# Fast Coding Unit Selection Based on Local Texture Characteristics for HEVC Intra Frame

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# Outline

- HEVC Introduction
- HEVC Intra Coding
- HEVC Complexity and Performance - Motivation for our research
- Local Binary Patterns - LBP
- Proposed Solution
- Simulation Results
- Q/A

# HEVC Introduction

- Novel video compression standard
- High importance to the industrial and academic circles due to
  - New devices with wide range of different resolution
  - New services – live sports, live music, other events, home theater, mobile streaming (for e.g. new Twitter video)
  - Increasing need for video transmission: most IP traffic is video
  - Increasing use of parallel processing architectures
- Goal was to achieves 2x higher compression compared to H.264/AVC and to improve throughput

# HEVC Introduction

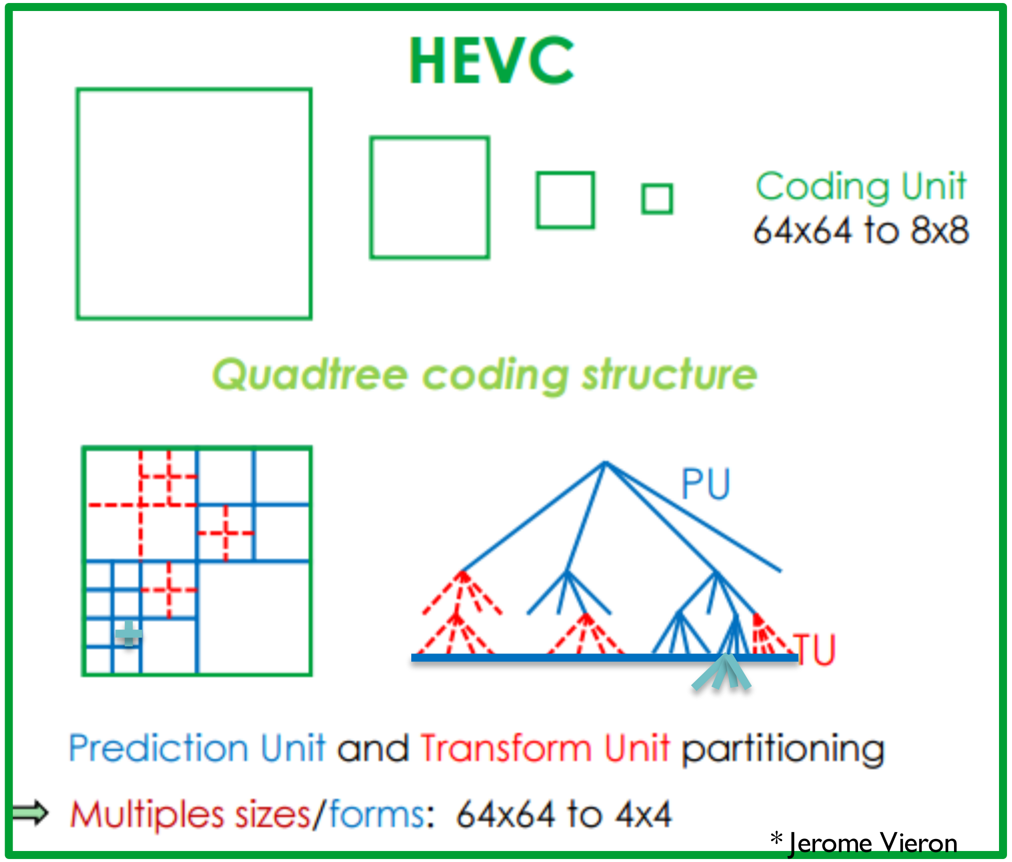
- Block based compression approach
  - Each frame is segmented into blocks
- Larger and flexible block size
- More intra prediction modes
- Larger DCT transform sizes
- High throughput CABAC
- New Advanced Motion Vector Precision with ¼ pixel accuracy
- Etc.

# HEVC Intra Coding – block structure

- Support more flexible block size – quadtree structure
- Basic processing unit is Coding Unit - CU
- CU size ranges from 8x8 up to 64x64 pixels
- Each CU can incorporate within its structure PUs and TUs with different sizes
  - from 4x4 to 64x64 for PU
  - from 4x4 to 32x32 for TU

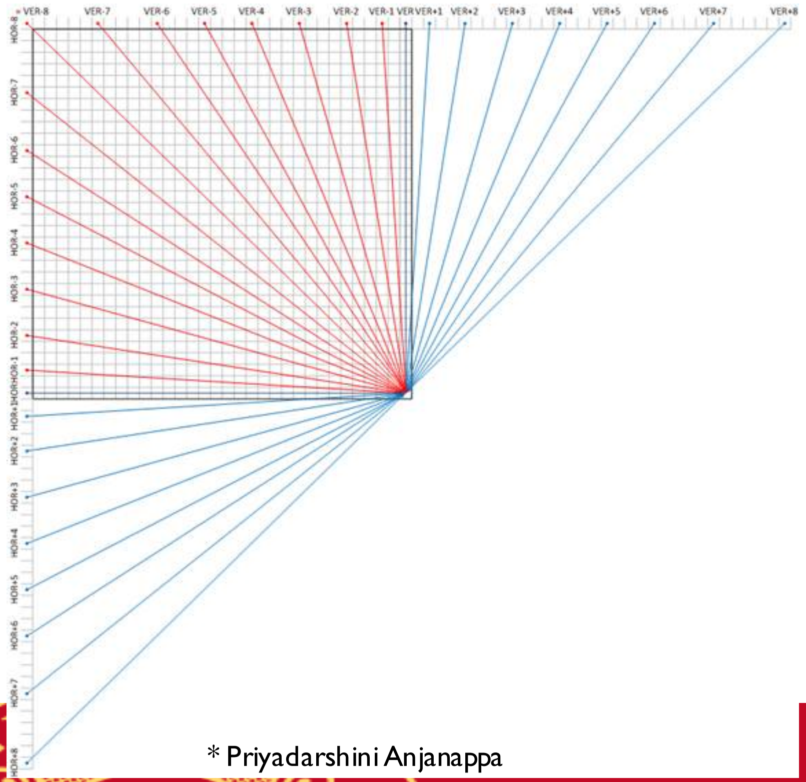
# HEVC Intra Coding – block structure

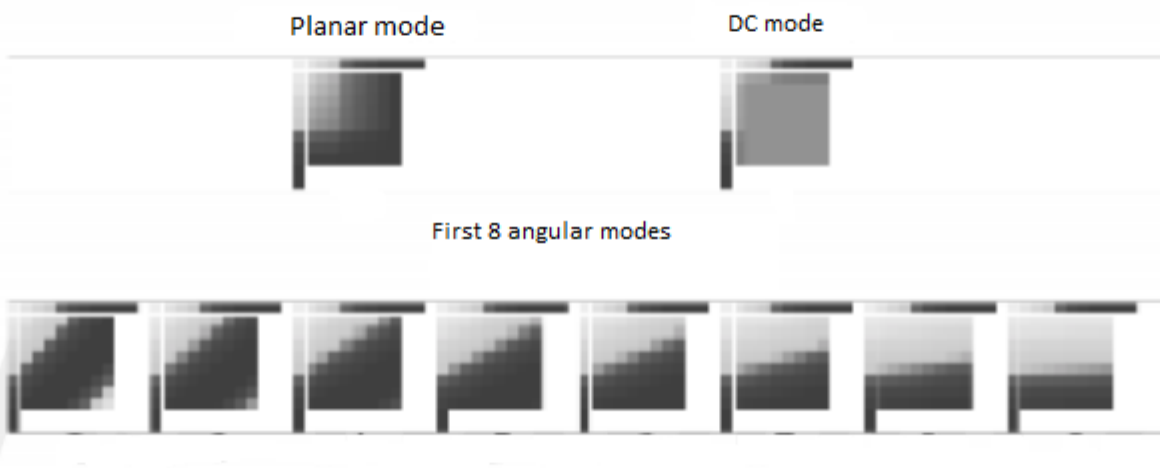
- Quadtree structure example
- Green – CU (64x64-8x8)
- Blue – PU (64x64-4x4)
  - For Intra: 2Nx2N mode or NxN mode
- Red – TU(32x32-4x4)
  - DCT/DST transform




# HEVC Intra Coding – prediction modes

- Number of intra prediction modes grows up to 35, compared with 9 in H.264/AVC
- HEVC uses DC, Planar, and 33 angular modes






* Priyadarshini Anjanappa

# HEVC Complexity/Motivation for our work

- Decisions are based on cost minimization
  - $J = D + \lambda * R$
  - Rate-Distortion Optimization based on Lagrangian method
- In order to get D and R in brute force approach
  - Full forward (encoding) process has to be performed
  - Full inverse (decoding) process has to be performed
- Prediction, DCT, quantization, entropy coding, get R, entropy decoding, inverse quantization, IDCT, get D

# HEVC Complexity/Motivation for our work

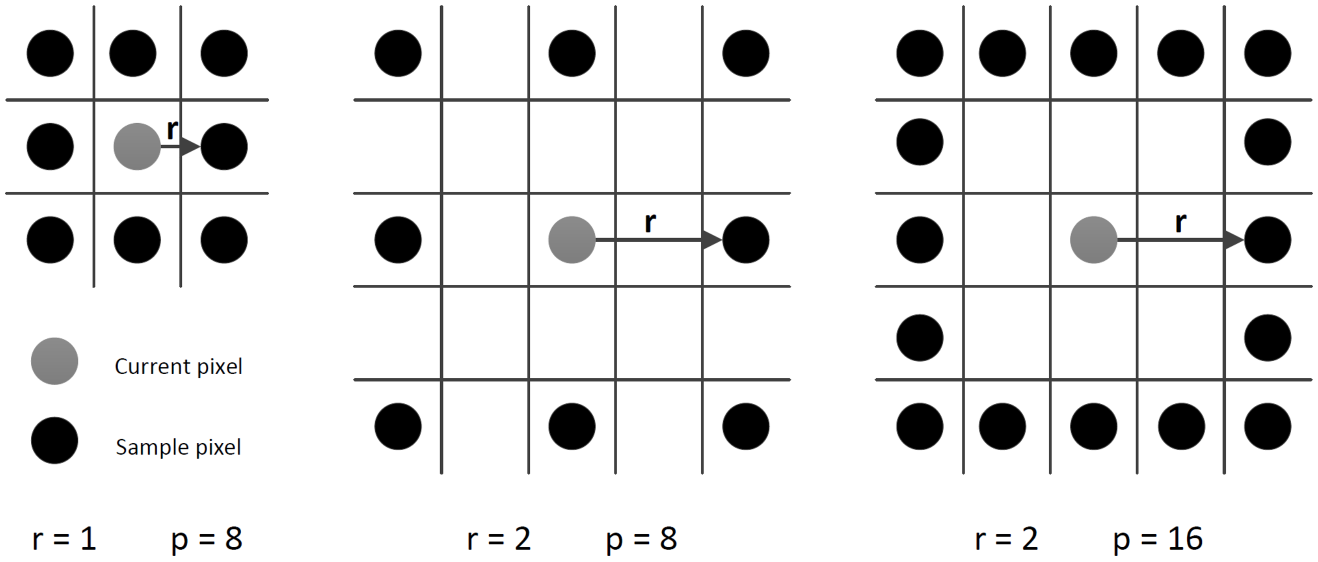
- To decide an optimal quadtree structure and prediction mode
  - Go trough all possible outcomes in terms of different block sizes and different prediction modes
  - Minimize the cost J
- Time consuming process
  - Impossible to do it in real time
- HEVC reference software has implemented fast approaches
  - Still space (and need) for more speed-up and simplification
  - For the price of some performance degradation

# HEVC Complexity/Motivation for our work

- Correlation between the CU size and the texture within the CU
- RDO tend to use smaller CUs
  - Rich texture regions
  - On the edge between objects
  - Between objects and background
  - Transition between different textures
- Use texture descriptors to decide
  - If CU contains different textures
  - Flat regions
  - Texture rich/complex regions

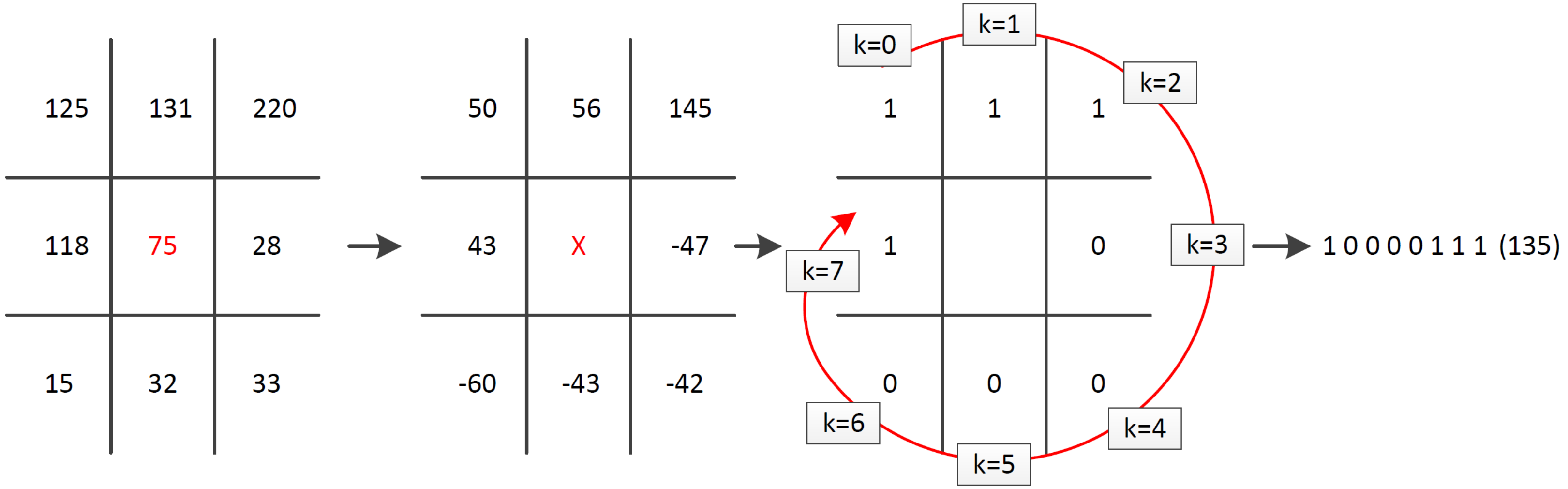
# Local Binary Patterns - LBP

- LBP as texture descriptor
  - Histograms of LBPs
- Calculated on pixel level
  - assigning to each pixel a corresponding LBP value (LBP code)



# Local Binary Patterns - LBP

$$LBP_{p,r}^{u} = \sum_{k=0}^{p-1} I(sp_k - cp)2^k \qquad I(x) = \begin{cases} 1 & \text{if } x \geq 0 \\ 0 & \text{otherwise} \end{cases}$$




Original pixel values

Difference with the sample pixels

Threshold values and sampling order

Binary representation of the LBP code and corresponding decimal value

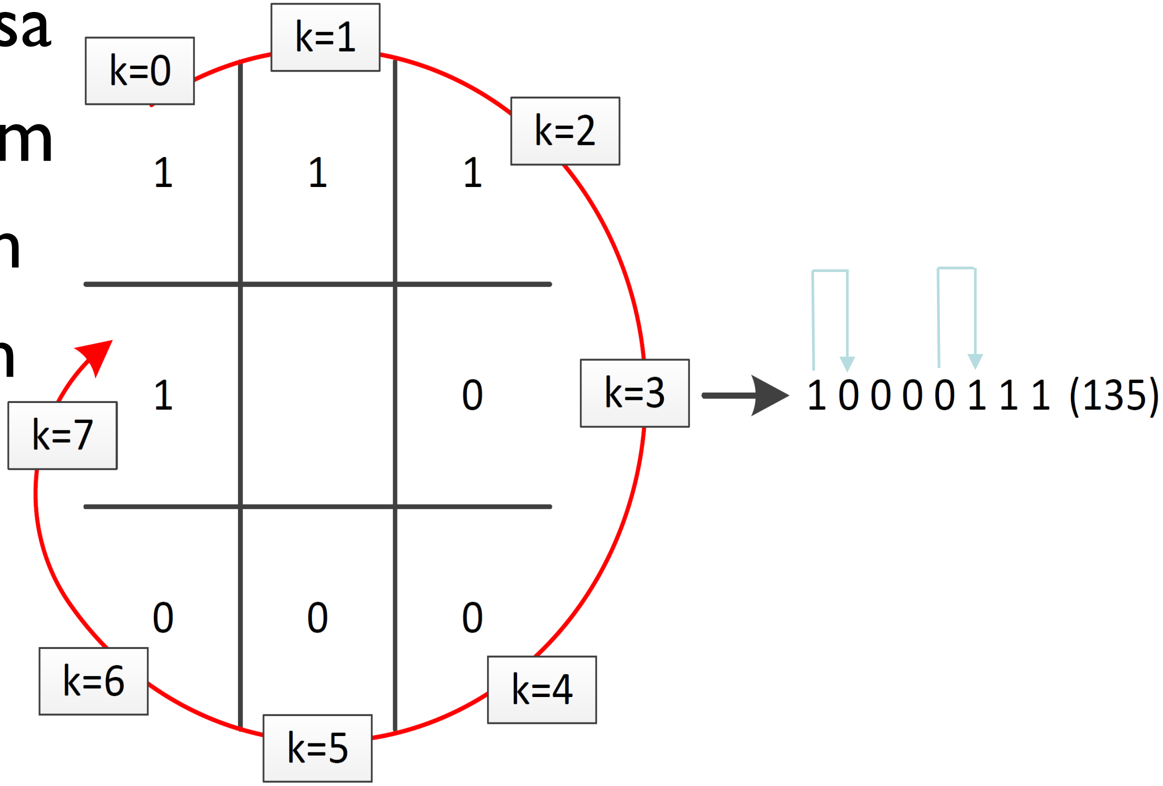
# Local Binary Patterns - LBP

- Fast implementation using only shifts and logical operations

$$LBP_{code}| = (sp(i-1, j-1) > sp(i, j)) << 0;$$
$$LBP_{code}| = (sp(i-1, j) > sp(i, j)) << 1;$$
$$LBP_{code}| = (sp(i-1, j+1) > sp(i, j)) << 2;$$
$$LBP_{code}| = (sp(i, j+1) > sp(i, j)) << 3;$$
$$LBP_{code}| = (sp(i+1, j+1) > sp(i, j)) << 4;$$
$$LBP_{code}| = (sp(i+1, j) > sp(i, j)) << 5;$$
$$LBP_{code}| = (sp(i+1, j-1) > sp(i, j)) << 6;$$
$$LBP_{code}| = (sp(i, j-1) > sp(i, j)) << 7;$$

# Local Binary Patterns - LBP

- Uniform patterns
  - u=2 in our research
  - 2 transitions from 0 to 1 and vice versa
- Group uniform patterns into histogram
  - Each uniform allocated to separate bin
  - All non-uniform voted to only one bin
- For u=2 ⇒ 58 uniform codes
  - 58 + 1 dimensional histogram

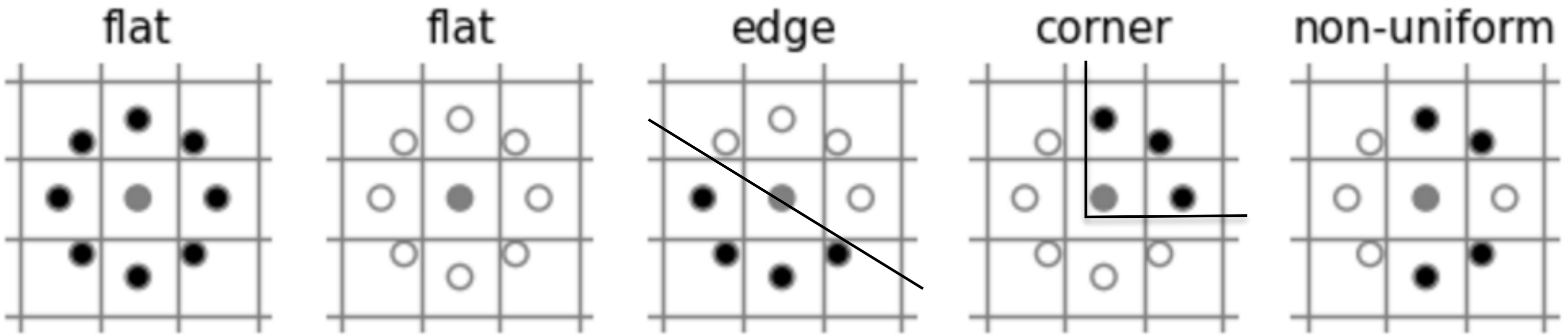


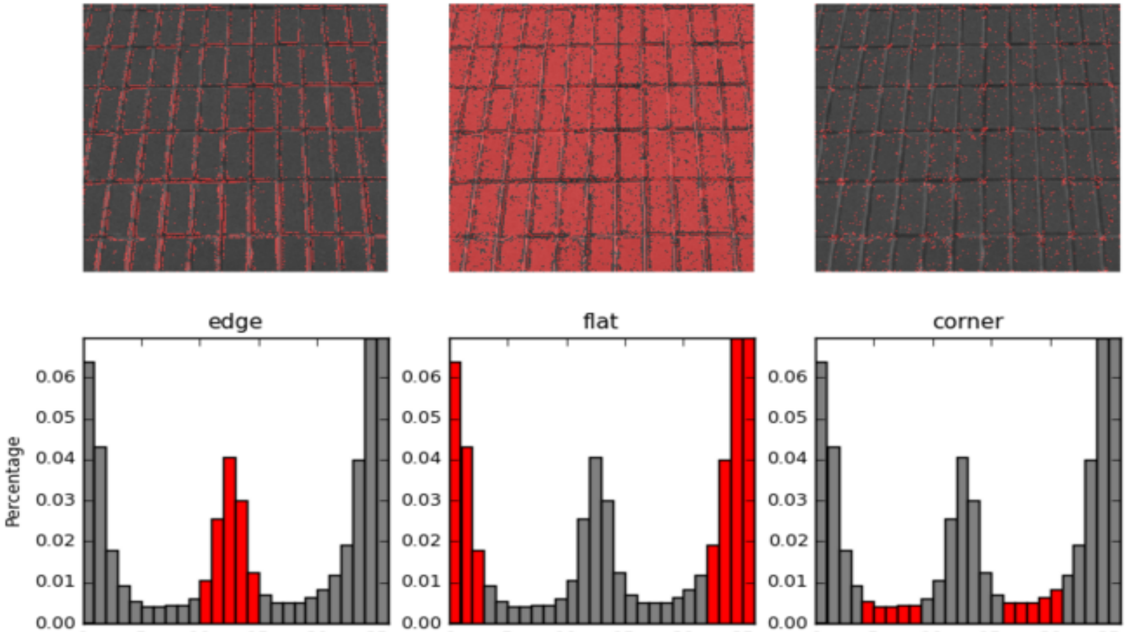
# Local Binary Patterns - LBP

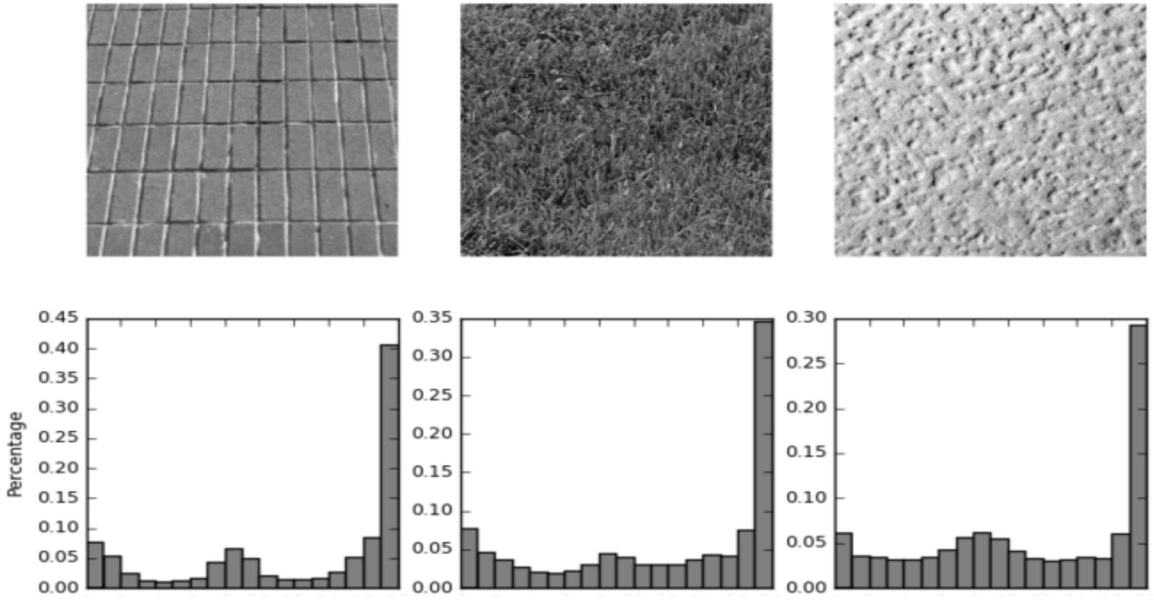
| No. | value | | No. | value | | No. | value | |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 00000000 | 21 | 62 | 00111110 | 41 | 207 | 11001111 |
| 2 | 1 | 00000001 | 22 | 63 | 00111111 | 42 | 223 | 11011111 |
| 3 | 2 | 00000010 | 23 | 64 | 01000000 | 43 | 224 | 11100000 |
| 4 | 3 | 00000011 | 24 | 96 | 01100000 | 44 | 225 | 11100001 |
| 5 | 4 | 00000100 | 25 | 112 | 01110000 | 45 | 227 | 11100011 |
| 6 | 6 | 00000110 | 26 | 120 | 01111000 | 46 | 231 | 11100111 |
| 7 | 7 | 00000111 | 27 | 124 | 01111100 | 47 | 239 | 11101111 |
| 8 | 8 | 00001000 | 28 | 126 | 01111110 | 48 | 240 | 11110000 |
| 9 | 12 | 00001100 | 29 | 127 | 01111111 | 49 | 241 | 11110001 |
| 10 | 14 | 00001110 | 30 | 128 | 10000000 | 50 | 243 | 11110011 |
| 11 | 15 | 00001111 | 31 | 129 | 10000001 | 51 | 247 | 11110111 |
| 12 | 16 | 00010000 | 32 | 131 | 10000011 | 52 | 248 | 11111000 |
| 13 | 24 | 00011000 | 33 | 135 | 10000111 | 53 | 249 | 11111001 |
| 14 | 28 | 00011100 | 34 | 143 | 10001111 | 54 | 251 | 11111011 |
| 15 | 30 | 00011110 | 35 | 159 | 10011111 | 55 | 252 | 11111100 |
| 16 | 31 | 00011111 | 36 | 191 | 10111111 | 56 | 253 | 11111101 |
| 17 | 32 | 00100000 | 37 | 192 | 11000000 | 57 | 254 | 11111110 |
| 18 | 48 | 00110000 | 38 | 193 | 11000001 | 58 | 255 | 11111111 |
| 19 | 56 | 00111000 | 39 | 195 | 11000011 | 59 | all other | |
| 20 | 60 | 00111100 | 40 | 199 | 11000111 | | | |

# Local Binary Patterns - LBP

- Intuitior



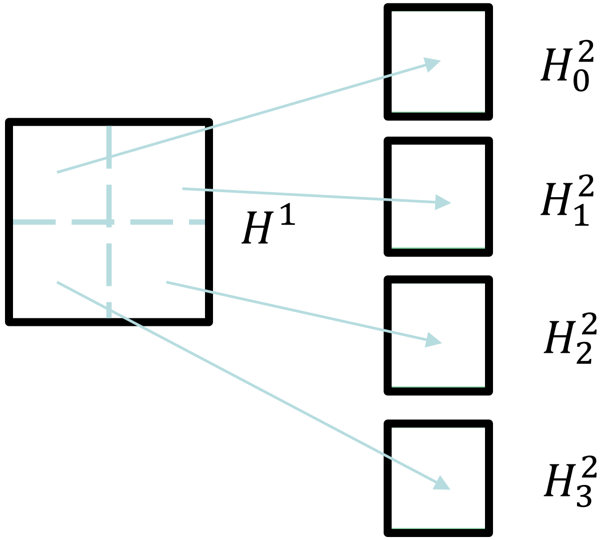




*skit-image database

# Fast CU size selection based on local texture descriptors

- Based on the LBP histogram matching
- Occurrence histogram $H^d$ is formed on the CU level
- Sub-histograms are calculated for sub-CUs on the higher depth $H_i^{d+1}$
- To make decisions use

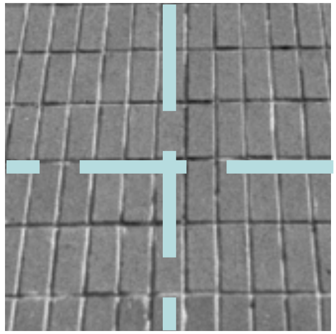
  $S(H^d; H_i^{d+1})$ similarity measure

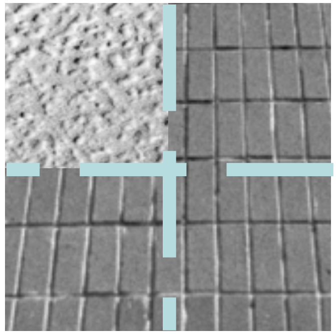


# Fast CU size selection based on local texture descriptors

– $S(H^d; H_i^{d+1})$ similarity measure function

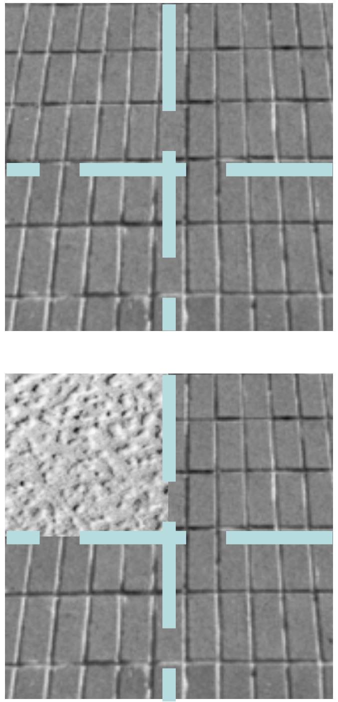
- Sufficiently high similarity $(\forall_i)$ $S(H^d; H_i^{d+1})$
  – CU consists only of one texture region
- Otherwise if $(\exists_i)$ $S(H^d; H_i^{d+1})$ is low
  – High possibility that the CU is composed of different textures
  – More likely that CU is going to be split





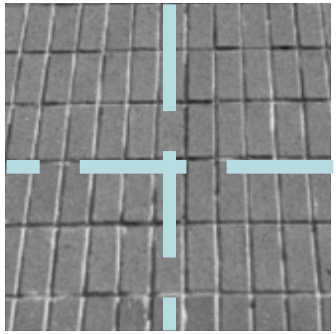
# Fast CU size selection based on local texture descriptors

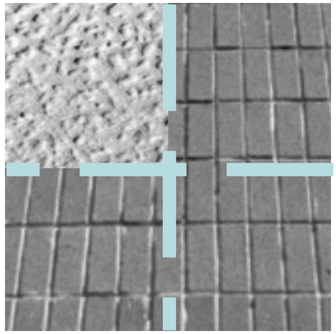
- CU split decision is given by
  - S($H^d$; $H_i^{d+1}$)$\leq thr(Qp)$
  - For at least one i
- If S($H^d$; $H_i^{d+1}$)$\leq thr(Qp)$ is not satisfied
  - 4 different approaches based on performance-complexity tradeoff



# Fast CU size selection based on local texture descriptors

- Criterion1
  - all further calculation is omitted and current CU depth is selected
- Criterion2
  - one additional depth with RDO is performed
- Criterion3
  - two additional depths are calculated with RDO
- Criterion4
  - all additional depths are calculated with RDO





# Performance

BD-PSNR AND TIME REDUCTION FOR THE PROPOSED ALGORITHM

| Sequence | Criterion1 | | Criterion2 | | Criterion3 | | Criterion4 | |
|---|---|---|---|---|---|---|---|---|
| | BD-PSNR [dB] | ΔT [%] | BD-PSNR [dB] | ΔT [%] | BD-PSNR [dB] | ΔT [%] | BD-PSNR [dB] | ΔT [%] |
| PeopleOnStreet(ClassA) | -0.9826 | 76.6890 | -0.5689 | 62.6812 | -0.1561 | 21.9119 | -0.0163 | 4.0559 |
| Cactus(ClassB) | -0.6277 | 80.2024 | -0.3486 | 57.2062 | -0.1249 | 25.1177 | -0.0062 | 3.2532 |
| RaceHorses1(ClassC) | -0.9997 | 81.4038 | -0.5296 | 58.8562 | -0.1348 | 19.0552 | -0.0068 | 6.9282 |
| BlowingBubbles(ClassD) | -1.0342 | 80.7887 | -0.4416 | 45.0893 | -0.0955 | 14.3006 | -0.0011 | 6.9940 |
| Johnny(ClassE) | -1.0230 | 79.0388 | -0.5330 | 58.8651 | -0.1435 | 24.7559 | -0.0502 | 2.6000 |
| Lena_Image | -0.5871 | 83.0630 | -0.2895 | 58.2412 | -0.0682 | 25.8615 | -0.0104 | 8.5753 |
| Average | -0.8757 | 80.1976 | -0.4519 | 56.8232 | -0.1205 | 21.8338 | -0.0152 | 5.4011 |

# Questions ?

# Backup slide

Similarity measure-histogram correlation

$$S(H_1, H_2) = \frac{\sum_I (H_1(I) - \overline{H}_1)(H_2(I) - \overline{H}_2)}{\sqrt{\sum_I (H_1(I) - \overline{H}_1)^2 \sum_I (H_1(I) - \overline{H}_1)^2}}$$

where,

$$\overline{H}_k = \frac{1}{N} \sum_J H_k(J)$$

Threshold values

| Qp | thr | Qp | thr | Qp | thr | Qp | thr | Qp | thr |
|---|---|---|---|---|---|---|---|---|---|
| 0-7 | 0.99 | 16 | 0.75 | 25 | 0.66 | 34 | 0.57 | 43 | 0.44 |
| 8 | 0.98 | 17 | 0.74 | 26 | 0.65 | 35 | 0.56 | 44 | 0.41 |
| 9 | 0.95 | 18 | 0.73 | 27 | 0.64 | 36 | 0.55 | 45 | 0.38 |
| 10 | 0.93 | 19 | 0.72 | 28 | 0.63 | 37 | 0.54 | 46 | 0.35 |
| 11 | 0.90 | 20 | 0.71 | 29 | 0.62 | 38 | 0.53 | 47 | 0.32 |
| 12 | 0.88 | 21 | 0.70 | 30 | 0.61 | 39 | 0.52 | 48 | 0.29 |
| 13 | 0.83 | 22 | 0.69 | 31 | 0.60 | 40 | 0.51 | 49 | 0.26 |
| 14 | 0.79 | 23 | 0.68 | 32 | 0.59 | 41 | 0.50 | 50 | 0.23 |
| 15 | 0.76 | 24 | 0.67 | 33 | 0.58 | 42 | 0.47 | 51 | 0.20 |

Other similarity metrics can be in use but it requires thr recalculation