HDTV1080p HEVC Intra Encoder with Source Texture based CU/PU Mode Pre-decision

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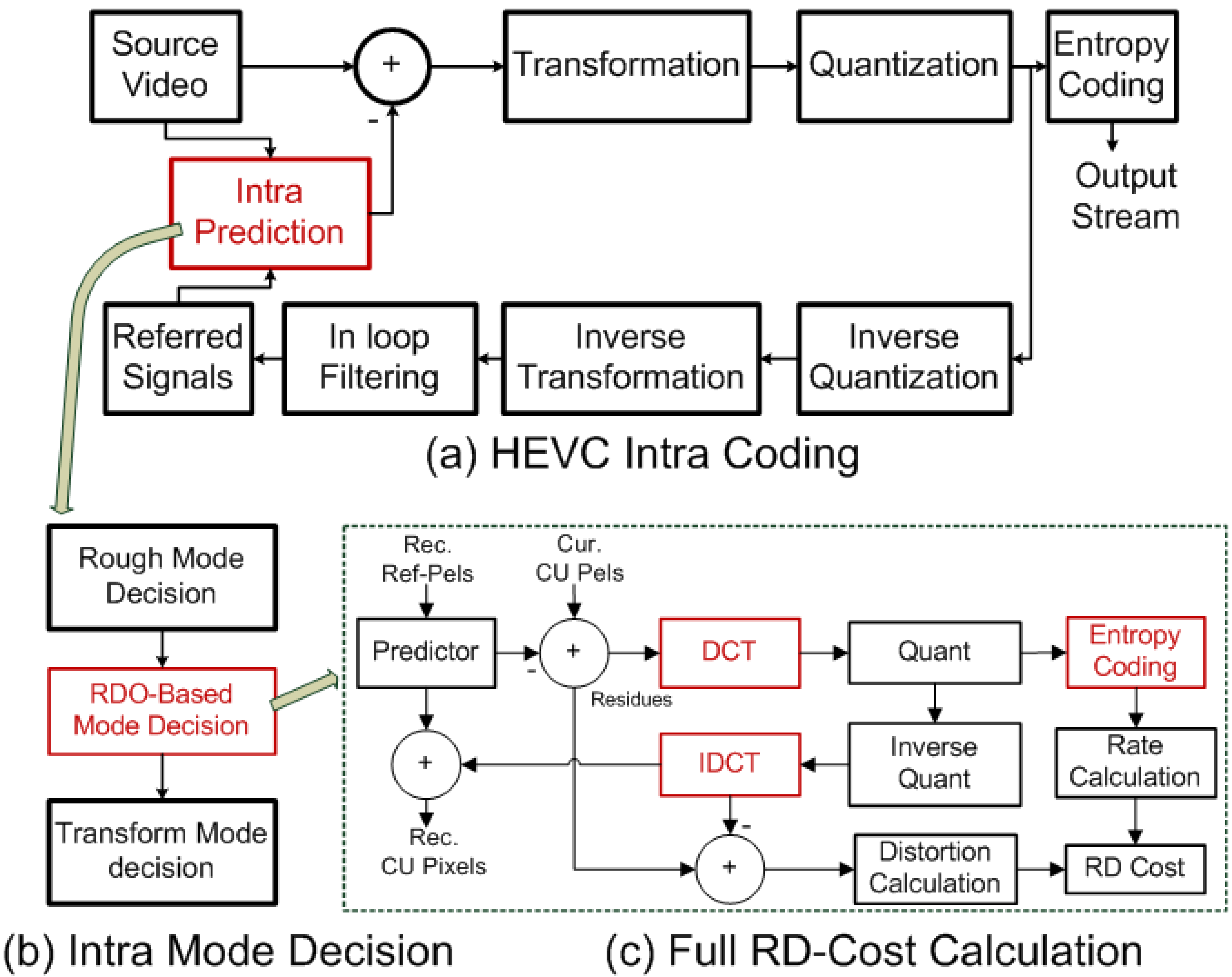
Outlines

- Background Introduction
- Proposed Method
  - Predict Error Model
  - Pre CU Filtering
  - Intra Coding Process
- Hardware Design
- Experiment Result Soft. & Hard.
- Conclusion

HEVC Overview

- Emerging Video Coding Standard
  - developed by JCT-VC, finished in Jan-2013
  - aims to fulfill growing quality and resolution requirements
  - save 35-40% bit-rate cost compared to H.264/AVC
- Main Profile
  - quad-tree structure, CTU, luma and chroma
  - raise candidate parameter vector $\vec{p}$, including CU/PU/TU
  - RDO, $\vec{p}_0 = \arg\min_{\vec{p}} \{D(\vec{p}) + \lambda \cdot R(\vec{p})\}$
- Difficulties in Real-time Intra Coding
  - adopt large scale CTU, 64x64 against 16x16
  - employ 35 PU modes for more accuracy prediction
  - more $\vec{p}$, and explosive RD calculation.

HEVC Intra Coding



(b) Intra Mode Decision (c) Full RD-Cost Calculation

Time and hardware consuming, works could be done to move out redundancy.

Existent Work in Fast Intra Coding

- Primary categories:
  - Low-complexity RD-cost algorithms
  - Filtering out most impossible modes
  - Early termination based on pre-defined thresholds
- Theory basis:
  - Simplify estimation in non-critical cases
  - Explore spatial/temporal correlation
  - Reduce candidate number via image textures
- Existed Problems:
  - early termination method is sensitive to worst cases
  - image textures only used in PU search, rarely in CU
  - serial process is not change, parallel design is hard

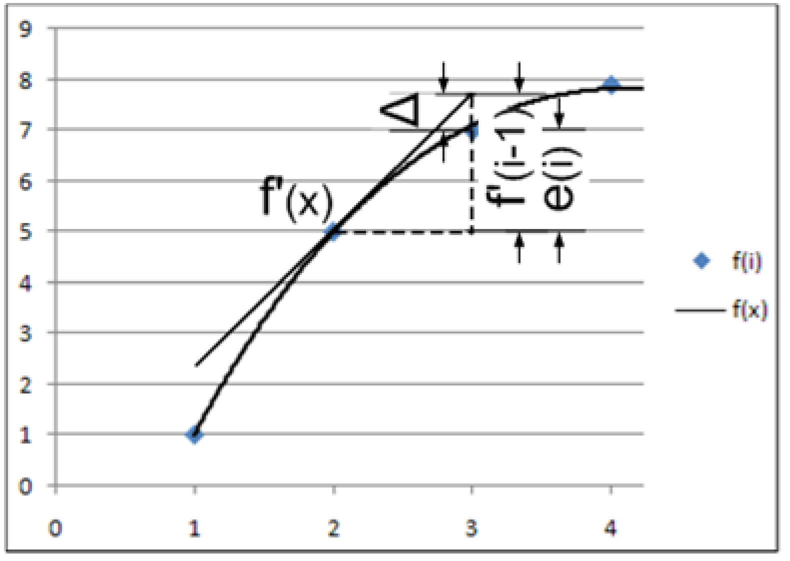
Original Idea

- Target
  - real-time, stable high throughput
  - low hardware cost
  - low coding effect loss
- Method
  - design parallel CU search engines
  - propose pre-CU mode filtering, 2 CU mode
  - base on source image texture, quantified by edge strength, introduce none extra delay in pipeline
  - embed other fast algorithms in each CU search engine

Texture based Predict Error Estimation

- Image Texture
  - obtained directly from source image
  - quantified as Edge Strength(ES)
- Estimate Predict Error
  - 1D example, x,f(x),i,f(i)
  - f’(x) is derivation, f’(i-1)
  - use f(i-1) to predict f(i)
  - e(i) is the real PE value
  - f’(i-1) is an estimation
  - then, $e(i) = f^{'}(i-1) - \Delta$

$$\approx f^{'}(i-1)$$



Linear Predict Error Models in a CB

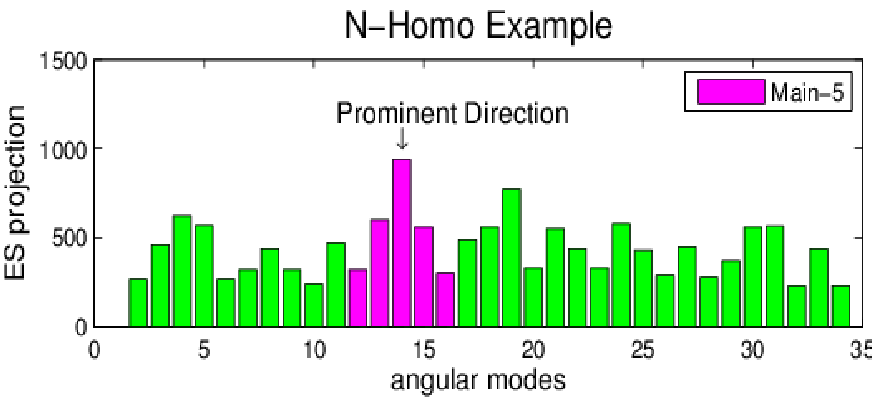
- Original Definition: $PE_k = (P_k - C_k)^2$
- Model Suppose: $\widetilde{PE}_k = a \cdot Qs^2 + b \cdot ES_k$
- Involved Items:
  - Qs is quantization step, ES_k is Edge Strength of k_{th} pixel
- Parameter Study:
  - Weighted least squares estimation:

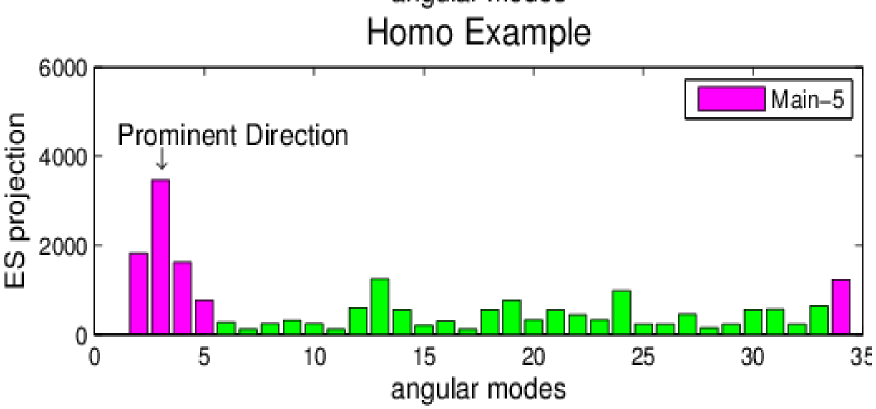
$$\arg\min_{\{a,b_k\}} \left\{ \sum_{\tau=0}^{M-1} \left[\sum_{k=1}^{N^2-1} \omega_k \cdot \underline{(PE_k(\tau) - \widetilde{PE}_k(\tau))^2} + \omega_{N^2} \cdot \underline{(\sum_{k=1}^{N^2-1} PE_k(\tau) - \sum_{k=1}^{N^2-1} \widetilde{PE}_k(\tau))^2} \right] \right\}$$

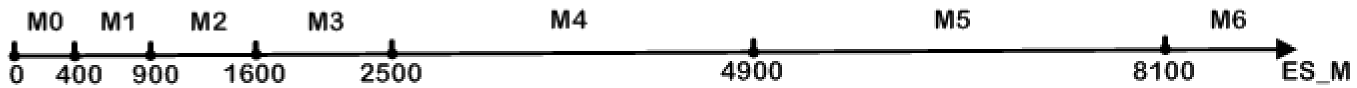
each pixel weight $\omega_k = 1$, sum. of all pixels weight $\omega_{N^2} = \frac{1}{N^2}$

PE Model Classification

- Histogram of ES
  - axis x, 33 angular mode
  - axis y, projected ES
- Prominent Direction
  - 4 classes
- Directional Homogeneity
  - main-neighbor-5 vs. all
  - 2 classes
- ES Amplitude
  - 7 classes

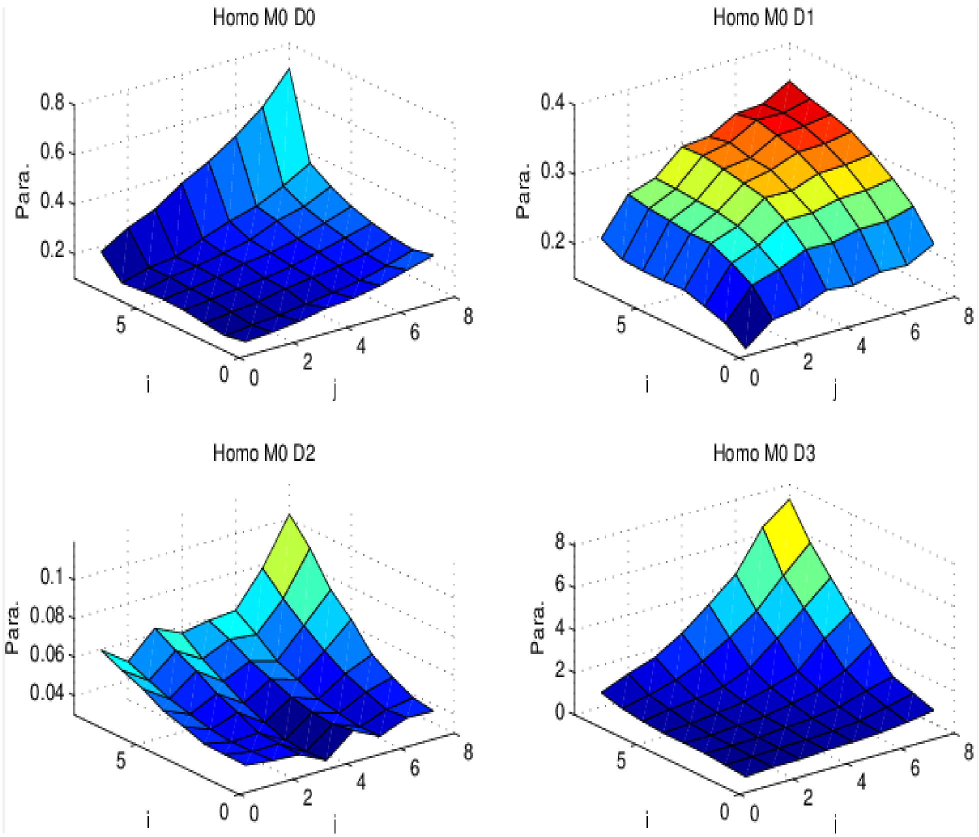






Model Para. Examples

- Prominent Direction
  - D0, 07-13, horizontal
  - D1, 14-22, -45 degree
  - D2, 23-29, vertical
  - D3, others, 45 degree
- Homogeneity
  - homo
- ES Amplitude
  - M0: ES<400



PE based RD Cost Estimation

- Pixel Rate&Distortion Estimation

$$\widetilde{R}_k = \alpha \cdot \omega_r \cdot \widetilde{PE_k} \quad , \quad \widetilde{D}_k = \omega_d \cdot \widetilde{PE_k}$$

  - $\alpha = 7/64$, rate conversation factor
  - ω_r, ω_d , weighting factors, theory and experience based
- RD Cost of NxN Blocks
  - N=4,8,16,32

$$RD_N = \sum_{k=0}^{N^2-1} (\widetilde{R}_k + \widetilde{D}_k)$$

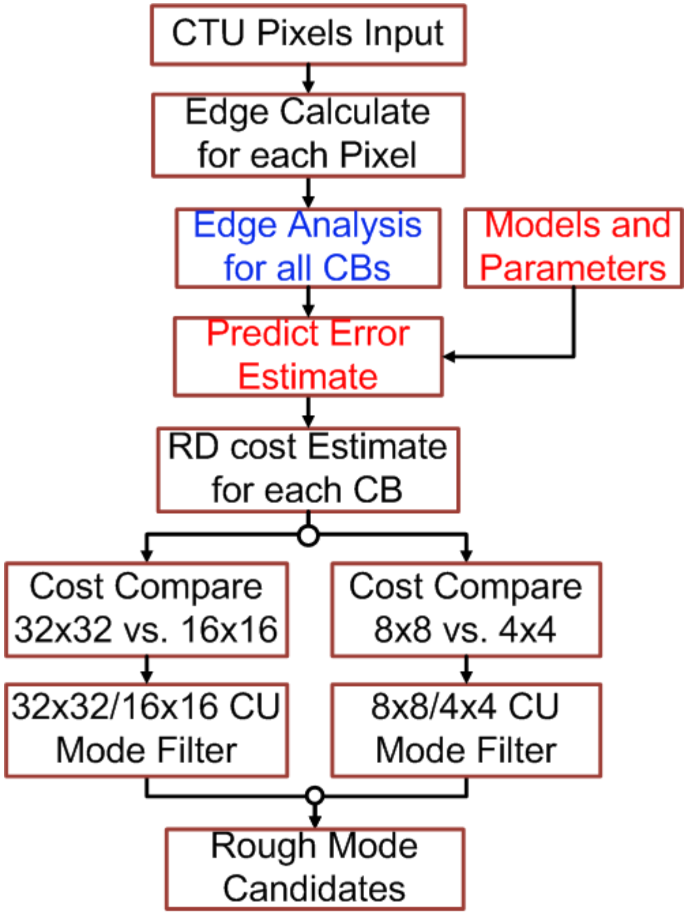
- RD Cost of partitioned Block

$$RD_{\oplus N} = \sum_{n=0}^{3} RD_{\frac{N}{2}}(n) + 3 \cdot \alpha \cdot (\gamma_{\mathrm{mode}} + \gamma_{cbf})$$

  - 4 sub-blocks' RD cost and merge cost
  - $\gamma_{\mathrm{mode}} = 4, \quad \gamma_{cbf} = 1$, prediction mode bits and code-block-flag bit

Pre Modes Filtering

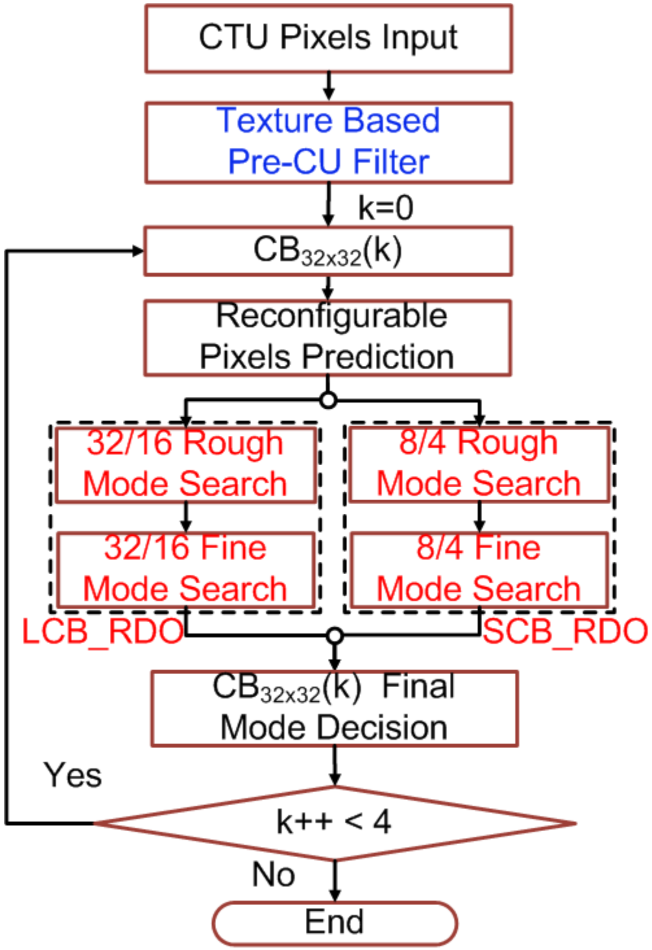
- Edge Calculation
  - 1 pixel cal. once, map to all CBs
- ES based Models Classify:
  - each CB is an unit, through EA
- Predict Error Estimate
  - corres. model and para.
- RD estimation
- Pre-CU Mode Filtering
  - LCB: 32x32 vs. 4 16x16
  - SCB: 8 x 8 vs. 4 4 x 4



Pre CU filtering flows

Panoramic View of Proposed Method

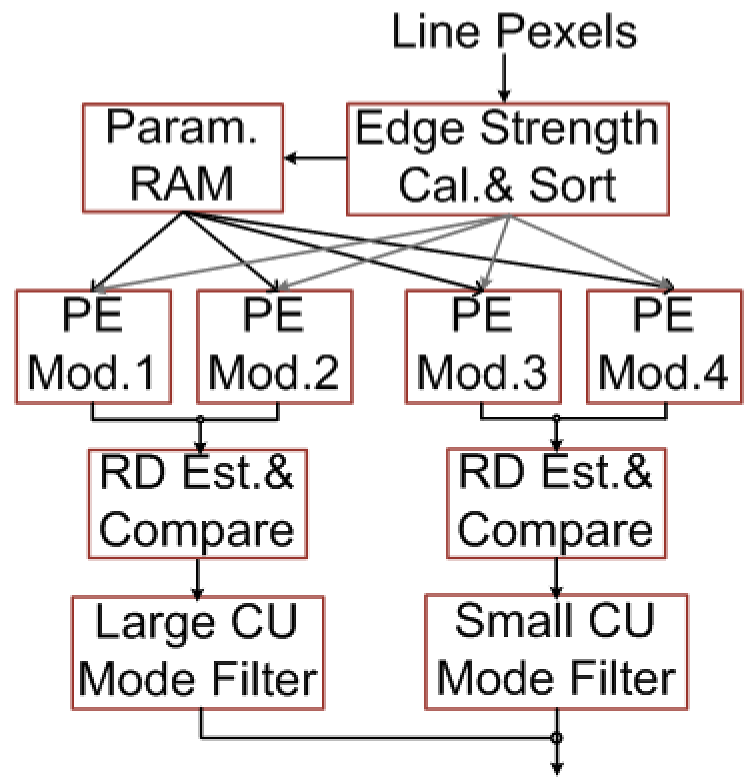
- CTU luma partition
  - 64x64-> 4 32x32 CBs
  - 64x64 is abandoned
- Pre-process:
  - CU mode filtering model
- Parallel PU search:
  - fast search applied
  - LCB_RDO: 32 / 16
  - SCB_RDO: 8 / 4
- Final Mode Decision.



Proposed RDO process

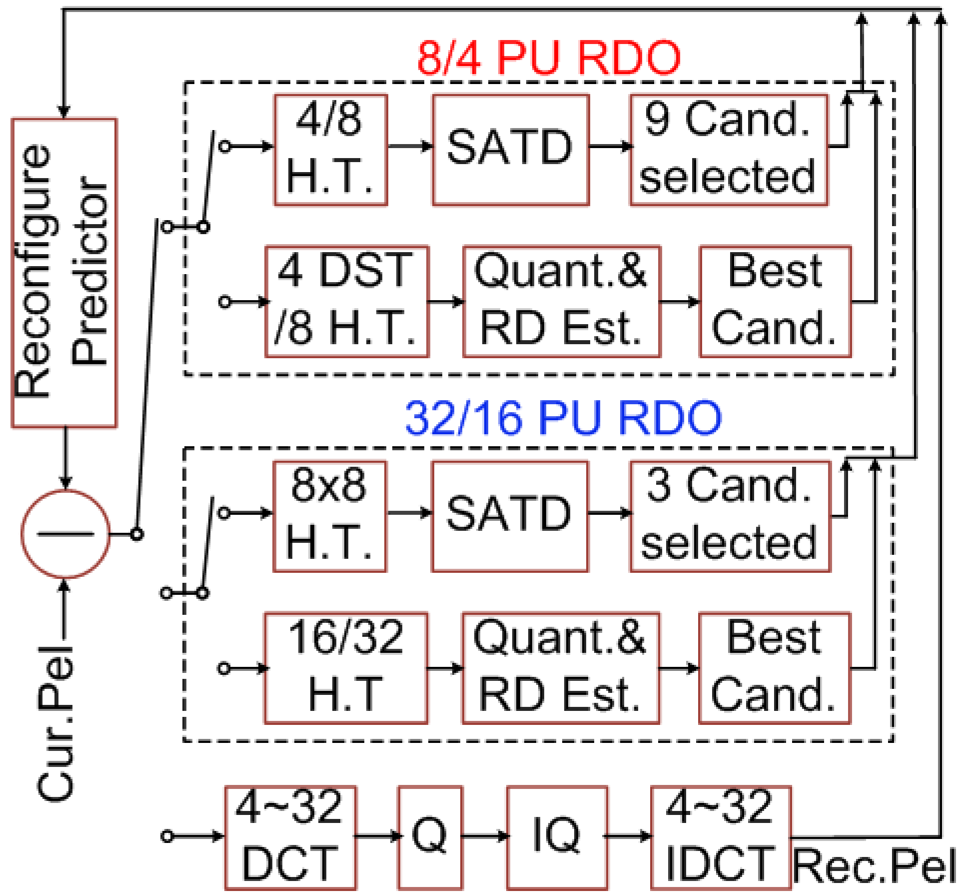
Pre-CU Filtering Structure

- ES Analysis
  - pixels input row by row
  - block finished->class info.
  - send class info, save ES
- PE Models & RD Estimation
  - Mod.1,2,3,4: size 32,16,8,4
  - row by row cal. & acc.
- Mode Filter
  - $RD_N, RD_{\oplus N}, N \in \{8, 32\}$
  - mode reserved cases: $\{32,8\},\{16,8\},\{32,4\},\{16,4\}$

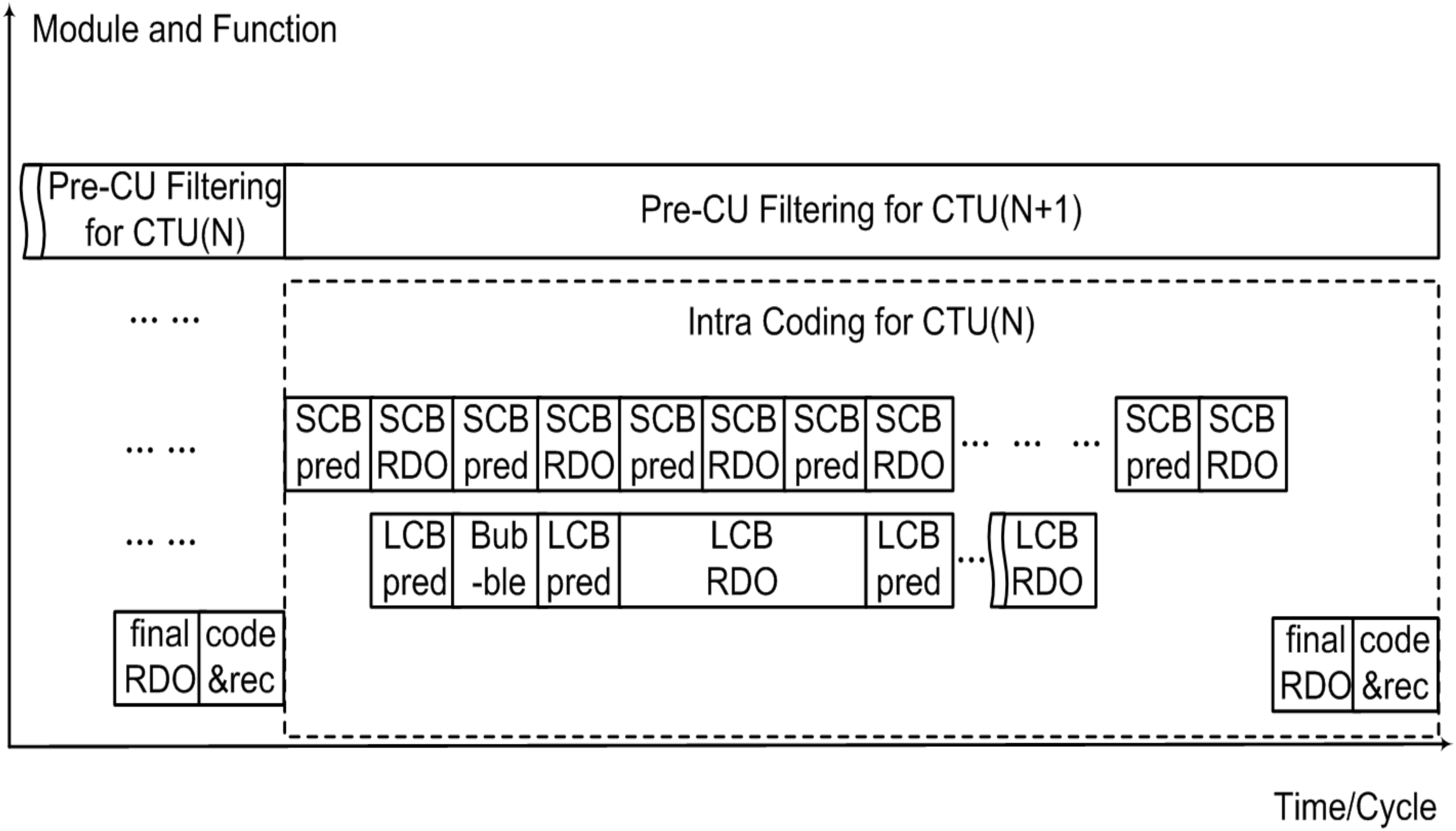


PU/TU Mode Search Structure

- Predictor
  - 128 pixel*mode/cycle
  - timing conflict: interrupt
  - critical path: small one
- Two Search Engines
  - SCB PU RDO
  - LCB PU RDO
  - fast search used
- Trans. Mode Decision
  - compare the best 2 cand.
  - search the best TU mode



Coding Timing Analysis



Coding Performance

- Environment
  - reference:HM-10
  - sequence: typical 22
  - QP={22,27,32,37}
- Result

	BD-PSNR [dB]	BD-Rate [%]	Time Saved [%]
Max	-0.41	6.73	72.6
Min	-0.11	1.97	54.2
Average	-0.20	4.53	61.7

Class	Sequence	BD-PSNR [dB]	BD-Rate [%]	Time Saved [%]
A	PeopleOnStreet	-0.21	4.61	61.4
	Traffic	-0.21	4.34	61.9
B	BasketballDrive	-0.17	6.73	61.7
	BQTerrace	-0.19	4.32	64.9
	Cactus	-0.14	4.28	72.6
	Kimono	-0.12	4.39	68.1
	ParkScene	-0.11	3.39	58.3
	Tennis	-0.18	5.92	62.0
C	BasketballDrill	-0.21	4.63	60.0
	BasketballDrillText	-0.21	4.75	60.6
	BQMall	-0.20	4.15	58.4
	RaceHorses	-0.19	3.38	58.6
D	BasssketballPass	-0.24	4.80	58.8
	BlowingBubbles	-0.19	3.44	54.2
	BQSquare	-0.15	1.97	55.1
	Keiba	-0.21	4.02	60.3
E	SlideEditing	-0.41	2.94	61.1
	Vidyo1	-0.25	6.04	64.8
	Vidyo3	-0.23	5.35	63.4
	Vidyo4	-0.21	5.19	63.6
	Johnny	-0.21	5.15	63.5
	KristenAndSara	-0.24	5.86	63.6
Average		-0.20	4.53	61.7

Hardware Consumption

- Environment
  - described with Verilog HDL
  - synthesized with DC, TSMC90nm 1P9M technology
- Results
  - maximum speed, 357 MHz
  - fulfill HD1080p@44fps real-time intra coding

Module	Pre-Mode Filter	Rcnf. Predictor	32/16 CU RDO	8/4 PU RDO	Rcns. Datapath	Total
Gates(K)	214.1	817.3	781.3	450.6	507.2	2269.0
Pwr(mW)	26.2	101.4	25.2	32.9	32.2	217.9

Conclusion

- Fast HECV Intra Encoder
  - EdgeStrength based PredictError models
  - pre-CU/PU mode filtering
  - parallel fast search engines
- Results and Contributions
  - averagely 61.7% time save while 0.20dB BD-PSNR loss
  - stable and robust acceleration
  - 57% hardware saved totally in mode searching
  - max speed: 357MHz with TSMC90
  - support4:2:0 HD1080p@44fps HEVC real-time encoding

THANK YOU!