

**Component Based MMIX Simulator using Multiple
Programming Paradigms**

A dissertation submitted in partial fulfilment of the requirements for the
MSc in Advanced Computing Technologies

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Abstract

There are currently over 2,500¹ different programming languages, with more created every year. These programming languages can get grouped together in numerous different ways. This makes the decision of what language to use when starting a new project extremely difficult.

There are several ways in which we can reach this decision; choose the language that your team knows best; choose the language that makes the most sense to implement the critical part of your system; choose a simple general purpose language; choose a language that has got an active community. There is no acknowledged best approach to take.

Another approach would be to split your application up into separate components and using a different programming language for each component. This allows us choose the most appropriate programming language for each component.

The purpose of this project is to examine this approach. The application that we will create will be a simulator for an artificial machine language. The artificial machine language that we will use is called MMIX, it was developed by Donald Knuth as part of his seminal work *The Art of Computer Programming*[Knu11].

¹From the language list[Kin]

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Appendix A

Source Code

A.1 Assembler

A.2 Graphical User Interface

A.3 Virtual Machine

Appendix B

Intermediate Assembler Representations

B.1 Definitions

B.2 Test Application

B.2.1 Sample Test MMIXAL Code

The sample mmixal application I am using to test the system is taken from Fascile 1[Knu]. The complete code listing is


```

L      IS      500
t      IS      $255
n      GREG    0
q      GREG    0
r      GREG    0
jj     GREG    0
kk     GREG    0
pk     GREG    0
mm     IS      kk
      LOC      Data_Segment
PRIME1 WYDE    2
      LOC      PRIME1+2*L
ptop   GREG    @
j0     GREG    PRIME1+2-@
BUF    OCTA    0
      LOC      #100
Main   SET     n,3
      SET     jj,j0
2H     STWU    n,ptop,jj
      INCL    jj,2
3H     BZ      jj,2F
4H     INCL    n,2
5H     SET     kk,j0
6H     LDWU    pk,ptop,kk
      DIV     q,n,pk
      GET     r,rR
      BZ      r,4B
7H     CMP     t,q,pk
      BNP     t,2B
8H     INCL    kk,2
      JMP     6B
      GREG    @
Title  BYTE    "First Five Hundred Primes"
NewLn  BYTE    #a,0
Blanks BYTE    " ",0
2H     LDA     t,Title
      TRAP    0,Fputs,StdOut
      NEG     mm,2
3H     ADD     mm,mm,j0
      LDA     t,Blanks
      TRAP    0,Fputs,StdOut
2H     LDWU    pk,ptop,mm
0H     GREG    #2030303030000000
      STOU    0B,BUF
      LDA     t,BUF+4
1H     DIV     pk,pk,10
      GET     r,rR
      INCL    r,'0'
      STBU    r,t,0
      SUB     t,t,1
      PBNZ    pk,1B
      LDA     t,BUF
      TRAP    0,Fputs,StdOut
      INCL    mm,2*L/10
      PBN     mm,2B
      LDA     t,NewLn
      TRAP    0,Fputs,StdOut
      CMP     t,mm,2*(L/10-1)
      PBNZ    t,3B
      TRAP    0,Halt,0

```

B.2.2 Parsed Sample File

The final version of the parsed source code for the test application is

```
LabelledPILine {
    lppl_id = IsNumber 500, lppl_ident = Id "L", lppl_loc = 0
}
LabelledPILine {
    lppl_id = IsRegister 255, lppl_ident = Id "t", lppl_loc = 0
}
LabelledPILine {
    lppl_id = GregEx (ExpressionRegister '\254' (ExpressionNumber
        0)), lppl_ident = Id "n", lppl_loc = 0
}
LabelledPILine {
    lppl_id = GregEx (ExpressionRegister '\253' (ExpressionNumber
        0)), lppl_ident = Id "q", lppl_loc = 0
}
LabelledPILine {
    lppl_id = GregEx (ExpressionRegister '\252' (ExpressionNumber
        0)), lppl_ident = Id "r", lppl_loc = 0
}
LabelledPILine {
    lppl_id = GregEx (ExpressionRegister '\251' (ExpressionNumber
        0)), lppl_ident = Id "jj", lppl_loc = 0
}
LabelledPILine {
    lppl_id = GregEx (ExpressionRegister '\250' (ExpressionNumber
        0)), lppl_ident = Id "kk", lppl_loc = 0
}
LabelledPILine {
    lppl_id = GregEx (ExpressionRegister '\249' (ExpressionNumber
        0)), lppl_ident = Id "pk", lppl_loc = 0
}
LabelledPILine {
    lppl_id = GregEx (ExpressionRegister '\248' (ExpressionNumber
        0)), lppl_ident = Id "mm", lppl_loc = 0
}
PlainPILine {
    ppl_id = LocEx (ExpressionNumber 536870912), ppl_loc =
        536870912
}
LabelledPILine {
    lppl_id = WydeArray "\STX", lppl_ident = Id "PRIME1", lppl_loc
        = 536870912
}
PlainPILine {
    ppl_id = LocEx (ExpressionNumber 536871912), ppl_loc =
        536871912
}
LabelledPILine {
    lppl_id = GregEx (ExpressionRegister '\247' (ExpressionNumber
        536871912)), lppl_ident = Id "ptop", lppl_loc = 536871912
}
LabelledPILine {
    lppl_id = GregEx (ExpressionRegister '\246' (ExpressionNumber
        (-998))), lppl_ident = Id "j0", lppl_loc = 536871912
}
LabelledPILine {
    lppl_id = OctaArray "\NUL", lppl_ident = Id "BUF", lppl_loc =
        536871912
}
```

```

PlainPILine {
    ppl_id = LocEx (ExpressionNumber 256), ppl_loc = 256
}
LabelledPILine {
    lppl_id = Set (Expr (ExpressionIdentifier (Id "n")),Expr (
        ExpressionNumber 3)), lppl_ident = Id "Main", lppl_loc =
        256
}
PlainPILine {
    ppl_id = Set (Expr (ExpressionIdentifier (Id "jj")),Expr (
        ExpressionIdentifier (Id "j0"))), ppl_loc = 260
}
LabelledOpCodeLine {
    lpocl_code = 166, lpocl_ops = [Expr (ExpressionIdentifier (Id
        "n")),Expr (ExpressionIdentifier (Id "ptop")),Expr (
        ExpressionIdentifier (Id "jj"))], lpocl_ident = Id "??2H0"
    , lpocl_loc = 264
}
PlainOpCodeLine {
    pocl_code = 231, pocl_ops = [Expr (ExpressionIdentifier (Id "
        jj")),Expr (ExpressionNumber 2)], pocl_loc = 268
}
LabelledOpCodeLine {
    lpocl_code = 66, lpocl_ops = [Expr (ExpressionIdentifier (Id "
        jj")),Ident (Id "??2H1")], lpocl_ident = Id "??3H0",
    lpocl_loc = 272
}
LabelledOpCodeLine {
    lpocl_code = 231, lpocl_ops = [Expr (ExpressionIdentifier (Id
        "n")),Expr (ExpressionNumber 2)], lpocl_ident = Id "??4H0"
    , lpocl_loc = 276
}
LabelledPILine {
    lppl_id = Set (Expr (ExpressionIdentifier (Id "kk")),Expr (
        ExpressionIdentifier (Id "j0"))), lppl_ident = Id "??5H0",
    lppl_loc = 280
}
LabelledOpCodeLine {
    lpocl_code = 134, lpocl_ops = [Expr (ExpressionIdentifier (Id
        "pk")),Expr (ExpressionIdentifier (Id "ptop")),Expr (
        ExpressionIdentifier (Id "kk"))], lpocl_ident = Id "??6H0"
    , lpocl_loc = 284
}
PlainOpCodeLine {
    pocl_code = 28, pocl_ops = [Expr (ExpressionIdentifier (Id "q"
        )),Expr (ExpressionIdentifier (Id "n")),Expr (
        ExpressionIdentifier (Id "pk"))], pocl_loc = 288
}
PlainOpCodeLine {
    pocl_code = 254, pocl_ops = [Expr (ExpressionIdentifier (Id "r
        ")),Expr (ExpressionIdentifier (Id "rR"))], pocl_loc = 292
}
PlainOpCodeLine {
    pocl_code = 66, pocl_ops = [Expr (ExpressionIdentifier (Id "r"
        )),Ident (Id "??4H0")], pocl_loc = 296
}
LabelledOpCodeLine {
    lpocl_code = 48, lpocl_ops = [Expr (ExpressionIdentifier (Id "
        t")),Expr (ExpressionIdentifier (Id "q")),Expr (
        ExpressionIdentifier (Id "pk"))], lpocl_ident = Id "??7H0"
    , lpocl_loc = 300
}
}

```

```

PlainOpCodeLine {
    pocl_code = 76, pocl_ops = [Expr (ExpressionIdentifier (Id "t"
    )),Ident (Id "??2H0")], pocl_loc = 304
}
LabelledOpCodeLine {
    lpocl_code = 231, lpocl_ops = [Expr (ExpressionIdentifier (Id
    "kk")),Expr (ExpressionNumber 2)], lpocl_ident = Id "??8H0
    ", lpocl_loc = 308
}
PlainOpCodeLine {
    pocl_code = 240, pocl_ops = [Ident (Id "??6H0")], pocl_loc =
    312
}
PlainPILine {
    ppl_id = GregEx (ExpressionRegister '\245' ExpressionAT),
    ppl_loc = 316
}
LabelledPILine {
    lppl_id = ByteArray "First_Five_Hundred_Primes", lppl_ident =
    Id "Title", lppl_loc = 316
}
LabelledPILine {
    lppl_id = ByteArray "\n\NUL", lppl_ident = Id "NewLn",
    lppl_loc = 341
}
LabelledPILine {
    lppl_id = ByteArray "\u\u\u\NUL", lppl_ident = Id "Blanks",
    lppl_loc = 343
}
LabelledOpCodeLine {
    lpocl_code = 34, lpocl_ops = [Expr (ExpressionIdentifier (Id "
    t")),Expr (ExpressionIdentifier (Id "Title"))],
    lpocl_ident = Id "??2H1", lpocl_loc = 347
}
PlainOpCodeLine {
    pocl_code = 0, pocl_ops = [Expr (ExpressionNumber 0),
    PseudoCode 7,PseudoCode 1], pocl_loc = 351
}
PlainOpCodeLine {
    pocl_code = 52, pocl_ops = [Expr (ExpressionIdentifier (Id "mm
    )),Expr (ExpressionNumber 2)], pocl_loc = 355
}
LabelledOpCodeLine {
    lpocl_code = 32, lpocl_ops = [Expr (ExpressionIdentifier (Id "
    mm")),Expr (ExpressionIdentifier (Id "mm")),Expr (
    ExpressionIdentifier (Id "j0"))], lpocl_ident = Id "??3H1"
    , lpocl_loc = 359
}
PlainOpCodeLine {
    pocl_code = 34, pocl_ops = [Expr (ExpressionIdentifier (Id "t"
    )),Expr (ExpressionIdentifier (Id "Blanks"))], pocl_loc =
    363
}
PlainOpCodeLine {
    pocl_code = 0, pocl_ops = [Expr (ExpressionNumber 0),
    PseudoCode 7,PseudoCode 1], pocl_loc = 367
}
LabelledOpCodeLine {
    lpocl_code = 134, lpocl_ops = [Expr (ExpressionIdentifier (Id
    "pk")),Expr (ExpressionIdentifier (Id "ptop")),Expr (
    ExpressionIdentifier (Id "mm"))], lpocl_ident = Id "??2H2"
    , lpocl_loc = 371
}

```

```

}
LabelledPILLine {
    lppl_id = GregEx (ExpressionRegister '\244' (ExpressionNumber
        2319406791617675264)), lppl_ident = Id "??0H0", lppl_loc =
        375
}
PlainOpCodeLine {
    pocl_code = 174, pocl_ops = [Ident (Id "??0H0"),Expr (
        ExpressionIdentifier (Id "BUF"))], pocl_loc = 375
}
PlainOpCodeLine {
    pocl_code = 34, pocl_ops = [Expr (ExpressionIdentifier (Id "t"
        )),Expr (ExpressionNumber 536870924)], pocl_loc = 379
}
LabelledOpCodeLine {
    lpocl_code = 28, lpocl_ops = [Expr (ExpressionIdentifier (Id "
        pk")),Expr (ExpressionIdentifier (Id "pk")),Expr (
        ExpressionNumber 10)], lpocl_ident = Id "??1H0", lpocl_loc
        = 383
}
PlainOpCodeLine {
    pocl_code = 254, pocl_ops = [Expr (ExpressionIdentifier (Id "r
        ")),Expr (ExpressionIdentifier (Id "rR"))], pocl_loc = 387
}
PlainOpCodeLine {
    pocl_code = 231, pocl_ops = [Expr (ExpressionIdentifier (Id "r
        ")),Expr (ExpressionNumber 48)], pocl_loc = 391
}
PlainOpCodeLine {
    pocl_code = 162, pocl_ops = [Expr (ExpressionIdentifier (Id "r
        ")),Expr (ExpressionIdentifier (Id "t")),Expr (
        ExpressionNumber 0)], pocl_loc = 395
}
PlainOpCodeLine {
    pocl_code = 36, pocl_ops = [Expr (ExpressionIdentifier (Id "t"
        )),Expr (ExpressionIdentifier (Id "t")),Expr (
        ExpressionNumber 1)], pocl_loc = 399
}
PlainOpCodeLine {
    pocl_code = 90, pocl_ops = [Expr (ExpressionIdentifier (Id "pk
        ")),Ident (Id "??1H0)], pocl_loc = 403
}
PlainOpCodeLine {
    pocl_code = 34, pocl_ops = [Expr (ExpressionIdentifier (Id "t"
        )),Expr (ExpressionIdentifier (Id "BUF"))], pocl_loc = 407
}
PlainOpCodeLine {
    pocl_code = 0, pocl_ops = [Expr (ExpressionNumber 0),
        PseudoCode 7,PseudoCode 1], pocl_loc = 411
}
PlainOpCodeLine {
    pocl_code = 231, pocl_ops = [Expr (ExpressionIdentifier (Id "
        mm")),Expr (ExpressionNumber 100)], pocl_loc = 415
}
PlainOpCodeLine {
    pocl_code = 80, pocl_ops = [Expr (ExpressionIdentifier (Id "mm
        ")),Ident (Id "??2H2)], pocl_loc = 419
}
PlainOpCodeLine {
    pocl_code = 34, pocl_ops = [Expr (ExpressionIdentifier (Id "t"
        )),Expr (ExpressionIdentifier (Id "NewLn"))], pocl_loc =
        423
}

```

```

}
PlainOpCodeLine {
    pocl_code = 0, pocl_ops = [Expr (ExpressionNumber 0),
        PseudoCode 7,PseudoCode 1], pocl_loc = 427
}
PlainOpCodeLine {
    pocl_code = 48, pocl_ops = [Expr (ExpressionIdentifier (Id "t"
        )),Expr (ExpressionIdentifier (Id "mm")),Expr (
        ExpressionNumber 98)], pocl_loc = 431
}
PlainOpCodeLine {
    pocl_code = 90, pocl_ops = [Expr (ExpressionIdentifier (Id "t"
        )),Ident (Id "??3H1")], pocl_loc = 435
}
PlainOpCodeLine {
    pocl_code = 0, pocl_ops = [Expr (ExpressionNumber 0),
        PseudoCode 0,Expr (ExpressionNumber 0)], pocl_loc = 439
}

```