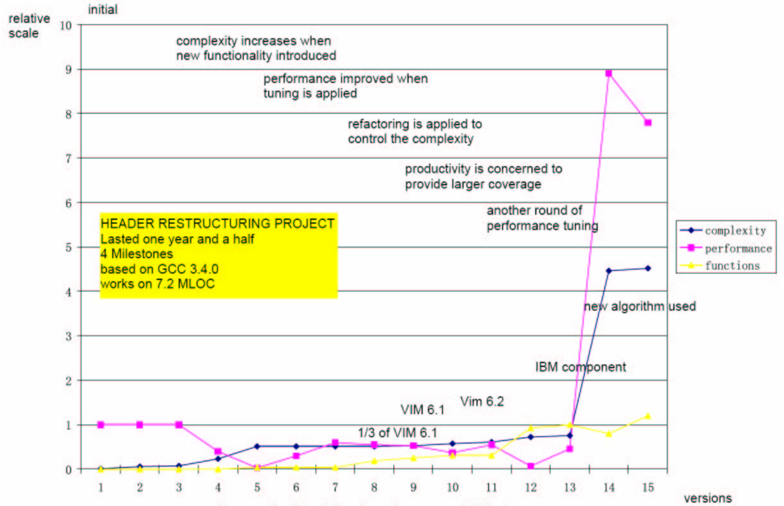
Tutorial V.
Software Measurements: Performance and Complexity

Timing: /bin/time

Profiler: gprof, java -prof

Metrics: McCabe, Halstead

Software evolution based on quantitative metrics (part of Deliverable of phase C)



An example of evolution through measured attributes

Software Quality

- Software Quality is too abstract without measurement
- Break down into Performance, Understandability, Testability, Maintainability, Security, and so on …
- Today, we handle Performance and Complexity
- Performance is broken down into Time and Space performance
- Complexity is the major reason for low Understandability, Testability, Maintainability

Time Performance

- Tool: /bin/time

```
werewolf~/>/usr/bin/time
Usage: /usr/bin/time [-apvV] [-f format] [-o file] [--append] [--verbose]
       [--portability] [--format=format] [--output=file] [--version] [--quiet] [--help]
command [arg...]
```

- Example:

```
werewolf~/software/axis-1_1/>/usr/bin/time client.sh
IBM: Armonk, NY
1.48user 0.07system 0:01.59elapsed 97%CPU (0avgtext+0avgdata 0maxresident)k
0inputs+0outputs (2527major+2588minor)pagefaults 0swaps
```

- What are User time, CPU time, System Time ?
- How to know where the time is spent?

Profiler

- Profiler instruments the code by book-keeping instructions. When the program runs, these instructions can be used to tell
  - Which functions are called the most
  - How is time distributed among different functions?
  - From these data, one can pinpoint the bottleneck of the execution time
- Profiler usually comes together with Compilers
- Many different profilers:
  - For GNUCC (C/C++/Java/Fortran/Ada), use gprof
  - For Java, use “java –prof”

Profiler Case Study - Hello.c

```
#include<stdio.h>
void hibernate(void)
{
   long i;
   for(i =0; i<1000000; i=i+1)
   {
      printf(" A long hibernate...\n");
   }
}
void nap(void)
{
   printf(" Just a short nap!\n");
}
int main()
{
   printf("Take a nap!\n");
   nap();
   printf("Go to hibernate!\n");
   hibernate();
}
```

Gprof

- gcc –p –pg hello.c
  (gmon.out is generated)
- gprof a.out

```
index % time   self   children  called name
                0.02    0.00      1/1    main [2]
[1]     100.0  0.02    0.00        1    hibernate [1]
 -----------------------------------------------
[2]     100.0   0.00    0.02             main [2]
                0.02    0.00      1/1    hibernate [1]
                0.00    0.00      1/1    nap [3]
-----------------------------------------------
                0.00    0.00      1/1    main [2]
[3]       0.0   0.00    0.00       1     nap [3]
```

Profiler Case Study - Hello.java

```
public class Hello {

     static private void hibernate(){
                    long i;
                    for(i=0; i<100; i++){
                                   System.out.println("- A long hibernate...");
                    }
     }
     static private void nap(){
                    long i;
                    System.out.println("- Just a nap...");
     }

     public static void main(String args[]){
                    System.out.println("Take a nap!");
                    Hello.nap();
                    System.out.println("Go to hibernate!");
                    Hello.hibernate();
     }
}
```

java –prof

- javac Hello.java
- java –prof Hello

```
count              callee                                    caller
100    java.io.PrintStream.println(Ljava/lang/String;)V Hello.hibernate()
1      java.io.PrintStream.println(Ljava/lang/String;)V Hello.nap()
1      Hello.nap()V Hello.main([Ljava/lang/String;)
1      Hello.hibernate()V Hello.main([Ljava/lang/String;)
```

Tools for space performance

- Monitoring memory consumptions
- Gabage collection: System.gc()
- Jim Patrick, “Handling memory leaks in Java programs”, http://www-106.ibm.com/developworks/java/library/j-leaks.
- Borland Optimizeit (It may be used for evaluation purposes)

Complexity Metrics

- McCabe complexity:
  - Control flow graph <V,E>
  - |V| + |E| - 2
  - It is also measure for test coverage
- Halstead complexity:
  - Operators: N1, unique n1, Operands: N2, unique n2
  - Length = (N1+N2)
    Volume = (N1+N2) $\log_2$ (n1+n2)
    Level = (2/n1)*(n2/N2)
    Efforts (mental discrimination) = Volume / Level
    Time = Efforts / 180000 (hours)
    (50 discrimination per second)
  - It is also useful for project estimations

Metric tools you can use

- /u/yijun/software/bin/mccabe
- /u/yijun/software/bin/halstead
- Example
- cd /u/yijun/src/vim63/src
  mccabe *.c
  halstead *.c

Results for the VIM example

```
mccabe *.c | less
File           Name           Complexity     No. of returns
-------------- --------------- ----------     --------------
arabic.c       chg_c_f2m             34              1
arabic.c       A_is_a                38              2
arabic.c       A_is_special           1              1
arabic.c       A_is_f                40              2
arabic.c       A_is_iso               1              1
arabic.c       chg_c_i2m             25              1
arabic.c       A_is_s                37              2
arabic.c       chg_c_a2f             39              1
arabic.c       chg_c_a2i             39              1
arabic.c       half_shape             3              3
arabic.c       A_is_ok                1              1
arabic.c       chg_c_a2m             39              1
arabic.c       chg_c_a2s             39              1
arabic.c       A_is_valid             1              1
arabic.c       arabic_shape          12              2
arabic.c       chg_c_laa2i            6              1
arabic.c       chg_c_laa2f            6              1
arabic.c       A_firstc_laa           2              2
arabic.c       A_is_formb             1              1
arabic.c       A_is_harakat           1              1
buffer.c       fileinfo              18              0
…
3923 functions
…
```

```
halstead *.c | less
File        length  volume  level  effort   time

arabic.c       2334    18441   0.016967       1086882 6.0
buffer.c       16778   166692  0.004443       37516321       208.4
charset.c      6106    56173   0.007947       7068181 39.3
diff.c  7598    65257   0.003931       16600691       92.2
digraph.c      14522   157014  0.009542       16455714       91.4
edit.c  22527   230316  0.004175       55170619       306.5
eval.c  37745   397470  0.002855       139198597      773.3
ex_cmds.c      19611   198997  0.004440       44821078       249.0
ex_cmds2.c     18711   191075  0.004472       42729876       237.4
ex_docmd.c     32895   355904  0.004319       82409564       457.8
ex_eval.c      5541    45754   0.004331       10564642       58.7
ex_getln.c     18338   182191  0.003881       46943439       260.8
farsi.c 6161    52634   0.006575       8004959 44.5
fileio.c       26949   278105  0.003520       79013285       439.0
fold.c  10686   93084   0.002786       33409135       185.6
getchar.c      13661   129337  0.003870       33416492       185.6
gui.c   15406   153995  0.004973       30963256       172.0
gui_at_fs.c    11929   110062  0.003880       28365559       157.6
gui_at_sb.c    5690    48870   0.005467       8939484 49.7
gui_athena.c   7797    71321   0.005297       13464608       74.8
gui_beval.c    4587    41152   0.008172       5035965 28.0
gui_gtk.c      11409   111274  0.005997       18553811       103.1
gui_gtk_f.c    3136    25477   0.007770       3278996 18.2
       … 65 files …
```