November 24, 1969

MPL-43

To: Multics Performance Log

From: J. H. Saltzer

Subject: Comparison of Compile Time, Run Time and Size of a Small Program Using BASIC, FORTRAN, and PL/I.

A short FORTRAN subroutine which reads a number, ℓ , and then computes and prints the $(\ell + 2)$'nd prime was borrowed from the Multics standard certifier script, and recoded in BASIC and PL/I. The three versions were then compared on several points; the results are presented here.

I. Source Programs

The two new language versions were coded to be as similar as possible in algorithm to the original FORTRAN routine. The lack of a modulo function in BASIC was bypassed by a direct computation using the integer function; this change being in the innermost loop may have affected execution time performance described in Section II.

The three source programs are listed for comparison in Figure I.

II. Execution Time

Each program was executed several times each, with input values of 5, 20, 40, 90, and 175. The input lines to both the command interpreter and the program itself were queued. In order to distinguish page fault time from pure execution time, each command was queued two or more times, in an attempt to drive the number of page-faults to zero on second and later executions. Each experiment was repeated several times, and the smallest cpu time observed was recorded, in an attempt to minimize the effect of interrupts whose execution time is currently charged to the executing process. The results are shown in Figure III. In general, this graph suggests that the execution time of the three object programs is in the ratio 1:2:3 for FORTRAN, PL/I, and BASIC, respectively. Note that with input value 175, the required execution time of all three programs solidly swamps out the end effects of program starting and input/output statements, and even of BASIC compilation time.

The difference in execution time of FORTRAN and PL/I appeared worth further study, so the object programs were compared in detail. Figure IV and V exhibit the two object programs. In terms of the physical program

I. Comparison of source program listings:

fpm.fortran

11/24/69

```
 subroutine fpm
 read(5,70) l
70 format(i3)
 m = 1
 do 10 i = 3,100000
 k = i-1
 do 20 j = 2,k
 if(mod(i,j)) 20,10,20
20 continue
 m = m+1
 if(m-l) 10,40,40
10 continue
40 write(6,60) m,i
60 format(7h Prime ,i4,3h is,i6)
 return
 end
```

pm.pl1

```
pm:          procedure;
declare (m,i,k,j,l) fixed binary;
             call read_list_(l);
             m = 1;
             do i = 3 to 100000;
             k = i - 1;
             do j = 2 to k;
             if mod(i,j) = 0 then go to 1190;
1160:        end;
             m = m+1;
             if m>= l then go to 1200;
1190:        end;
1200:        call ioa_("prime ¬d is ¬d", m, i);
             end;
```

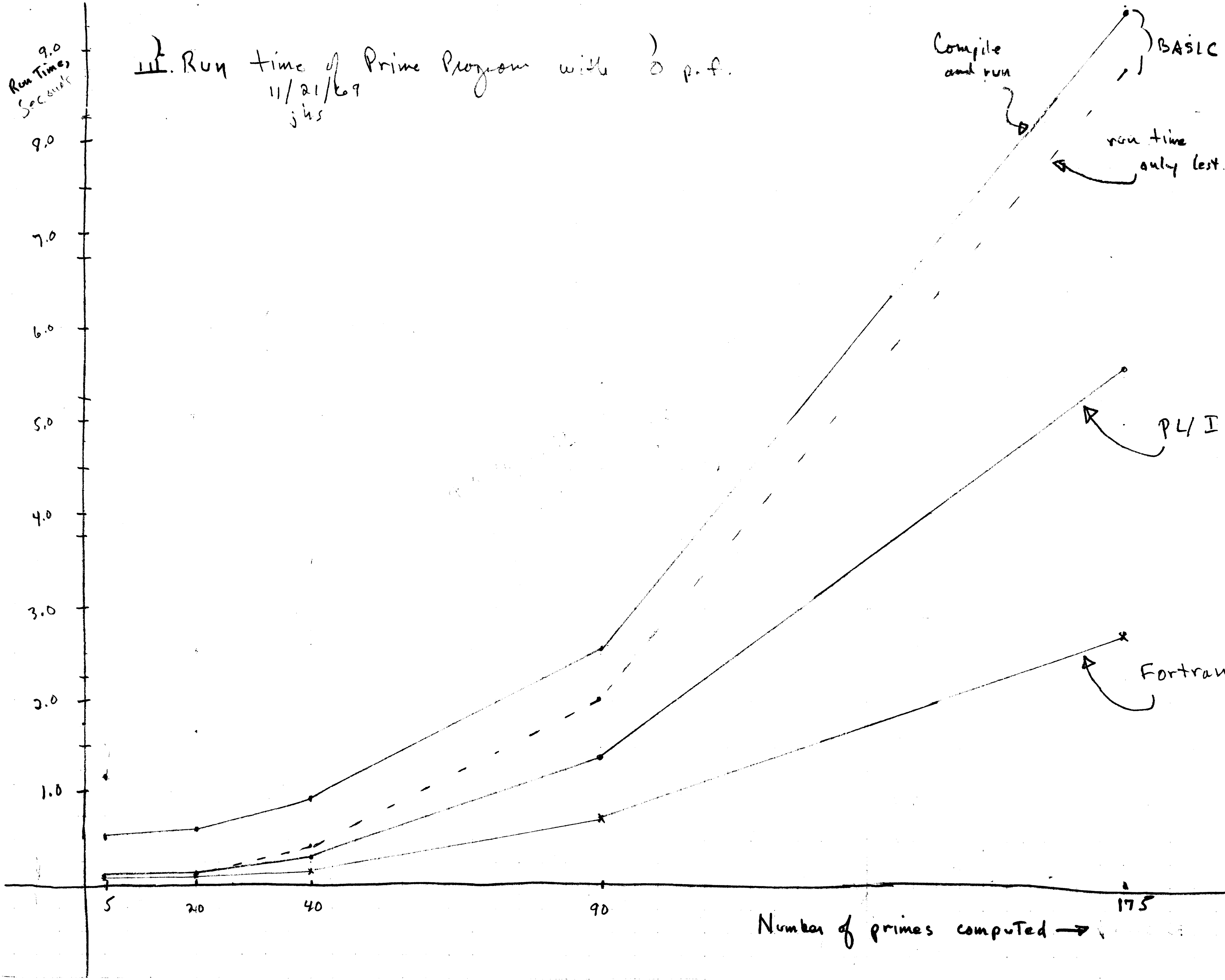
pm.basic

```
100 input l
110 let m = 1
120 for i = 3 to 100000
130 let k = i - 1
140 for j = 2 to k
150 if (i = int(i/j)*j) then 190
160 next j
170 let m = m + 1
180 if m >= l then 200
190 next i
200 print "prime";m;"is";i
210 end
```

II. Queuing of command input to obtain zero-page-fault case:

```
basic pm
20
basic pm
20
basic pm

Compile time in ms. = 368, Page waits = 21
            11/21/69          23:07

? PRIME 20    IS 71

r 2307  1.178  67


Compile time in ms. = 193, Page waits = 0
            11/21/69          23:07

? PRIME 20    IS 71

r 2307  .611  0
```

III. Run time of Prime Program with $\emptyset$ p.f.
11/21/69
jhs



sizes, the reason for the difference in execution time is clear. The inner and outer program loops measure out as follows:

	FORTRAN	PL/I
Inner loop	11 instructions	14 inst. + 5 in subroutine = 19
Outer loop	22 instructions	39 inst. (including subroutine

Upon inspecting the compiled code, the difference seems to be primarily that FORTRAN is very good on register optimization, while PL/I largely ignores the subject. Compare also the FORTRAN compiled "AOS" on line 152, compared with the PL/I sequence starting at 73, both for the statement "m = m + 1". It appears that FORTRAN misses few tricks.

III. Compile Time

The compile times were compared, using a similar command stacking technique to get the compiler "in core" and minimize the effect of missing page faults. It was found to be impossible to bring the number of page faults to zero when using PL/I as the compiler apparently does not fit into the available (~160K) core. Results were as follows, in both cases after linking had been accomplished by an earlier command.

	Compile Time/sec.	Page Faults
FORTRAN	1.720	0
PL/I	4.698	170
BASIC	.500(est.)	0

The BASIC compile time is estimated from the lower asymptote of its compile-and-execute curve in Figure III.

IV. Working Set Size

Each program was compiled following a "flush" command, and then executed (with input value 5) following a "flush" command. The experiment was repeated several times to insure that other users had not distorted the result. The following table indicates the number of missing-page faults observed.

IV. Compilation of source lines 4-12 by FORTRAN:

11/24/69

```
STATEMENT BEGINNING ON LINE #     4
     000131  000001236007   000000                 LDQ       =0000001,DL
     000132  000001756100   000000                 STQ      AP/m
     000133  000003236007   000000                 LDQ        000003,DL
                    000134             A00037      NULL
     000134  000002756100   000000                 STQ      AP/i
STATEMENT BEGINNING ON LINE #     6
     000135  000001176007   000000                 SBQ       =0000001,DL
     000136  000004756100   000000                 STQ      AP/k
     000137  000002236007   000000                 LDQ        000002,DL



                    000140             A00063      NULL
     000140  000005756100   000000                 STQ      AP/j
STATEMENT BEGINNING ON LINE #     8
     000141  000002236100   000000                 LDQ      AP/i
     000142  000005506100   000000                 DIV      AP/j
     000143  000044773000   000000                 LRL        000044
     000144  000000600000   200000                 TZE        A00144
                    000145             A00105      NULL
     000145  000005236100   000000                 LDQ      AP/j
     000146  000001036007   000000                 ADLQ       000001,DL
     000147  000004116100   000000                 CMPQ     AP/k
     000150  000140600000   200000                 TZE        A00063
     000151  000140602000   200000                 TNC        A00063
STATEMENT BEGINNING ON LINE #    10
     000152  000001054100   000000                 AOS      AP/m
STATEMENT BEGINNING ON LINE #    11
     000153  000001236100   000000                 LDQ      AP/m
     000154  000003176100   000000                 SBQ      AP/1
     000155  000000605000   200000                 TPL        A00156
                    000156             A00144      NULL
     000156  000002236100   000000                 LDQ      AP/i
     000157  000001036007   000000                 ADLQ       000001,DL
     000160  303241116007   000000                 CMPQ       303241,DL
     000161  000134602000   200000                 TNC        A00037
                    000162             A00155      NULL
```

Inner Loop

Outer Loop

V. Compilation of source lines 4-12 by PL/I:

11/24/69

```
                                                               STATEMENT  1 ON LINE   4
000036  aa   777745 2360 04     liq      -27,ic                000003 = 000000000001
000037  aa  6 00124 7561 00     stq      sp|84

                                                               STATEMENT  1 ON LINE   5
000040  aa   777747 2360 04     liq      -25,ic                000007 = 000000000003
000041  aa  6 00125 7561 00     stq      sp|85
000042  aa  6 00125 2361 00     liq      sp|85
000043  aa   777745 1160 04     cmpq     -27,ic                000010 = 000000303240
000044  aa   000002 6000 04     tze      2,ic                  000046
000045  aa   000041 6050 04     tpl      33,ic                 000106
                                                               STATEMENT  1 ON LINE   6
000046  aa  6 00125 2361 00     liq      sp|85
000047  aa   777734 1760 04     sbq      -36,ic                000003 = 000000000001
000050  aa  6 00126 7561 00     stq      sp|86


                                             Outer
                                             Loop
                                                               STATEMENT  1 ON LINE   7
000051  aa  6 00126 2361 00     liq      sp|86
000052  aa  6 00131 7561 00     stq      sp|89
000053  aa   777736 2360 04     liq      -34,ic                000011 = 000000000002
000054  aa  6 00127 7561 00     stq      sp|87
000055  aa  6 00127 2361 00     liq      sp|87
000056  aa  6 00131 1161 00     cmpq     sp|89
000057  aa   000002 6000 04     tze      2,ic                  000061
000060  aa   000013 6050 04     tpl      11,ic                 000073
                                          Inner                STATEMENT  1 ON LINE   8
000061  aa  6 00125 2361 00     liq      sp|85                   5 instruction
000062  aa  6 00127 3521 00     eapbp    sp|87                   subroutine
000063  aa  0 00704 6701 00     tsblp    ap|452                mod_fx1
000064  aa   777716 1160 04     cmpq     -50,ic                000002 = 000000000000
000065  aa   000002 6010 04     tnz      2,ic                  000067
000066  aa   000014 7100 04     tra      12,ic                 000102
                                          Loop                 STATEMENT  1 ON LINE   9
000067  aa  6 00127 2361 00     liq      sp|87
000070  aa   777713 0760 04     aiq      -53,ic                000003 = 000000000001
000071  aa  6 00127 7561 00     stq      sp|87
000072  aa   777763 7100 04     tra      -13,ic                000055
                                                               STATEMENT  1 ON LINE  10
000073  aa  6 00124 2361 00     liq      sp|84
000074  aa   777707 0760 04     aiq      -57,ic                000003 = 000000000001
000075  aa  6 00124 7561 00     stq      sp|84
                                                               STATEMENT  1 ON LINE  11
000076  aa  6 00124 2361 00     liq      sp|84
000077  aa  6 00130 1161 00     cmpq     sp|88
000100  aa   000002 6040 04     tmi      2,ic                  000102
000101  aa   000005 7100 04     tra      5,ic                  000106
                                                               STATEMENT  1 ON LINE  12
000102  aa  6 00125 2361 00     liq      sp|85
000103  aa   777700 0760 04     aiq      -64,ic                000003 = 000000000001
000104  aa  6 00125 7561 00     stq      sp|85
000105  aa   777735 7100 04     tra      -35,ic                000042
```

	Compile	Run
BASIC	74	
FORTRAN	105	15
PL/I	225	27

Note that the PL/I compiler taken only a few more page faults when it follows "flush" than when it follows itself. The unusually large number of pages required to execute the PL/I object program suggested further analysis. Figure VI shows a page trace of the PL/I program. Most of the trouble clearly arose from the use of subroutine "read_list_" for input, since that subroutine call resulted in 12 distinct page faults. It also appears that in system 4.7f, segment "pl1-operators is not yet wired-down.

A second fact uncovered by the page trace is that segment 110, the Teletype DIM (bound-tty-active) is organized so that all six of its pages are touched by a write and read call. In earlier systems, this segment was "optimally bound" such that only three pages were touched. A review of the contents of bound-tty-active suggests that such a reordering ot its components could again reduce the number of pages touched to three.

VI. Page fault trace of PL/I object program execution following a "flush" command:

10/23/69

```
meter_start;flush
measurement started
pm 5
5
meter_stop
r 819  2.564  293

Ready for 1 value
prime 5 is 11
r 819  .322  27

measurement stopped
r 819  .098  6
                                 Page #
                                     Segment # or name if known
print_pages 35
 18696668625  0 000124              meter_stop
 18696643303  0 phcs_.link          command
 18696508150 10 meter_start
 18696489710 31 !BBBHwmPcGZQDDx
 18696402098  5 !BBBHwmPcGZQDDx
 18696359160  3 read_list_
 18696328938  0 free_
 18696286736  0 bin_oct               12 pages
 18696240114  0 read_list_            touched
 18696192060  4 read_list_            by
 18696169407  2 read_list_            read_list_
 18696031631  0 write_out
 18696006734 11 !BBBHwmPcGZQDDx
 18695970285  2 stack_01                          27 pages
 18695959267  1 stack_01                          touched
 18695923550  3 stack_01
 18695839472  1 read_list_
 18695803045  1 pl1_operators  not wired yet!
 18695770729  0 pl1_operators
 18695621299  0 pm
 18695598870 32 !BBBHwmPcGZQDDx
 18695567624  6 000110
 18695546720  0 000110
 18695510733  3 000110
 18695475981  1 000053     TTY DIM
 18695432839  2 000110
 18695384450  0 000112
 18695345641  5 000110
 18695319802  4 000110
 18695288055  5 000016
 18695266610  1 listen_
 18695217248  1 hcs_.link            tail end
 18695180876  0 000120               of flush
 18695155433  0 process_info         command
 18695135919  0 hcs_.link
r 820  3.227  63
```

Time in μsec.