



Minimizing the cost and risk when migrating software to multicore platforms

24 April 2009

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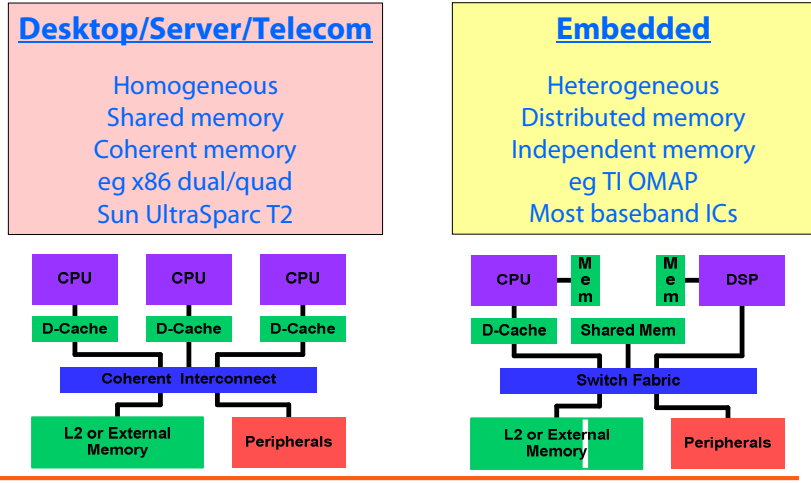
CriticalBlue | 2009



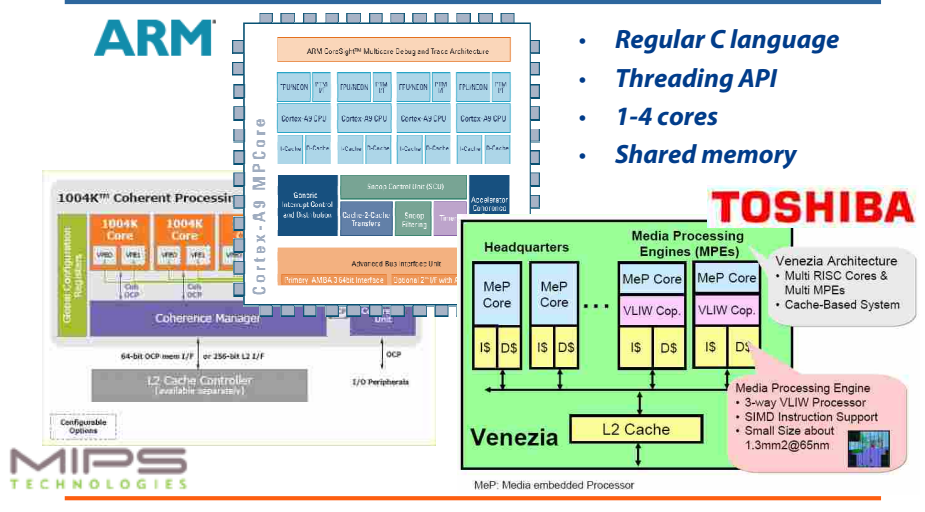
Agenda

- **Mainstream Multicore Programming**
- **What We Heard From Engineers**
- **How We Are Addressing These Issues**

Multicore & Software: State of the Embedded Art (1)



Multicore & Software: State of the Embedded Art (2)



Multicore & Software: State of the Embedded Art (3)

- **Putting lots of cores on silicon is relatively simple**
- **There are many clever memory and communication architectures**
- **However... the mass market of software developers haven't yet adopted multicore programming...**
- **Because...**
- **Software developers didn't ask for multicore!**
- **Software developers don't care about multicore block diagrams**
- **Software developers need motivation to migrate aggressively to multicore**

Feedback From Engineers

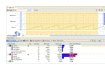
- **We love the C language**
 - It's not that C is the perfect parallel language
 - 100s of millions of lines of existing code
 - Existing code maintenance is a huge overhead
- **We love our Compiler/IDE/ISS**
 - Companies typically standardize on a particular toolchain
 - Huge investment in the developers' desktop
 - Real world C/C++ is less portable than you might think
- **We need motivation to move software to multicore**
 - Benefits need to be clear before code changes are made
 - Multithreading simple to implement, hard to understand

Feedback From Engineers

- **Do not synthesize my code!**
 - Maintaining sequential code is hard enough already
 - Requirement to retain control of source code changes
 - Identify minimal set of code changes to deliver benefit
- **We must have confidence in code changes**
 - Check that the code modifications deliver expected benefits
 - Check that no new problems were added
 - Check that the code is 'safe'
- **We need education in multicore programming**
 - Lots of FUD, but also plenty of products in the market
 - Plenty of buzzwords, less clear explanation
 - How does this relate to my code?

Collating The Data

1. Analyze – characterize existing code. Identify parallelism determining issues



2. Explore – without code changes, evaluate alternative concurrent scenarios



3. Implement – select parallelization strategy and write code in existing IDE



4. Verify – check for code safety, race, threading and synchronization issues



5. Tune – inspect for further performance opportunities on target platform



What might a practical and pragmatic flow look like?



JPEG Encoding

write header, image properties, and
decode and quantization tables

```
foreach macroblock {
    convert rgb to ybcr
    transform to DCT frequency coefficients
    quantize zig zag coefficients
    encode huffman bitstream
}
```



Analysis 1

• Understand serial code profile call tree

Function Name	Type	Force Thread	Call Count	Self Cycles	Total Cycles	Total Cycles Histogram
main			1	55	5992676	100.0%
jpeg_encode			1	519	6990327	100.0%
mb_encode			32	1081	6989763	100.0%
mb_dct			32	5232304	5232304	74.8%
mb_rgb2ycbcr			32	784485	784485	11.2%
mb_zzquant			32	586763	586763	8.4%
mb_huffman			32	3840	385130	5.5%
huffman_flush			1	31	31	0.0%
mb_destroy			1	14	14	0.0%

```
int mb_encode(mb_t *mb, image_t *image, int row, int col, huffman_t
*huffman) {
    int err;

    if ((err = mb_rgb2ycbcr(mb, image, row, col))) return err;
    if ((err = mb_dct(mb))) return err;
    if ((err = mb_zzquant(mb))) return err;
    if ((err = mb_huffman(mb, huffman))) return err;

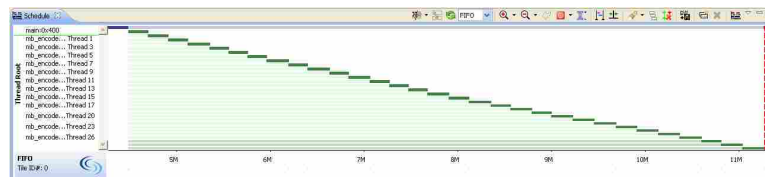
    return 0;
}
```

Exploration 1:1

- Force mb_encode to run parallel

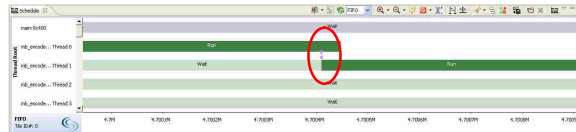
Function Name	Type	Force Thread	Call Count	Self Cycles	Total Cycles	Total Cycles Histogram
mb_encode		<input checked="" type="checkbox"/>	31	1054	6772452	96.9%
mb_dct		<input checked="" type="checkbox"/>	31	5066582	5066582	72.5%
mb_rgb2ycbcr		<input checked="" type="checkbox"/>	31	778798	778798	11.1%
mb_zquant		<input checked="" type="checkbox"/>	31	568663	568663	8.1%
mb_huffman		<input checked="" type="checkbox"/>	31	3720	357355	5.1%
main		<input checked="" type="checkbox"/>	1	35	216224	3.1%
loop_encode		<input checked="" type="checkbox"/>	1	519	217875	3.1%
huffman_flush		<input checked="" type="checkbox"/>	1	31	31	0.0%
mb_destroy		<input checked="" type="checkbox"/>	1	14	14	0.0%
mb_encode		<input checked="" type="checkbox"/>	31			

- Resulting Schedule



Exploration 1:2

- Dependencies between macroblocks



- Source and Cause

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79  ec, ec);
80  mb->du[ydu][cy][cy] =
81  RGB2Y(image->bitmap[1 + 0], image->bitmap[1 + 1], image->bitmap[1 +
82  n = log_debug(DX802), "d ", mb->du[ydu][cy][cy]);
83  mb->du[ydu][cy][cy + 1] =
84  RGB2Y(image->bitmap[1 + 1c + 0], image->bitmap[1 + 1c + 1], image->
85  n = log_debug(DX803), "d ", mb->du[ydu][cy][cy + 1]);
86  mb->du[ydu][cy + 1][cy] =
87  RGB2Y(image->bitmap[1 + ir + 0], image->bitmap[1 + ir + 1], image->
88  n = log_debug(DX804), "d ", mb->du[ydu][cy + 1][cy]);
89  mb->du[ydu][cy + 1][cy + 1] =
90  RGB2Y(image->bitmap[1 + ir + 1c + 0], image->bitmap[1 + ir + 1c + 1],
91  n = log_debug(DX805), "d ", mb->du[ydu][cy + 1][cy + 1]);
92  mb->du[du][ec][ec] =
93  (RGB2Cb(image->bitmap[1 + 0], image->bitmap[1 + 1], image->bitm
+ RGB2Cb(image->bitmap[1 + 1c + 0], image->bitmap[1 + 1c + 1], .
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+ RGB2Cb(image->bitmap[1 + ir + 1c + 0], image->bitmap[1 + ir +
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Coding 1

- Thread the mb_encode function

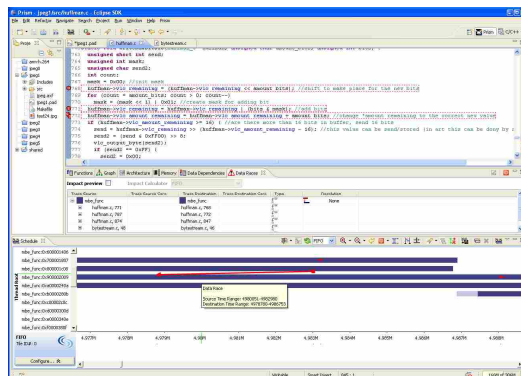
```
err = 0;
for (r = 0, i = 0; r < mb_rows; ++r) {
    for (c = 0; c < mb_cols; ++c, ++i) {
        // pack each macroblock arguments and launch thread
        mbe_arg_pack(&arg[i], image, r, c, huffman, 0);
        // each mb created locally
        pthread_create(&thread[i], NULL, mbe_func, &arg[i]);
    }

    // wait for threads to finish
    for (i = 0; i < mb_rows * mb_cols; ++i) {
        pthread_join(thread[i], (void *)&status);
        if (!err && arg[i].err) err = arg[i].err;
    }
}
```

- “Advise, check, but don’t touch our code!”

Verification 1

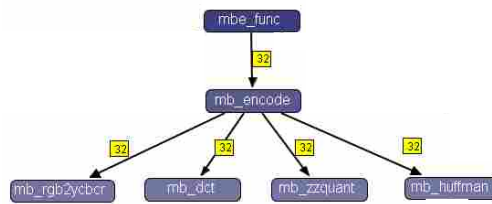
- Works on single core, 3.6/4x speedup



- Fails on multicore, races in Huffman encoder

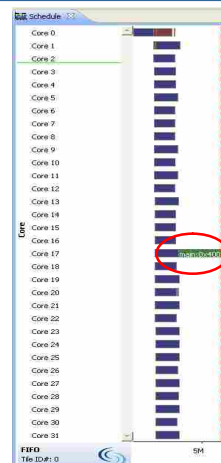
Exploration 2

- Removing the macroblock ant-dependency is a typical parallel code optimization.
- Huffman has inter macroblock dependencies
- Move down a level and try running sub functions in parallel



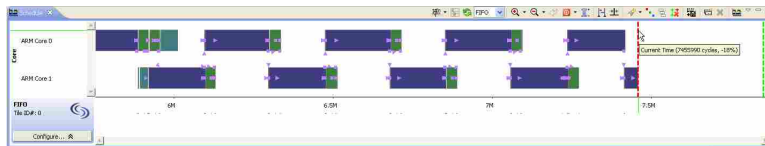
Verification 2

- Clean Schedule
- Most functions scale across cores
- Limited by serial Huffman tail
- Potentially uses more memory



Pass 3

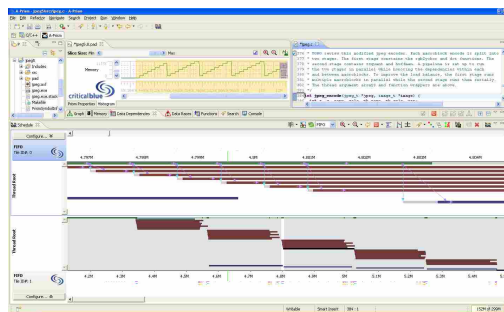
- **Consider function pipelining**
 - Stage 1: rgb2ycbcr, dct
 - Stage 2: zzquant, huffman



- **Poor load balancing, DCT dominates.**

Tuning 3

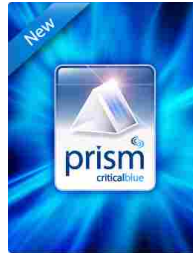
- **Balance pipeline work:**
 - Parallelize stage 1, serialize stage 2



- **Sensitive to DCT efficiency**

Summary

- We've made a start at a practical & pragmatic path for sequential to parallel software migration....
- Visit us at www.criticalblue.com and sign up for an evaluation....



Give us your feedback and help make Prism even better!
