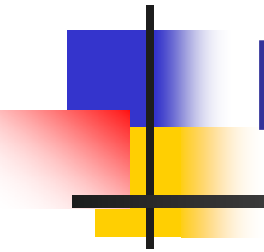
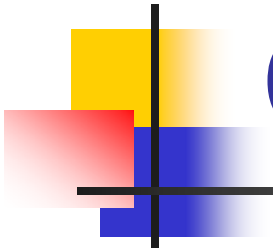


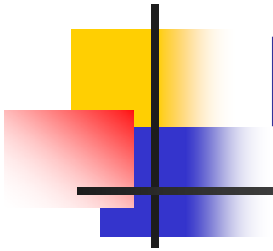
First Parts of H.264 Decoder

Chun-Chieh Lin



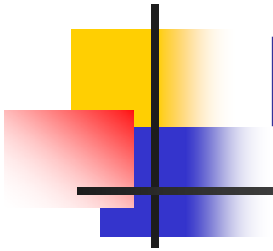
Contents

- H.264 Overview
  - NAL Unit Unwrapping Details
  - Entropy Decoding Details
- Hardware Design
- Design Explorations
- Benchmark Results



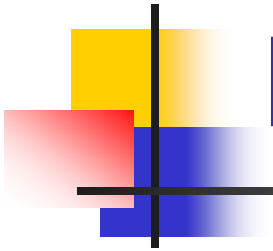
H.264 Overview

- Works on blocks of 4x4 to 16x16 pixels
- Encoder picks a way to approximate current block using previous data
- Residual data transformed in 4x4 blocks
- Almost everything is entropy coded
- Units of encoded data wrapped in Network Abstraction Layer (NAL)



NAL Unit Unwrapping

- Units separated by 3 byte combination “start code prefix”
- End of units might be padded with bytes with value 0
- Encoder inserts bytes to prevent start code prefix inside units
- Unwrapper reverses these effects



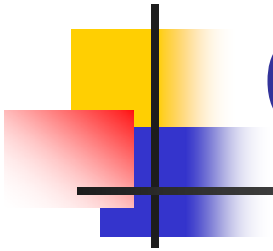
Entropy Decoding

- First checks the type of a NAL unit
- Parses the unit accordingly
- Most syntax elements coded with Exp-Golomb codes
- Transformed residual data coded with Context-based Adaptive Variable Length Coding (CAVLC)

Exp-Golomb Codes

Bit string	codeNum
1	0
0 1 0	1
0 1 1	2
0 0 1 0 0	3
0 0 1 0 1	4
0 0 1 1 0	5
0 0 1 1 1	6
0 0 0 1 0 0 0	7
0 0 0 1 0 0 1	8
0 0 0 1 0 1 0	9
…	…

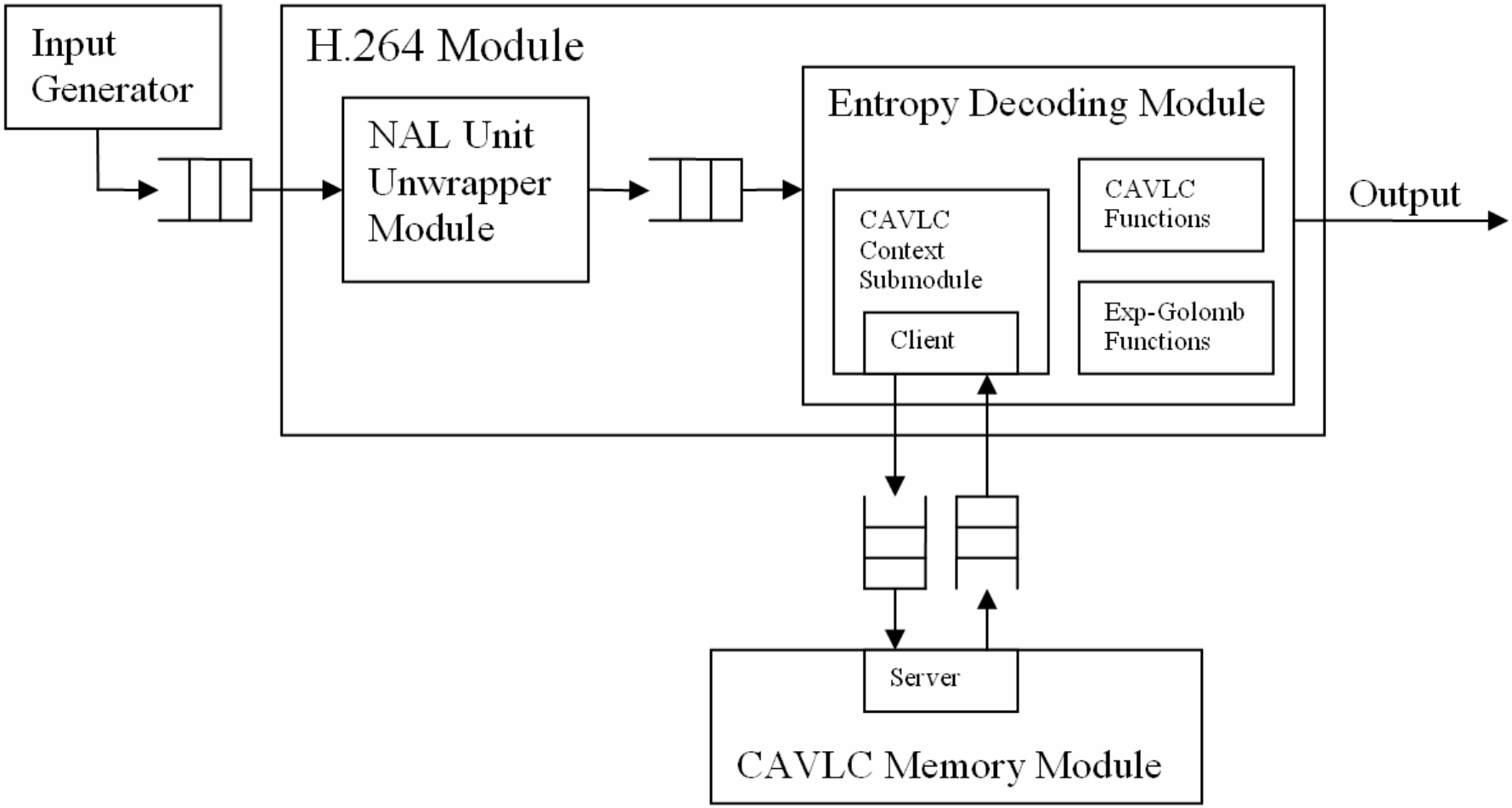
codeNum	syntax element value
0	0
1	1
2	–1
3	2
4	–2
5	3
6	–3
k	$(-1)^{k+1}$ Ceil(k÷2)

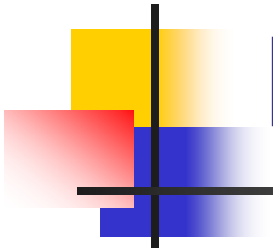


CAVLC

- Data encoded in several components
- Each component has a set of tables
- A table is chosen based on context
- Decoded result from neighboring blocks used as context for one component

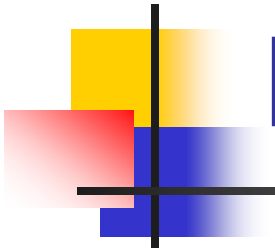
Hardware Design





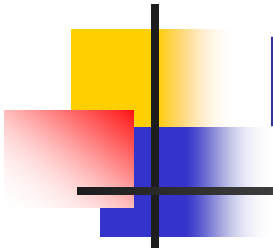
NAL Unwrapper Module States

- Three byte buffer
- Counter for number of bytes in buffer
- Counter for number of consecutive bytes with value 0



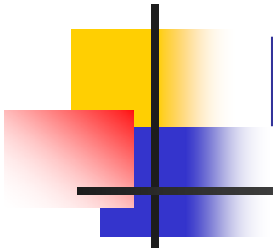
NAL Unwrapper Module Rules

- A rule fills the buffer
- A rule checks for start code prefix
- A rule removes extra bytes that prevent start code prefix from appearing in data
- A rule for normal operation
- A rule for end of file case



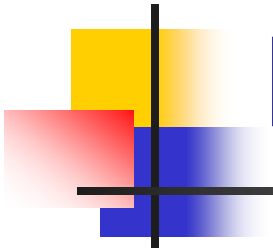
Entropy Decoder States

- Parsing state register
- 77-bit input buffer
- Input buffer counter
- 16-element FIFO for intermediate results of CAVLC
- Registers for decoded syntax elements that are needed for parsing



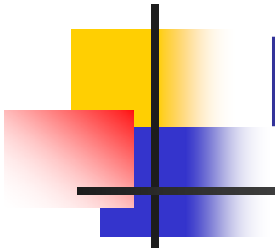
Entropy Decoding Rules

- A rule for initializing
- A rule for checking the NAL unit type
- A rule for filling the input buffer
- A rule for parsing the data
  - Basically a large finite state machine



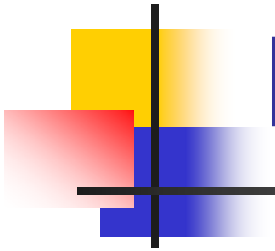
Design Exploration A

- Residual data (output of CAVLC) usually contains many consecutive zeros
- Original: outputs zeros one by one
- Change: outputs the consecutive number of zeros



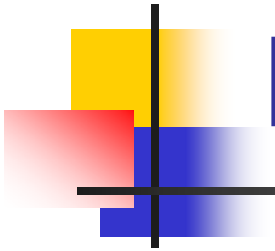
Design Exploration B

- Most of the Exp-Golomb syntax elements only up to 16 bits decoded
- Some infrequent ones are up to 32 bits
- Original: use same decoder function
- Change: two versions of decoder
  - 1-cycle 16 bit decoder function
  - 32 bit decoder split into 2 parts (2 cycles)



Design Exploration C

- The input buffer filler and parser rules of entropy decoder conflict
- Original: buffer filled one byte at a time
- Change: an extra 32-bit buffer is used
  - An extra rule adds bytes into extra buffer
  - 32 bits inserted into main buffer each time



Benchmarks

- Small clips of three different files
  - 5 frames with 176x144 resolution
  - 15 frames with 176x144 resolution
  - 5 frames with 352x288 resolution

Benchmark Results

	Total Cycles	Cycle Delay	Total Time	Area (mm^2)
Original	654290	6.468 ns	4.232 ms	0.3378
A	251524	6.405 ns	1.611 ms	0.3283
A+B	251552	5.955 ns	1.498 ms	0.2820
A+C	230750	6.400 ns	1.477 ms	0.3690
A+B+C	230712	6.184 ns	1.427 ms	0.2932