Code Tuning Techniques

CPSC 315 – Programming Studio

adapted from John Keyser's 315 slides

Tuning Code

- Tuning can be at several "levels" of code
  - Routine level to system level
- No "do this and improve code" technique
  - Same technique can increase *or decrease* performance, depending on situation
  - Must measure to see what effect is
- Remember:

Tuning code can make it harder to understand and maintain!

Tuning Code

- We'll describe several categories of tuning, and several specific cases
  - Logical Approaches
  - Tuning Loops
  - Transforming Data
  - Tuning Expressions
  - Others

Logical Approaches:

Stop Testing Once You Know the Answer

- Short-Circuit Evaluation

```
if ((a > 1) and (a < 4))
if (a > 1)
   if (a < 4)
```

  - Note: Some languages (C++/Java) do this automatically

Logical Approaches:

Stop Testing Once You Know the Answer

- Breaking out of “Test Loops”

```
flag = False;
for (i=0; i<10000; i++) {
    if (a[i] < 0) flag = True;
}
```

- Several options:
  - Use a break command (or goto!)
  - Change condition to check for Flag
  - Sentinel approach

Logical Approaches:

Stop Testing Once You Know the Answer

- Break Command

```
flag = False;
for (i=0; i<10000; i++) {
    if (a[i] < 0) {
        flag = True;
        break();
    }
}
```

Logical Approaches:

Stop Testing Once You Know the Answer

- Change Condition to Check for Flag

```
flag = False;
for (i=0; (i<10000) && !flag; i++) {
    if (a[i] < 0) {
        flag = True;
    }
}
```

Logical Approaches:

Stop Testing Once You Know the Answer

- Sentinel Approach

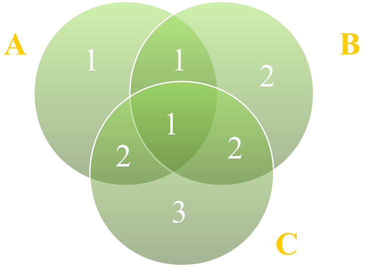
```
flag = False;
for (i=0; i<10000; i++) {
    if (a[i] < 0) {
        flag = True;
        i=10000;
    }
}
```

Logical Approaches:
Order Tests by Frequency

- Test the most common case first
  - Especially in switch/case statements
  - Remember, compiler may reorder, or not short-circuit
- Note: it’s worthwhile to compare performance of logical structures
  - Sometimes switch is faster, sometimes if-then
- Generally a useful approach, but can potentially make tougher-to-read code
  - Organization for performance, not understanding

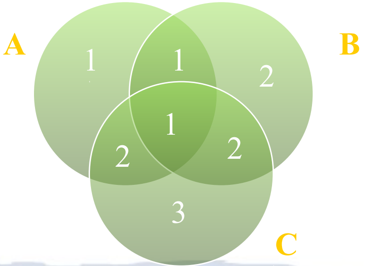
Logical Approaches:
Use Lookup Tables

- Table lookups can be much faster than following a logical computation
- Example: diagram of logical values:



Logical Approaches:
Use Lookup Tables

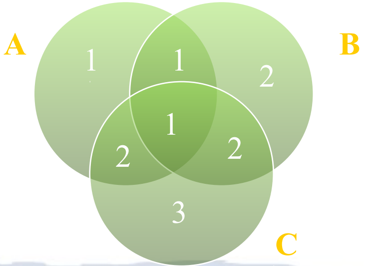
```
if ((a && !c) || (a && b && c)) {
    val = 1;
} else if ((b && !a) || (a && c && !b)) {
    val = 2;
} else if (c && !a && !b) {
    val = 3;
} else {
    val = 0;
}
```



Logical Approaches:
Use Lookup Tables

```
static int valtable[2][2][2] = {
   // !b!c   !bc    b!c    bc
       0,     3,     2,     2,   // !a
       1,     2,     1,     1,   // a
};

val = valtable[a][b][c]
```



Logical Approaches:
Lazy Evaluation

- Idea: wait to compute until you’re sure you need the value
  - Often, you never actually use the value!
- Tradeoff overhead to maintain lazy representations vs. time saved on computing unnecessary stuff

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Logical Approaches:
Lazy Evaluation

```
Class listofnumbers {
   private int howmany;
   private float* list;
   private float median;

   float getMedian() {
      return median;
   }

   void addNumber(float num) {
      //Add number to list
      //Compute Median
   }
```

Logical Approaches:
Lazy Evaluation

```
Class listofnumbers {
   private int howmany;
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   float getMedian() {
      //Compute Median
      return median;
   }

   void addNumber(float num) {
      //Add number to list
   }
```

Tuning Loops:
Unswitching

- Remove an if statement unrelated to index from inside loop to outside

```
for (i=0; i<n; i++)
    if (type == 1)
        sum1 += a[i];
    else
        sum2 += a[i];

if (type == 1)
    for (i=0; i<n; i++)
        sum1 += a[i];
else
    for (i=0; i<n; i++)
        sum2 += a[i];
```

Tuning Loops:
Jamming

- Combine two loops

```
for (i=0; i<n; i++)
     sum[i] = 0.0;
for (i=0; i<n; i++)
     rate[i] = 0.03;

for (i=0; i<n; i++) {
     sum [i] = 0.0;
     rate[i] = 0.03;
}
```

Tuning Loops:
Unrolling

- Do more work inside loop for fewer iterations
  - Complete unroll: no more loop…
  - Occasionally done by compilers (if recognizable)

```
for (i=0; i<n; i++) {
    a[i] = i;
}

for (i=0; i<(n-1); i+=2) {
    a[i] = i;
    a[i+1] = i+1;
}
if (i == n-1)
    a[n-1] = n-1;
```

Tuning Loops:
Minimizing Interior Work

- Move pointer/memory references and repeated computation outside

```
for (i=0; i<n; i++) {
    balance[i] += purchase->allocator->indiv->borrower;
    amounttopay[i] = balance[i]*(prime+card)*pcentpay;
}

newamt = purchase->allocator->indiv->borrower;
payrate = (prime+card)*pcentpay;
for (i=0; i<n; i++) {
    balance[i] += newamt;
    amounttopay[i] = balance[i]*payrate;
}
```

Tuning Loops:
Sentinel Values

- Test value placed after the end of the array to guarantee termination

```
i=0;
found = FALSE;
while ((!found) && (i<n)) {
   if (a[i] == testval)
       found = TRUE;
   else
       i++;
}
if (found) … //Value found

savevalue = a[n];
a[n] = testval;
i=0;
while (a[i] != testval)
    i++;
if (i<n) … // Value found (loop terminated before reaching end)
```

Tuning Loops:
Busiest Loop on Inside

- Reduce overhead by calling fewer loops

```
for (i=0; i<100; i++)  // 100
    for (j=0; j<10; j++)   // 100x10=1000
        dosomething(i,j);
```

Total of 1100 loop iterations

```
for (j=0; j<10; j++)       // 10
    for (i=0; i<100; i++) // 10x100=1000
        dosomething(i,j);
```

Total of 1010 loop iterations

Tuning Loops:
Strength Reduction

- Replace multiplication involving loop index by addition

```
for (i=0; i<n; i++)
    a[i] = i*conversion;

sum = 0;                // or: a[0] = 0;
for (i=0; i<n; i++) {   // or: for (i=1; i<n; i++)
    a[i] = sum;         // or: a[i] =
    sum += conversion;  //     a[i-1]+conversion;
}
```

Transforming Data:
Integers Instead of Floats

- Integer math tends to be faster than floating point
- Use ints instead of floats where appropriate
- Likewise, use floats instead of doubles
- Need to test on system…

Transforming Data:
Fewer Array Dimensions

- Express as 1D arrays instead of 2D/3D as appropriate
  - Beware of assumptions on memory organization

```
for (i=0; i<rows; i++)
    for (j=0; j<cols; j++)
        a[i][j] = 0.0;

for (i=0; i<rows*cols; i++)
    a[i] = 0.0;
```

Transforming Data:
Minimize Array Refs

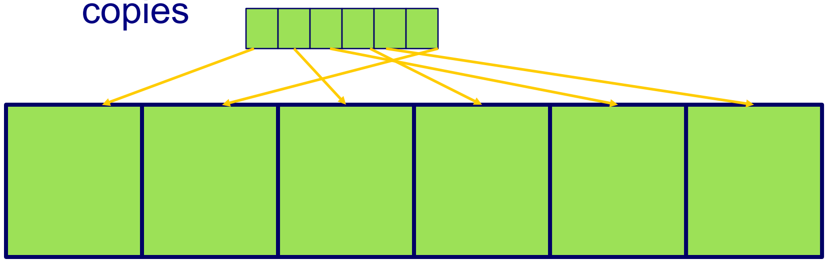
- Avoid repeated array references
  - Like minimizing interior work

```
for (i=0; i<r; i++)
    for (j=0; j<c; j++)
        a[j] = b[j] + c[i];

for (i=0; i<r; i++) {
    temp = c[i];
    for (j=0; j<c; j++)
        a[j] = b[j] + temp;
}
```

Transforming Data:
Use Supplementary Indexes

- Sort indices in array rather than elements themselves
  - Tradeoff extra dereference in place of copies



Transforming Data:
Use Caching

- Store data instead of (re-)computing
  - e.g. store length of an array (ended by sentinel) once computed
  - e.g. repeated computation in loop
- Overhead in storing data is offset by
  - More accesses to same computation
  - Expense of initial computation

Tuning Expressions:
Algebraic Identities and Strength Reduction

- Avoid excessive computation
  - sqrt(x) < sqrt(y) equivalent to x < y
- Combine logical expressions
  - !a || !b equivalent to !(a && b) -- 3 vs. 2 ops
- Use trigonometric/other identities
- Right/Left shift to multiply/divide by 2
- e.g. Efficient polynomial evaluation
  - A*x*x*x + B*x*x + C*x + D = (((A*x)+B)*x)+C)*x+D

Tuning Expressions:
Compile-Time Initialization

- Known constant passed to function can be replaced by value.

```
log2val = log(val) / log(2);


const double LOG2 =
  0.69314718;
log2val = log(val) / LOG2;
```

Tuning Expressions:
Avoid System Calls

- Avoid calls that provide more computation than needed
  - e.g. if you need an integer log, don’t compute floating point logarithm
    - Could count # of shifts needed
    - Could program an if-then statement to identify the log (only a few cases)

Tuning Expressions:
Use Correct Types

- Avoid unnecessary type conversions
- Use floating-point constants for floats, integer constants for ints

Tuning Expressions:
Precompute Results

- Storing data in tables/constants instead of computing at run-time
- Even large precomputation can be tolerated for good run-time
- Examples
  - Store table in file
  - Constants in code
  - Caching
  - Function look-up tables

Tuning Expressions:

Eliminate Common Subexpressions

- Anything repeated several times can be computed once ("factored" out) instead
  - Compilers pretty good at recognizing, now

```
a = b + (c/d) - e*(c/d) +
  f*(d/c);
```

```
t = c/d;
a = b + t - e*t + f/t;
```

Other Tuning:

Inlining Routines

- Avoiding function call overhead by putting function code in place of function call
  - Also called Macros
- Some languages support directly (C++: `inline`)
- Compilers tend to minimize overhead already, anyway

Other Tuning:

Recoding in Low-Level Language

- Rewrite sections of code in lower-level (and probably much more efficient) language
- Lower-level language depends on starting level
  - Python -> C++
  - C++ -> assembler
- Should only be done at bottlenecks
- Increase can vary greatly, can easily be worse

Other Tuning:

Buffer I/O

- Buffer input and output
  - Allows more data to be processed at once
  - Usually there is overhead in sending output, getting input

Other Tuning:
Handle Special Cases Separately

- After writing general purpose code, identify hot spots
  - Write special-case code to handle those cases more efficiently
- Avoid overly complicated code to handle all cases
  - Classify into cases/groups, and separate code for each

Other Tuning:
Use Approximate Values

- Sometimes can get away with approximate values
- Use simpler computation if it is “close enough”
  - e.g. integer sin/cos, truncate small values to 0.

Other Tuning:
Recompute to Save Space

- Opposite of Caching!
- If memory access is an issue, try *not* to store extra data
- Recompute values to avoid additional memory accesses, even if already stored somewhere

Code Tuning Summary

- Tuning is a “last” step, and should only be applied when it is needed
- Always test your changes
  - Often will not improve or even make worse
  - If there is no improvement, go back to earlier version
- Usually, code readability is more important than performance benefit gained by tuning