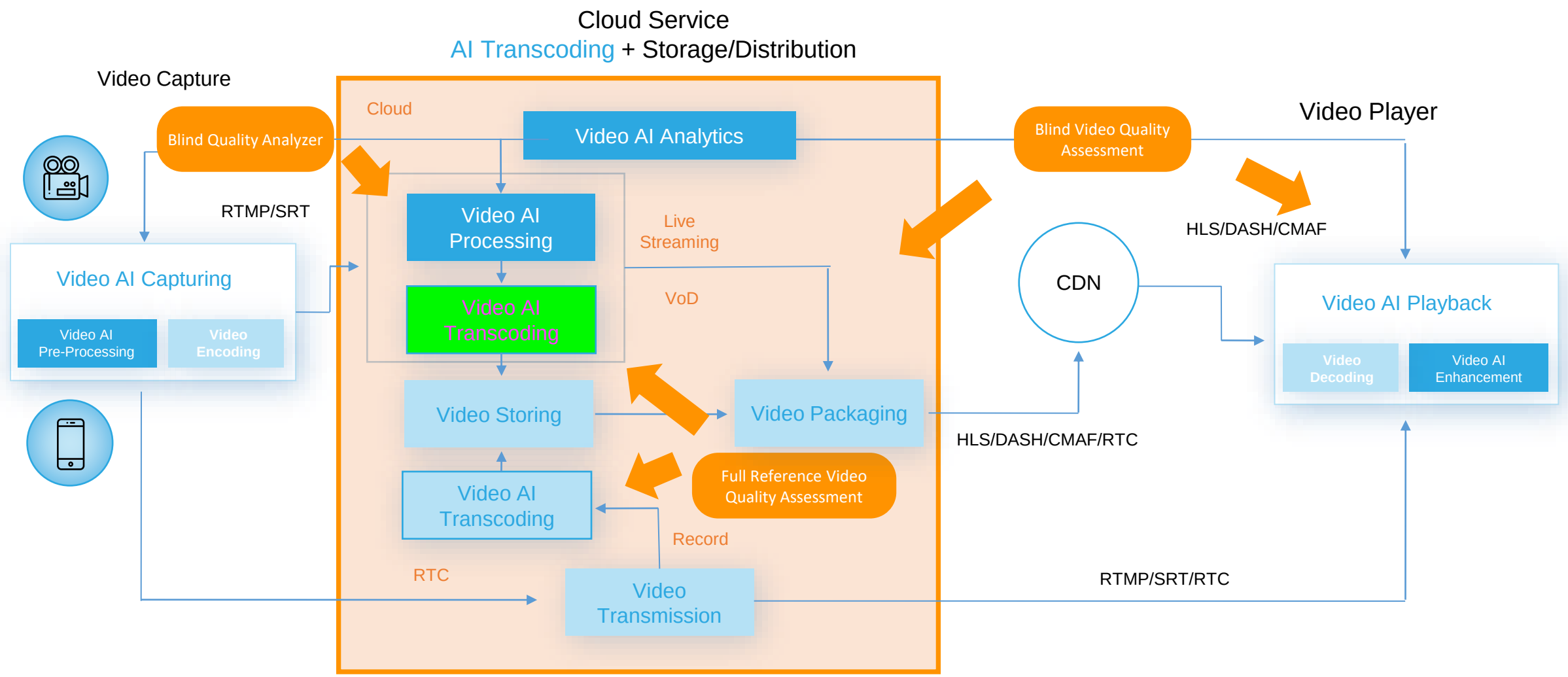
# J-CEEEO: Joint Coding Efficiency & Energy Efficiency Optimization




- Visual Quality
- Output Bitrates
- Encoding Speed
- Overall Latency
- CPU Usage

# Video Encoding by Intelligent Handling



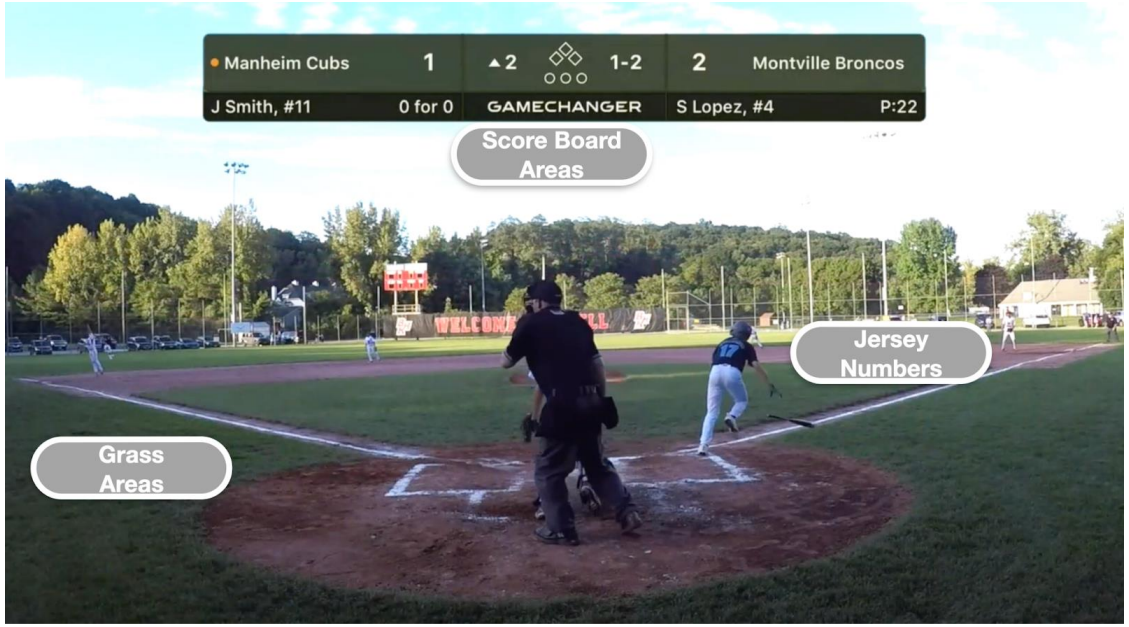

Allocate *bits* to the most **perceptually significant areas**.

# Identifying Perceptually Significant Regions

Transcoded by x264 (Open source)
Resolution: 241x136 File size: 1.3MB

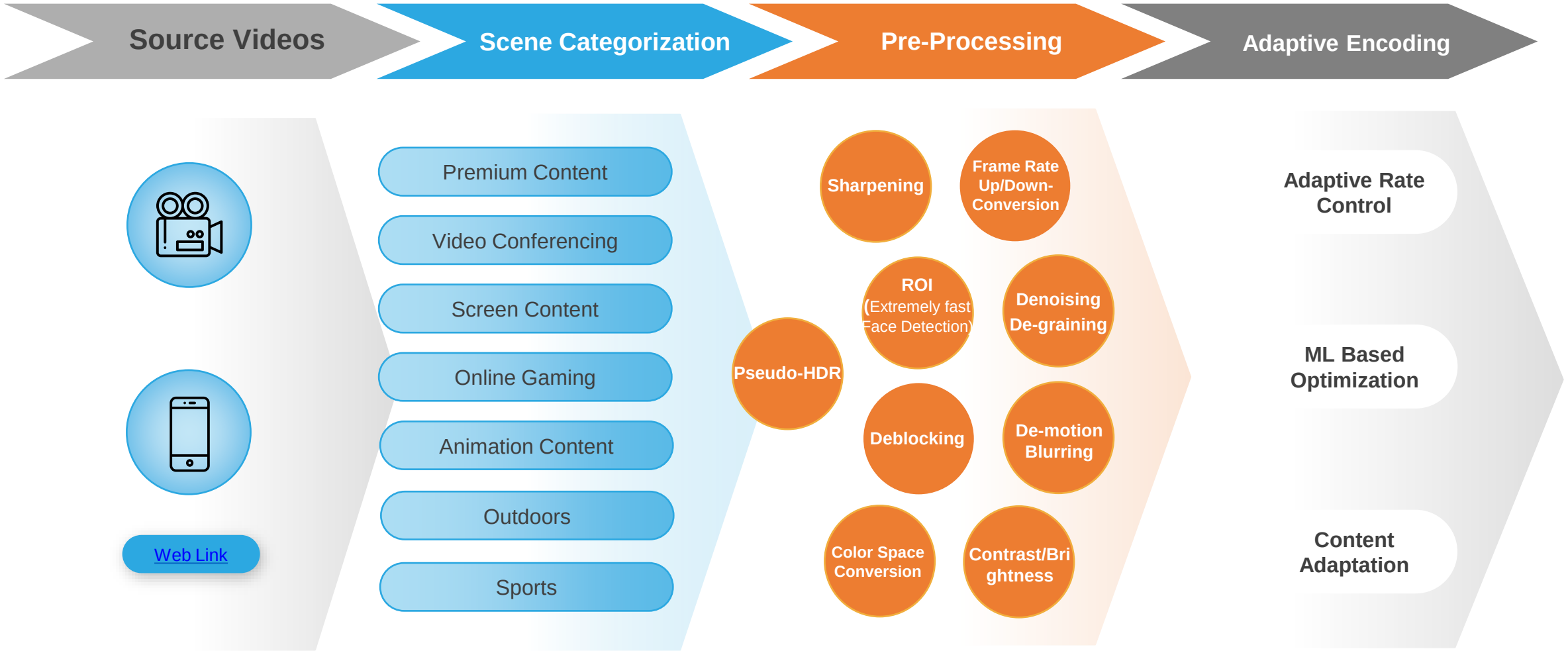
Transcoded by Enhanced H264 (Visionular)
Resolution: 426x240 File size: 1.3MB


Source Video (From customer)
Resolution: 640x360 File size: 2.0MB

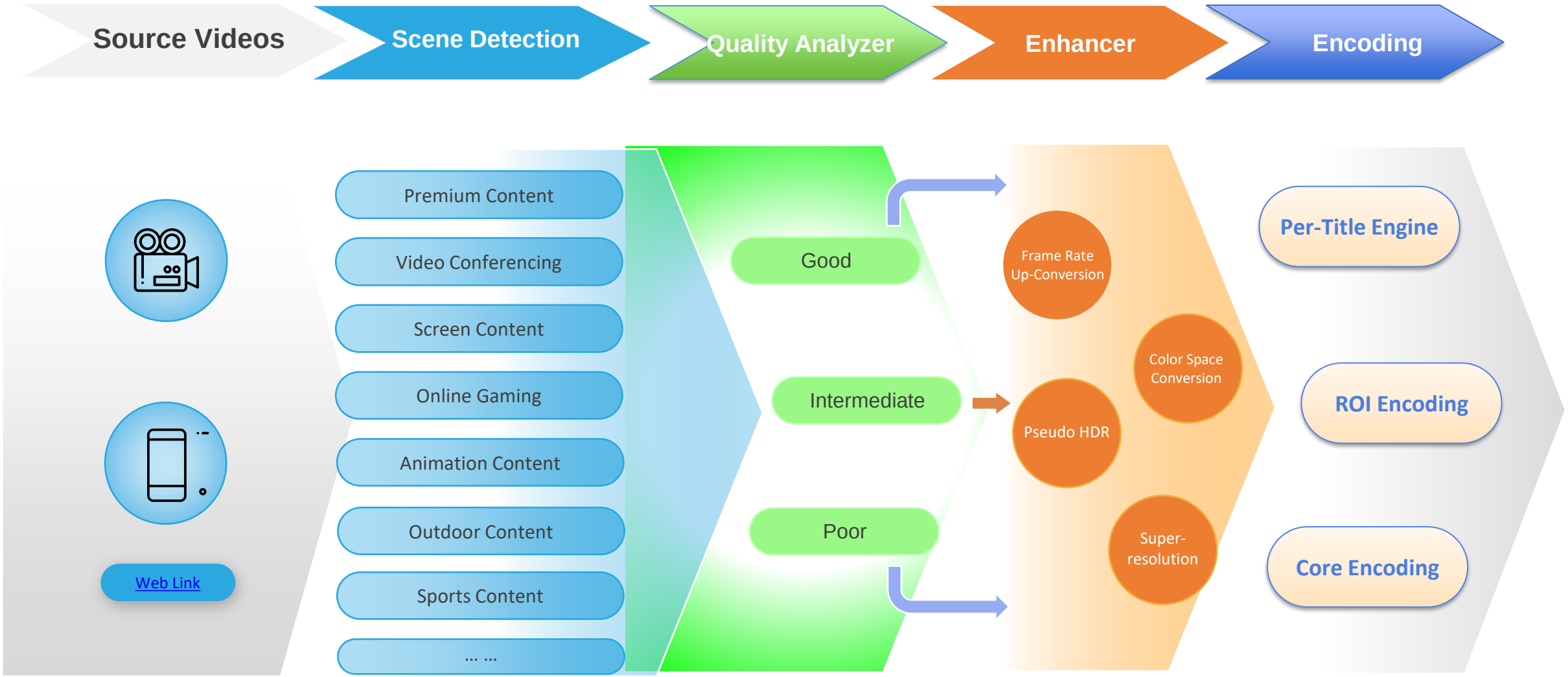



- **Encoding with Intelligent Optimization**: Much higher resolution with superior visual quality can be achieved while maintaining the same bitrate level.

# Intelligent Pre-Analysis & Preprocessing

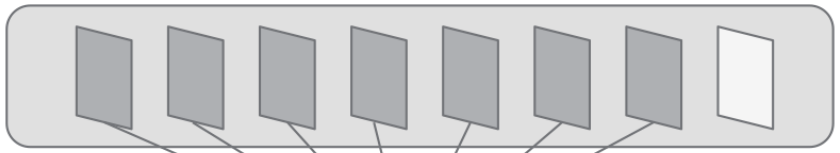


# Intelligent Pre-Analysis & Preprocessing with B-VQA



# ML-Based Video Core Encoding

## Prediction Framework



**Single ref INTER modes**
*Translation*
Global / Local Warp

**Compound ref INTER modes**
Average, Distance-wtd, Difference-wtd, Wedge
OBMC

1-reference
2+-references
7-references chosen per frame
Intra
1-reference + Intra
encoded frame

***INTRA modes*:**
CfL, DC, PAETH,
SMOOTH, SMOOTH_H, SMOOTH_V,
8 directional modes + finer directions,
Filter-intra modes, palette, intra-block-copy

***INTER-INTRA modes*:**
Gradual Inter-intra
Wedge Inter-intra

ML Mode Selection

ML GOP Structure Selection

ML Transform Size/Type Selection

ML RD-Model Refinement

ML Restoration Filter Selection

ML Partition Pruning

ML Mode Selection

ML Partition Pruning

ML GOP Structure Selection

ML RD-Model Refinement

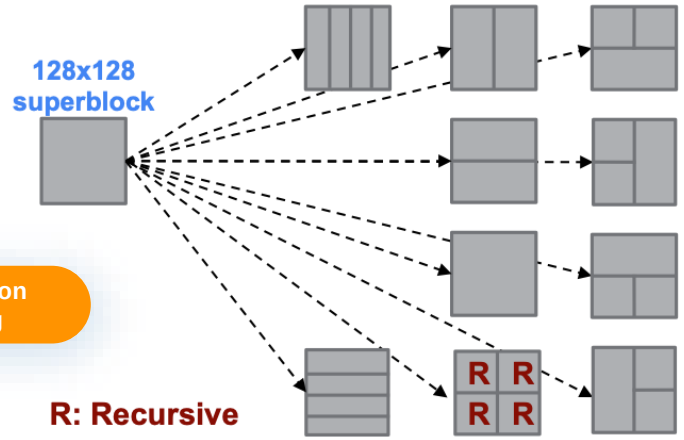
ML Transform Size/Type Selection

ML Restoration Filter Selection

AV1

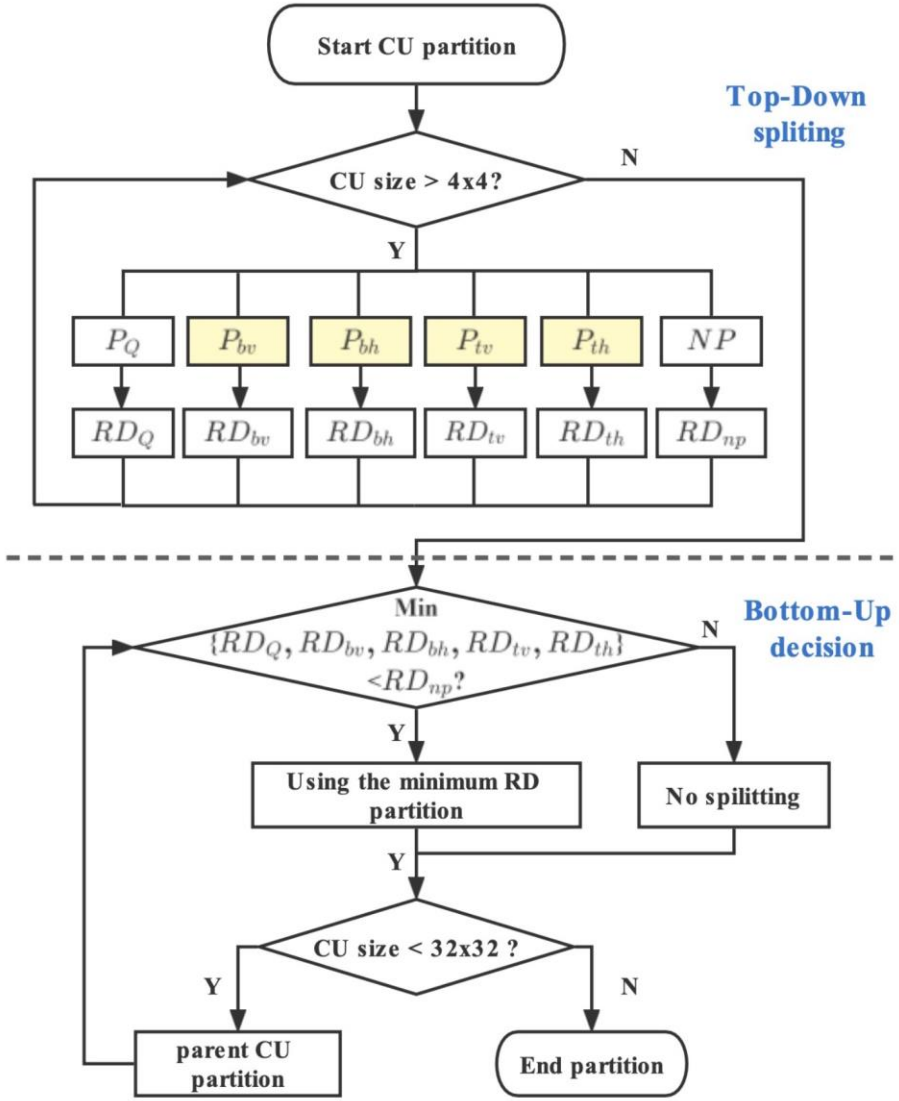
100+ coding tools

## Prediction Structure

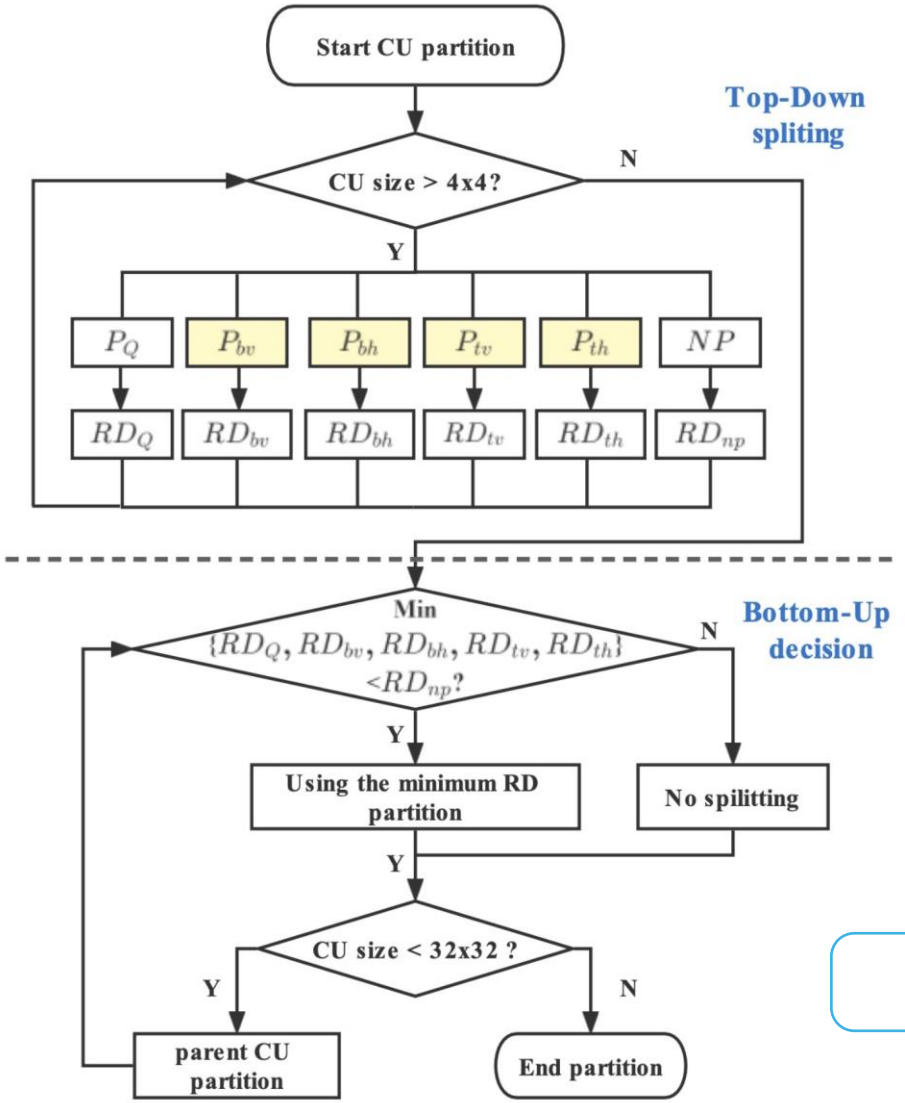



Courtesy to Dr. Debargha Mukherjee, Google Inc.

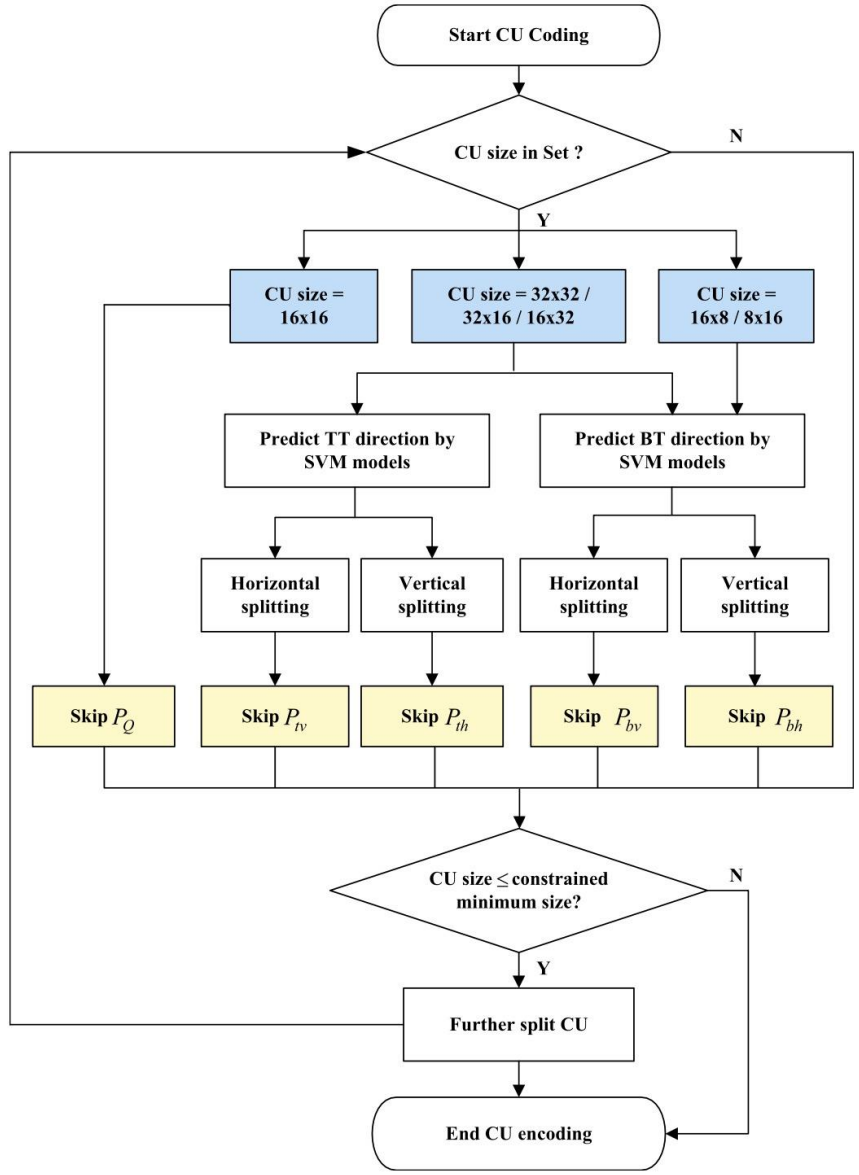
# Partition Pruning & Decision



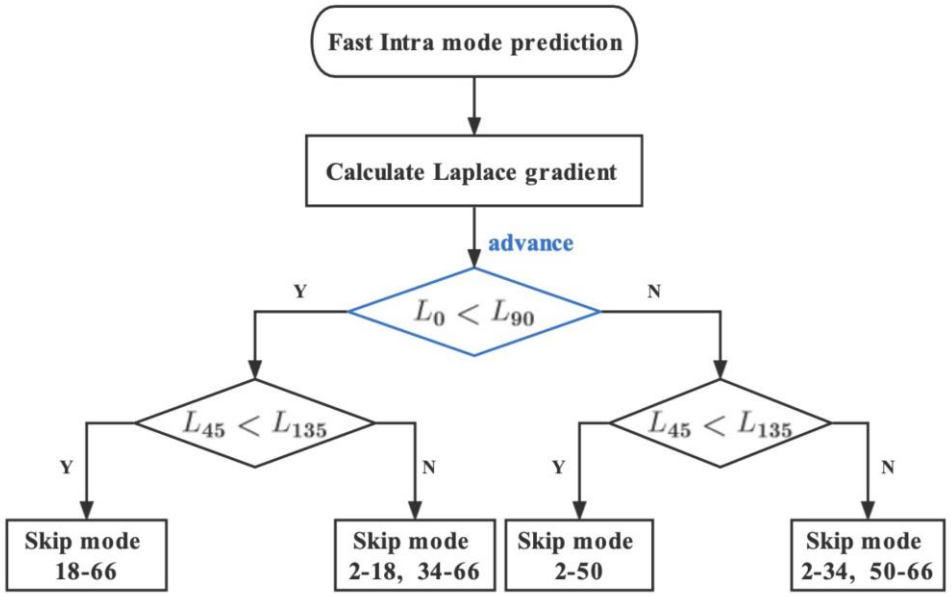
# Partition Pruning & Decision




SVM Based



# Intelligent Mode Selection




$$D1_{k,l} = |2g(k,l) - g(k-1,l+1) - g(k+1,l-1)|,$$

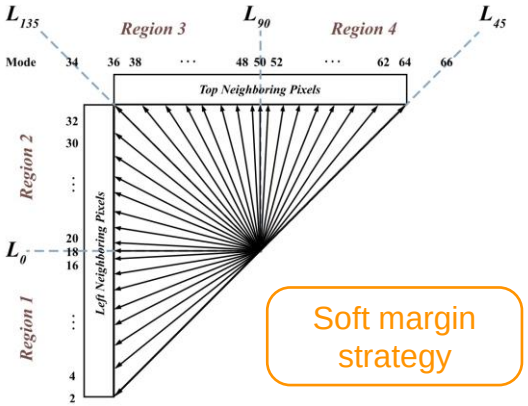
$$L_{45} = \sum_{k=1}^{h-1} \sum_{l=1}^{w-1} D1_{k,l},$$

and

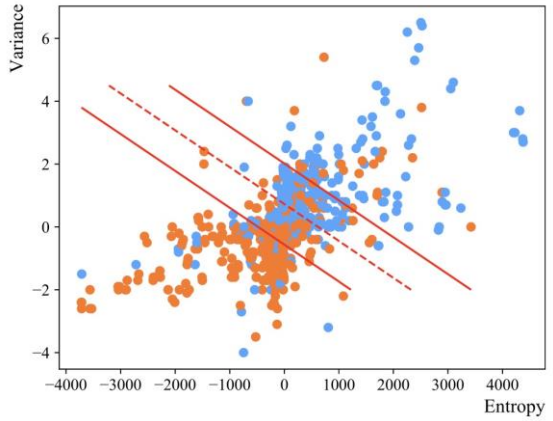
$$D2_{k,l} = |2g(k,l) - g(k-1,l-1) - g(k+1,l+1)|,$$

$$L_{135} = \sum_{k=1}^{h-1} \sum_{l=1}^{w-1} D2_{k,l},$$

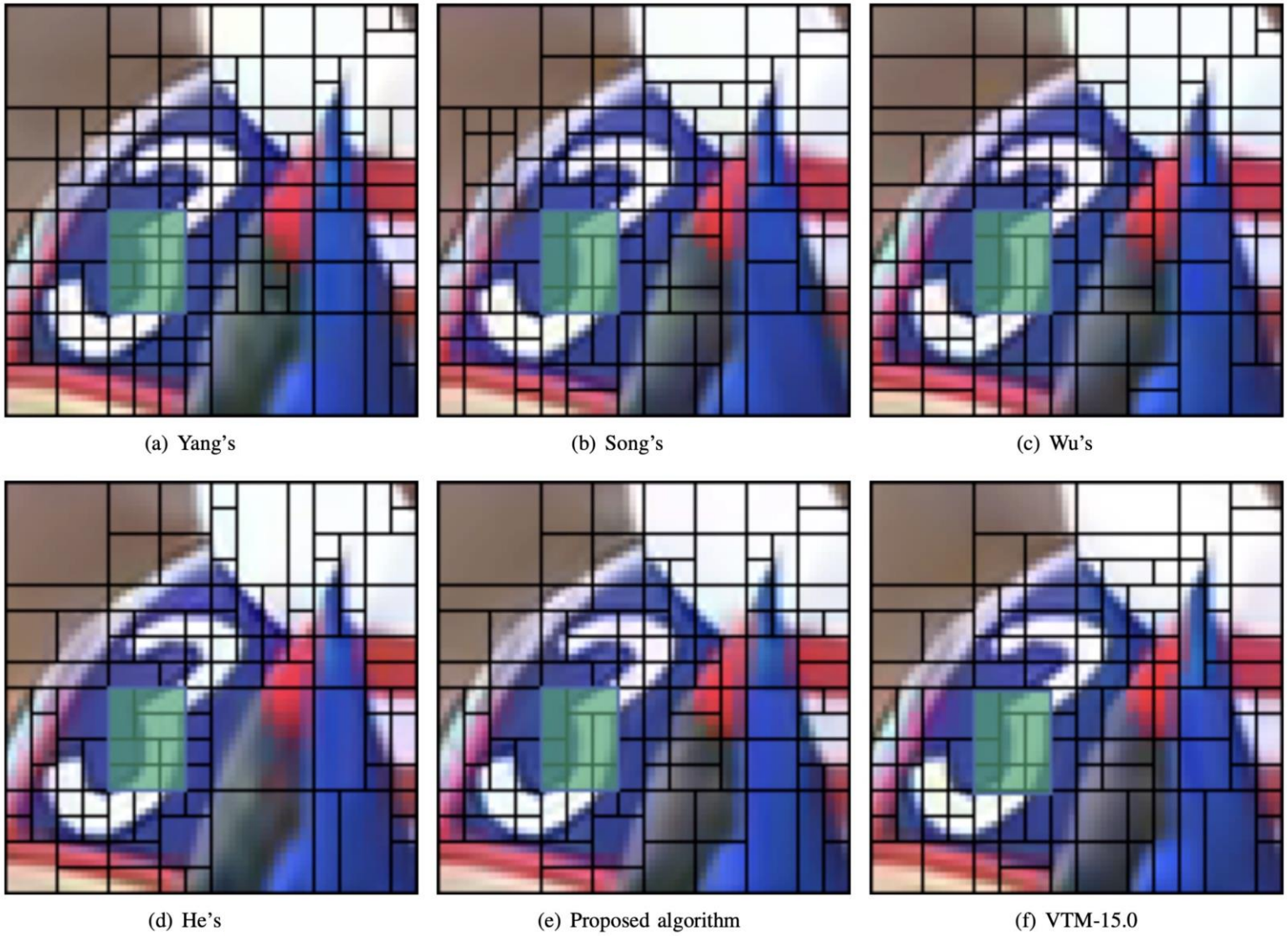
SKIP Mode Decision




Soft margin strategy



# Intelligent Partition Decision: Example



(a) Yang's (b) Song's (c) Wu's

(d) He's (e) Proposed algorithm (f) VTM-15.0

# J-CEEEO HEVC - Encoding Performance Evaluation

Test Set: Six (6) Open Available 1080p Raw Videos

CSGO_1080p60.y4m

DOTA2_1080p60.y4m

park_joy_1080p50.y4m

station2_1080p25.y4m

rush_hour_1080p25.y4m

tractor_1080p25.y4m

| Name | Frame Rate | Frame numbers | Download Link |
|---|---|---|---|
| park_joy_1080p50.y4m | 50 | 500 | https://media.xiph.org/video/derf/y4m/park_joy_1080p50.y4m |
| rush_hour_1080p25.y4m | 25 | 500 | https://media.xiph.org/video/derf/y4m/rush_hour_1080p25.y4m |
| station2_1080p25.y4m | 25 | 313 | https://media.xiph.org/video/derf/y4m/station2_1080p25.y4m |
| tractor_1080p25.y4m | 25 | 690 | https://media.xiph.org/video/derf/y4m/tractor_1080p25.y4m |
| DOTA2_1080p60.y4m | 60 | 3,602 | https://media.xiph.org/video/derf/twitch/y4m/DOTA2.y4m |
| CSGO_1080p60.y4m | 60 | 3,602 | https://media.xiph.org/video/derf/twitch/y4m/CSGO.y4m |

# J-CEEEO HEVC - Encoding Speed in FPS

Encoding Speed (FPS) for Multiple Simultaneous 1080p Renditions

x264 medium

x265 veryfast

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| Video Name | Frame Rate | Target Bitrate | Simultaneous 2 | | | Simultaneous 4 | | | Simultaneous 8 | | | Simultaneous 16 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | x264 | x265 | J-CEEEO | x264 | x265 | J-CEEEO | x264 | x265 | J-CEEEO | x264 | x265 | J-CEEEO |
| CSGO_1080p60.y4m | 60 | 6,000 | 59.91 | 48.32 | 59.94 | 56.40 | 33.15 | 59.92 | 27.20 | 17.77 | 57.95 | 13.77 | 8.12 | 31.94 |
| | | 3,000 | 59.93 | 58.24 | 59.94 | 59.91 | 40.54 | 59.93 | 33.76 | 20.67 | 59.93 | 15.50 | 10.08 | 39.33 |
| | | 2,000 | 59.93 | 59.77 | 59.95 | 59.93 | 45.54 | 59.95 | 40.84 | 23.64 | 59.93 | 17.61 | 11.40 | 44.07 |
| | | 1,000 | 59.93 | 59.77 | 59.95 | 59.94 | 55.08 | 59.95 | 48.60 | 29.14 | 59.94 | 25.94 | 14.19 | 49.05 |
| DOTA2_1080p60.y4m | 60 | 6,000 | 59.76 | 56.11 | 59.95 | 59.61 | 41.89 | 59.91 | 36.54 | 22.12 | 59.91 | 17.27 | 10.76 | 37.13 |
| | | 3,000 | 59.81 | 59.63 | 59.94 | 59.79 | 51.84 | 59.93 | 38.56 | 27.88 | 59.91 | 20.63 | 13.32 | 47.14 |
| | | 2,000 | 59.84 | 59.70 | 59.94 | 59.82 | 57.36 | 59.93 | 43.11 | 30.60 | 59.93 | 23.84 | 14.46 | 51.06 |
| | | 1,000 | 59.89 | 59.76 | 59.96 | 59.86 | 59.66 | 59.95 | 54.66 | 35.86 | 59.90 | 26.27 | 17.26 | 59.30 |
| park_joy_1080p50.y4m | 50 | 6,000 | 49.36 | 39.06 | 49.70 | 49.12 | 30.85 | 49.65 | 34.29 | 15.85 | 45.41 | 12.24 | 8.12 | 26.43 |
| | | 3,000 | 49.50 | 49.12 | 49.70 | 49.36 | 39.56 | 49.70 | 28.23 | 21.12 | 49.60 | 14.59 | 10.34 | 31.49 |
| | | 2,000 | 49.50 | 49.16 | 49.75 | 49.41 | 45.58 | 49.70 | 35.16 | 23.90 | 49.75 | 20.41 | 11.60 | 38.64 |
| | | 1,000 | 49.55 | 49.36 | 49.75 | 49.50 | 49.21 | 49.80 | 36.74 | 28.89 | 49.75 | 22.22 | 12.58 | 47.48 |
| rush_hour_1080p25.y4m | 25 | 6,000 | 24.70 | 24.49 | 24.90 | 24.67 | 20.60 | 24.90 | 15.91 | 12.96 | 24.88 | 11.63 | 4.95 | 24.70 |
| | | 3,000 | 24.81 | 24.62 | 24.91 | 24.76 | 24.56 | 24.91 | 24.12 | 13.33 | 24.88 | 8.70 | 6.15 | 24.81 |
| | | 2,000 | 24.81 | 24.64 | 24.93 | 24.80 | 24.63 | 24.91 | 24.76 | 14.68 | 24.89 | 13.55 | 8.26 | 24.89 |
| | | 1,000 | 24.86 | 24.73 | 24.94 | 24.86 | 24.69 | 24.91 | 24.85 | 18.37 | 24.93 | 20.82 | 9.45 | 24.91 |
| station2_1080p25.y4m | 25 | 6,000 | 24.51 | 24.59 | 24.90 | 24.47 | 23.77 | 24.90 | 23.97 | 14.81 | 24.88 | 18.23 | 5.76 | 24.84 |
| | | 3,000 | 24.70 | 24.68 | 24.92 | 24.63 | 24.67 | 24.90 | 24.49 | 21.31 | 24.90 | 12.50 | 7.40 | 24.86 |
| | | 2,000 | 24.74 | 24.70 | 24.92 | 24.74 | 24.70 | 24.92 | 24.65 | 19.72 | 24.90 | 15.47 | 9.27 | 24.88 |
| | | 1,000 | 24.82 | 24.74 | 24.92 | 24.82 | 24.74 | 24.92 | 24.78 | 24.40 | 24.90 | 19.02 | 11.31 | 24.82 |
| tractor_1080p25.y4m | 25 | 6,000 | 24.82 | 24.77 | 24.95 | 24.85 | 21.48 | 24.95 | 24.05 | 11.42 | 24.95 | 10.42 | 5.17 | 22.33 |
| | | 3,000 | 24.90 | 24.83 | 24.97 | 24.90 | 24.83 | 24.96 | 24.86 | 14.37 | 24.96 | 15.81 | 6.76 | 24.91 |
| | | 2,000 | 24.93 | 24.86 | 24.97 | 24.92 | 24.86 | 24.97 | 24.90 | 16.46 | 24.96 | 16.85 | 7.79 | 24.89 |
| | | 1,000 | 24.93 | 24.89 | 24.97 | 24.94 | 24.87 | 24.97 | 24.92 | 20.20 | 24.96 | 24.77 | 10.62 | 24.90 |
| **Avg % of real-time encoding instances** | | | **100.00%** | **66.67%** | **100.00%** | **91.67%** | **41.67%** | **100.00%** | **29.17%** | **0.00%** | **91.67%** | **4.17%** | **0.00%** | **45.83%** |

1. AWS machine: AMD EPYC 7R32, 16Cores 32Threads
2. Simultaneously encode multiple 1080p renditions:
   - Along with more renditions that are being encoded simultaneously over the same machine, the encoding speed will drop more accordingly for the encoding of each rendition.
3. Whenever the encoding speed in FPS matches or is greater than the source frame rate, the encoder is capable for live streaming.

# J-CEEEO HEVC - Encoding Speed in FPS

x264 medium

x265 veryfast

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Overall Performance of J-CEEEO HEVC, compared against x264 & x265

| Encoder Comparison | Overall PSNR | PSNR Y | SSIM AVG | SSIM Y | VMAF | Speedup | Memory Saving |
|---|---|---|---|---|---|---|---|
| J-CEEEO HEVC vs x264 medium | -46.85 | -47.14 | -46.83 | -46.50 | -40.87 | -64.83% | -38.33% |
| J-CEEEO HEVC vs x265 veryfast | -16.43 | -9.33 | -17.34 | -12.84 | -11.51 | -172.50% | -69.25% |

1. Compared against x264 medium, J-CEEEO can achieve a close to 40% encoding speed improvement whereas a coding efficiency BD-rate gain by 40~47% under various objective quality metrics
2. Compared against x265 veryfast, J-CEEEO can encode at a speed faster than 2.5x the speed of x265 fast, whereas a coding efficiency BD-rate gain by ~15% under various objective quality metrics

# J-CEEEO HEVC - Multiple Concurrent Live Streaming

x264 medium

x265 veryfast

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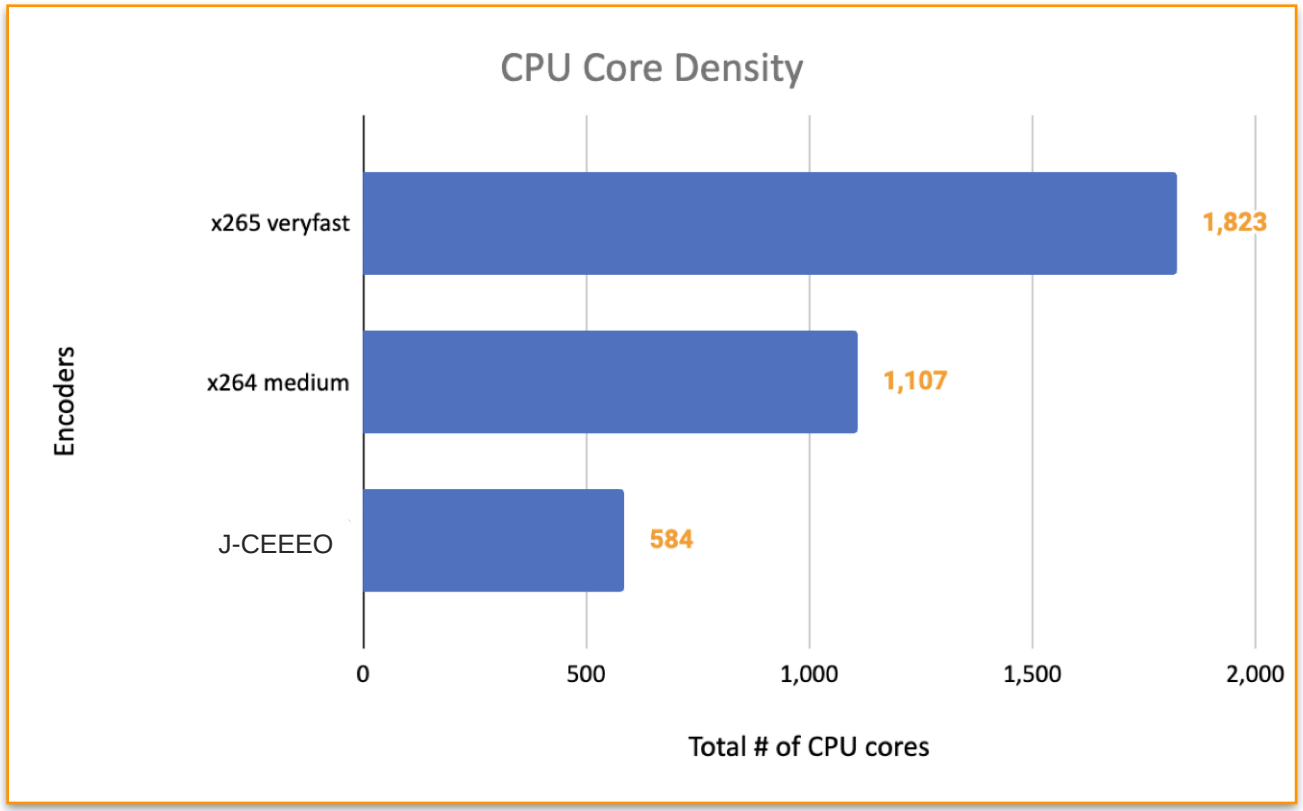
| Resolution & FPS | Target Bitrate (kbps) | J-CEEEO HEVC | x264 medium | x265 veryfast |
|---|---|---|---|---|
| 1080p50 | 6,000 | 229 | 400 | 800 |
| 1080p50 | 3,000 | 160 | 320 | 533 |
| 1080p50 | 1,000 | 107 | 266 | 320 |
| 360p25 | 500 | 31 | 43 | 62 |
| 360p25 | 300 | 29 | 39 | 54 |
| **Total # of CPU cores** | | **584** | **1,107** | **1,823** |
| **J-CEEEO: # of CPU cores saving** | | | **-47.22%** | **-67.96%** |




1. We have estimated the number of CPU cores needed to encode 100 1080p channels, each to generate 5 streams - 3HD and 2SD, at various bitrates. The underlying machine is AMD EPYC 7R32 with 16C/32T.
2. For encoding 100 channels of typical 1080p, 50fps video content, each channel to output 3HD+2SD live streams, the number of CPU cores needed by J-CEEEO is around 600, which is approximately *half of the cores* needed by x264 and *1/3 of the cores* needed by x265.

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# THANK YOU!

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