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2009-09-02

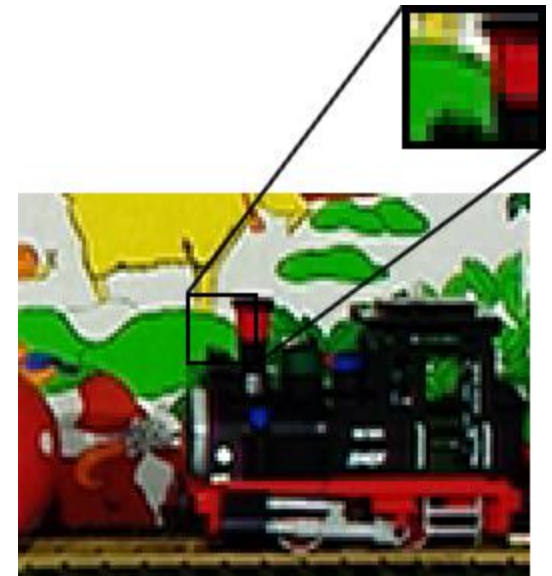
A Toolset for the Analysis and Optimization of Motion Estimation Algorithms and Processors



Department of Electrical and
Electronic Engineering

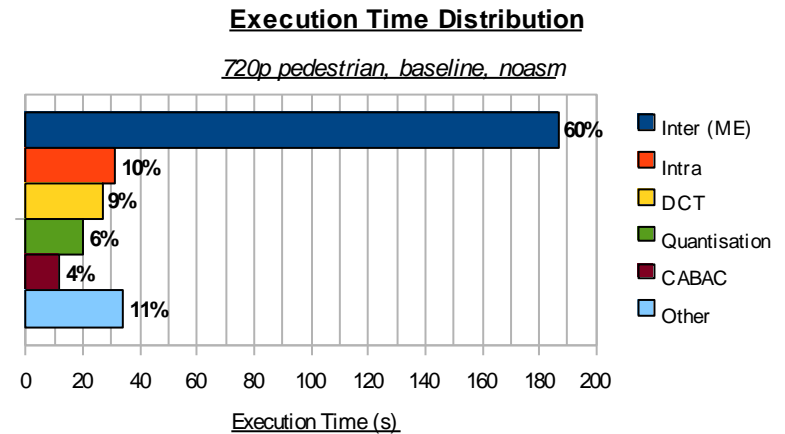
Overview

- Motion estimation takes time, full search expensive for HD.
- Flexible reconfigurable processor.
- IDE to design and test algorithms.
- Toolset to configure the processor.



Saving time

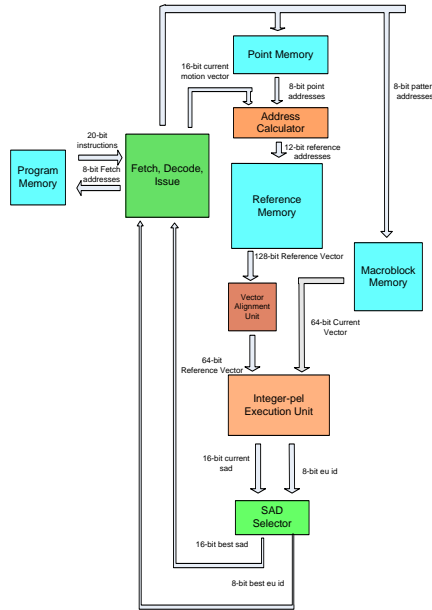
- Motion estimation takes processor time.
- The design space to explore is large.
- Configuring the ME processor takes developer times.



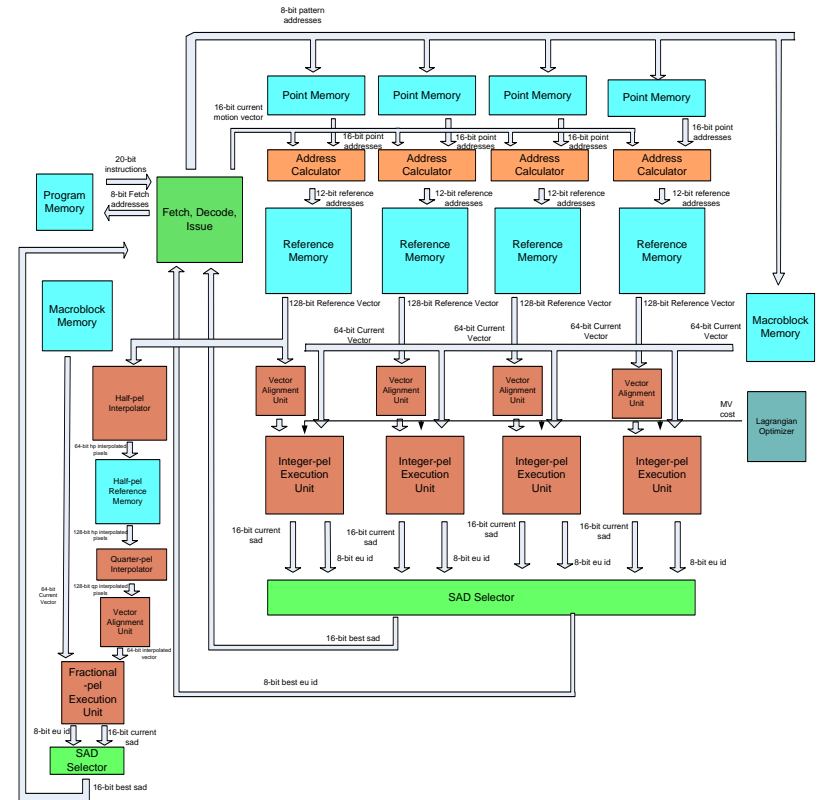
The reconfigurable processor

- Advanced features such as rate distortion optimization using Lagrangian techniques.
- Multiple motion vector candidates allowed.
- Multiple sub-partition sizes allowed.
- Multiple reference frames allowed.
- Can do fractional pel motion estimation that can be used for the H.264 standard.

Simple and complex configurations



Simple (1 integer pel unit)



Complex (4 int. pel units, 1 frac. pel unit, Lagrangian optimizer)

Processor performance and complexity evaluation

Processor Configuration	Speed (cycles/MB, frames/second)	FPGA size (LUTs, slices)	Memory (BRAMS)
Base configuration (1 integer-pel execution unit)	625 cycles/MB, 39 fps	2289 LUTs, 1300 slices	21 BRAMS (2 ref. areas, 112×128 pixels)
Complex configuration (4 integer-pel execution units)	234 cycles/MB, 104 fps	7074 LUTs, 3703 slices	72 BRAMS (2 ref. areas, 112×128 pixels)

Video sequence: 1080p *crowdrun* from SVT HD multi format test set

FPGA part: Virtex-4 SX35, 200 MHz clock frequency

Algorithm: 6-point hexagonal search (up to 8 steps), then 8-point square

Designing block-matching algorithms

- Estimo C: high-level language for search algorithms.
- Compiler targets the reconfigurable processor.
- No need to know how hardware works.
- Compiled program works across all configurations.

```
s = 8; // initial step size
check(0, 0);
check(0, s);
check(0, -s);
check(s, 0);
check(-s, 0);
update;
do {
    s = s / 2;
    for (i = 1 to 5 step 1) {
        check(0, s);
        check(0, -s);
        check(s, 0);
        check(-s, 0);
        update;
        #if (WINID == 0)
            #break;
        }
    } while (s > 1);
    for (x = -0.5 to 0.5 step 0.25)
        for (y = -0.5 to 0.5 step 0.25)
            check(x, y);
    update;
```


Cycle-accurate simulator

- Analysing processor configurations on hardware takes time.
- Using simulator, no need for synthesizing hardware and configuring board.
- No hardware required for evaluation of processor.



The IDE

SharpEye Studio 2008 - A complete framework for the Development of Motion Estimation Algorithms

File Edit Build Help

Project Explorer

Solution Files

- Project files
- Estimo Source Files
 - D:/projects/hex/hex.est
- Output Files
 - Assembly.asm
 - patterns.bin
 - program.bin

```

Pattern(quarter) (
    check(0.25, 0)
    check(0, 0.25)
    check(-0.25, 0)
    check(0, -0.25)
)

check(zero);
for(i = 1 to 8 step 1) (
    check(hex);
    #if(WINID == 0)
        #break;
)
check(square);
for(i = 1 to 2 step 1) (
    check(half);
    #if(WINID == 0)
        #break;
)

```

Cycle Accurate Model

Motion-estimation search configuration

Program memory: D:/projects/hex/estimo.output/program.bin Browse...

Points memory: D:/projects/hex/estimo.output/patterns.bin Browse...

Full-pel execution units: 2

Sub-pel execution units: 1

Smallest partition: 16x16

Enable Motion Vector cost optimization

Enable Motion Vector candidates

Video data

Video file: D:/test_sequences/1080p/pedestrian_area.yuv Browse...

Resolution: 1920 x 1080

Maximum number of frames: 50

QP (0 is lossless): 26

Reference frames: 1

Results

Processor configuration:	Results:
Label: Cfg 24	Bit rate (kbit/s): 6793.27
Full-pel units: 2	PSNR (dB): 41.3
Sub-pel units: 1	FPS: 20.7457
Smallest partition: 16x16	Cycles / macroblock: 1181.44
MV cost optimization: enabled	Energy / macroblock (n): 20.9706
MV candidates: enabled	Full- and sub-pel in parallel:
Logic cells: 11287	FPS: 31.8295
Video data:	Cycles / macroblock: 770.033
Frames processed: 50	Energy / macroblock (n): 13.6681
QP: 26	
Reference frames: 1	

Run Stop New Plot Table

Cycle Accurate Model

Configuration	PSNR (dB)	Bit rate (kbit/s)	Frames / second
pedestrian	41.3	6793.27	15.8396
rush hour	41.874	4811.23	16.0346
station	40.705	2713.17	16.8015
sunflower	42.326	3585.56	16.7534
tractor	39.171	12398.4	15.7436
pedest 2	41.3	6793.27	20.7457

Rename... Export configuration... Details Delete Clear

tractor

Processor configuration:

Label: tractor

Program memory: D:/projects/hex/estimo.output/program.bin

Point memory: D:/projects/hex/estimo.output/patterns.bin

Full-pel units: 1

Sub-pel units: 1

Smallest partition: 16x16

MV cost optimization: enabled

MV candidates: enabled

Logic cells: 9732

Results:

Bit rate (kbit/s): 12398.4

PSNR (dB): 39.171

FPS: 15.7436

Cycles / macroblock: 1556.81

Energy / macroblock (n): 22.3792

Full- and sub-pel in parallel:

FPS: 26.1083

Cycles / macroblock: 938.773

Energy / macroblock (n): 13.4949

Video data:

Video file: D:/test_sequences/1080p/tractor.yuv

Resolution: 1920x1080

Frames processed: 50

QP (0 is lossless): 26

Reference frames: 1

Fps against bit rate for different sequences

Fps against bit rate for different sequences

Frames / second (parallel)

Bit rate (kbit/s) x 10³

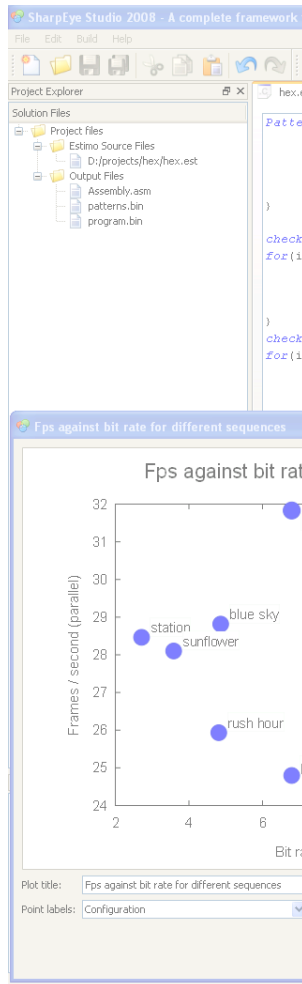
Plot title: Fps against bit rate for different sequences X-axis: Bit rate

Point labels: Configuration Y-axis: Frames / second (parallel)

Area: Logic cells

Export... Print...

The IDE



Cycle Accurate Model

Motion-estimation search configuration

Program memory: D:/projects/hex/estimo.output/program.bin

Points memory: D:/projects/hex/estimo.output/patterns.bin

Full-pel execution units: 2

Sub-pel execution units: 1

Smallest partition: 16x16

Enable Motion Vector cost optimization

Enable Motion Vector candidates

Video data

Video file: D:/test_sequences/1080p/pedestrian_area.yuv

Resolution: 1920 x 1080

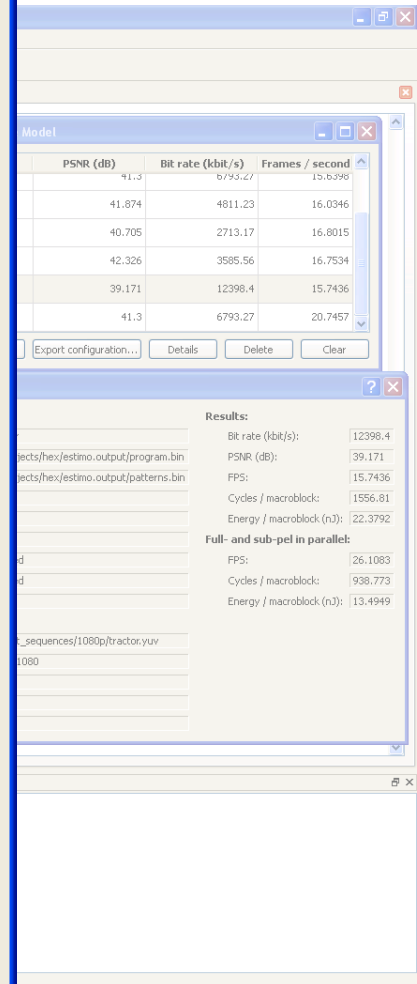
Maximum number of frames: 50

QP (0 is lossless): 26

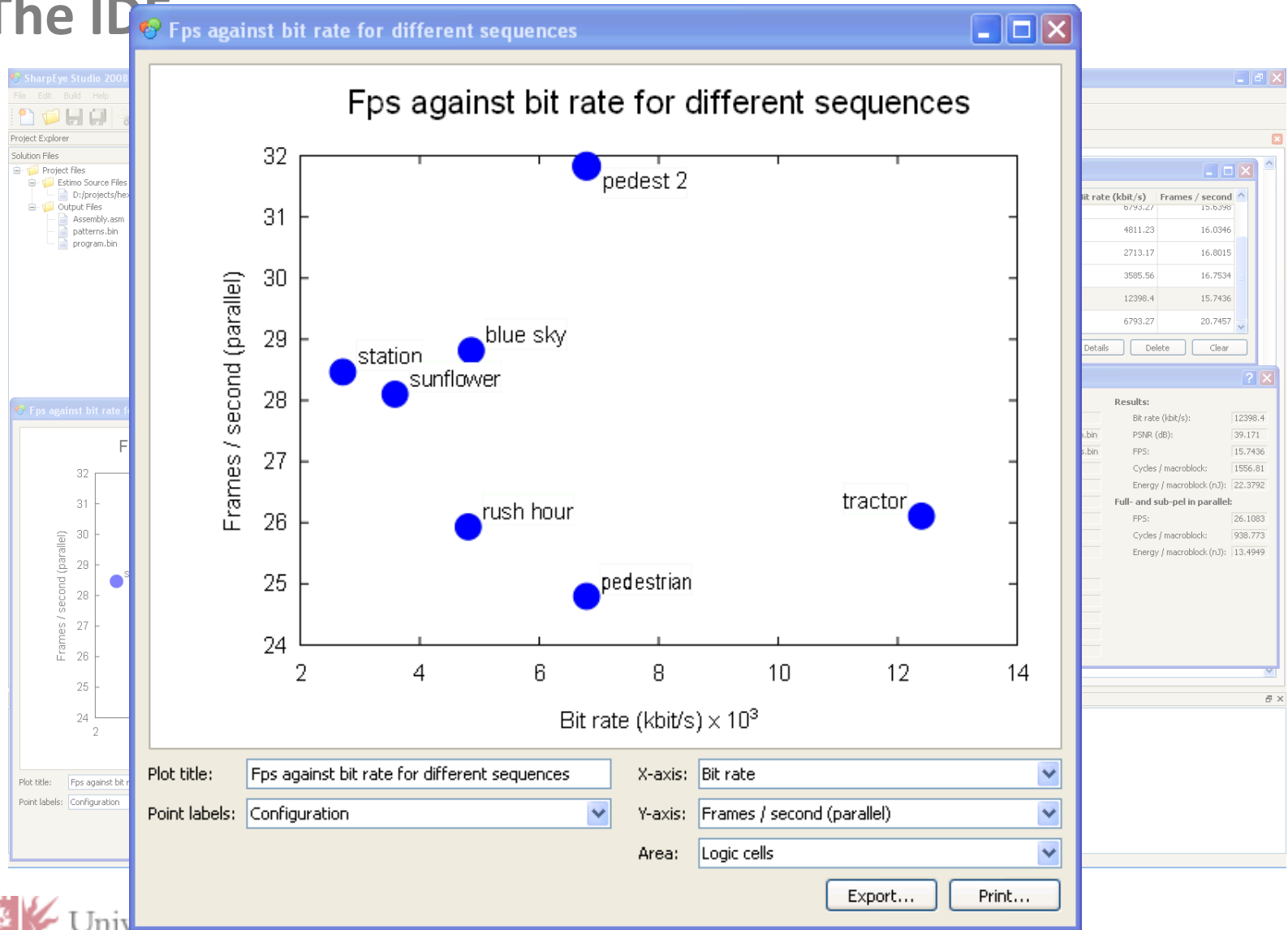
Reference frames: 1

Results

Processor configuration:		Results:	
Label:	Cfg 24	Bit rate (kbit/s):	6793.27
Full-pel units:	2	PSNR (dB):	41.3
Sub-pel units:	1	FPS:	20.7457
Smallest partition:	16x16	Cycles / macroblock:	1181.44
MV cost optimization:	enabled	Energy / macroblock (nJ):	20.9706
MV candidates:	enabled	Full- and sub-pel in parallel:	
Logic cells:	11287	FPS:	31.8295
Video data:		Cycles / macroblock:	770.033
Frames processed:	50	Energy / macroblock (nJ):	13.6681
QP:	26		
Reference frames:	1		



The IDE



The IDE

The screenshot displays the SharpEye Studio IDE interface. The main window, titled "Cycle Accurate Model", shows a table of configurations and their performance metrics. Below the table are buttons for "Rename...", "Export configuration...", "Details", "Delete", and "Clear".

Configuration	PSNR (dB)	Bit rate (kbit/s)	Frames / second
pedestrian	41.3	6793.27	15.6398
rush hour	41.874	4811.23	16.0346
station	40.705	2713.17	16.8015
sunflower	42.326	3585.56	16.7534
tractor	39.171	12398.4	15.7436
pedest 2	41.3	6793.27	20.7457

The "tractor" configuration window is open, showing the following settings:

Processor configuration:

- Label: tractor
- Program memory: D:/projects/hex/estimo.output/program.bin
- Point memory: D:/projects/hex/estimo.output/patterns.bin
- Full-pel units: 1
- Sub-pel units: 1
- Smallest partition: 16x16
- MV cost optimization: enabled
- MV candidates: enabled
- Logic cells: 9732

Video data:

- Video file: D:/test_sequences/1080p/tractor.yuv
- Resolution: 1920x1080
- Frames processed: 50
- QP (0 is lossless): 26
- Reference frames: 1

Results:

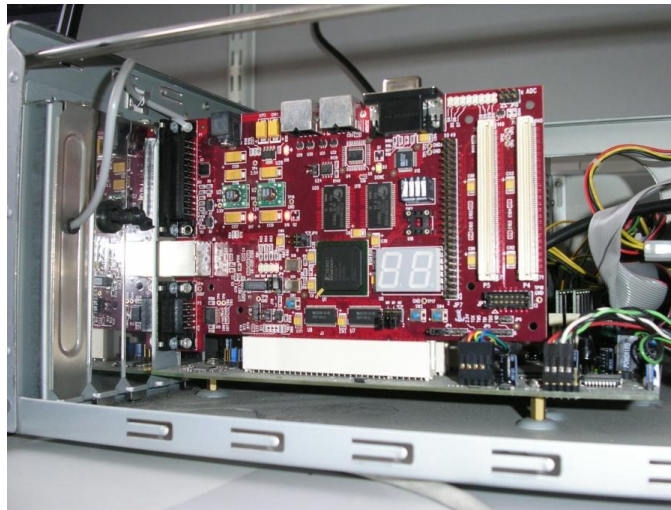
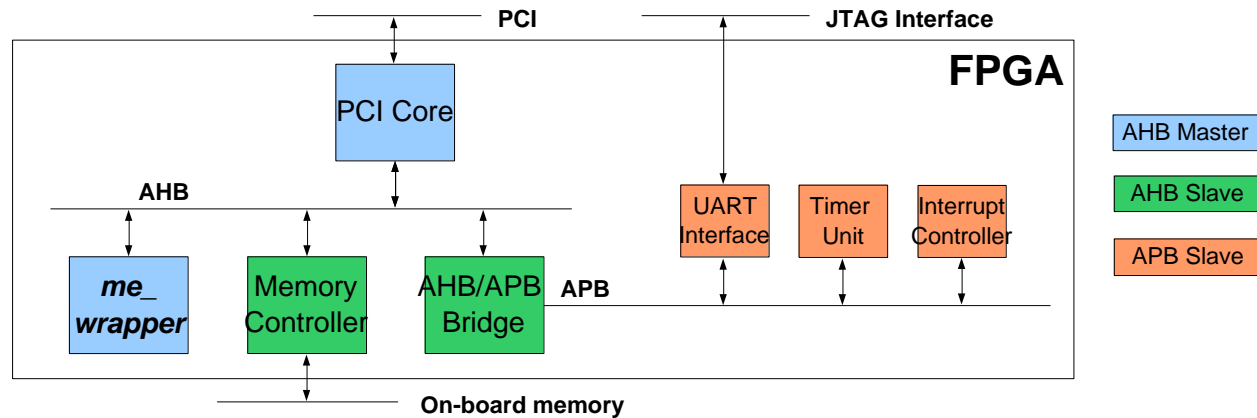
- Bit rate (kbit/s): 12398.4
- PSNR (dB): 39.171
- FPS: 15.7436
- Cycles / macroblock: 1556.81
- Energy / macroblock (nJ): 22.3792

Full- and sub-pel in parallel:

- FPS: 26.1083
- Cycles / macroblock: 938.773
- Energy / macroblock (nJ): 13.4949

In the background, a plot titled "Fps against bit rate for different configurations" shows the relationship between bit rate and FPS for various configurations. The plot shows a general trend where higher bit rates correspond to higher FPS, with the tractor configuration being an outlier with a high bit rate and moderate FPS.

Prototype implementation



Summary

- Programmable and configurable processor supports HD motion estimation (supports H.264, MPEG-4, MPEG-2, VC-1, AVS).
- Motion Estimation Processor: <http://www.opencores.org/>
- Estimo C compiler for easy development of proprietary block-matching algorithms.
- FPGA-based PCI demonstration board available.
- Cycle-accurate simulator for quick evaluation and design space exploration.
- SharpEye IDE: <http://sharpeye.borelspace.com/>