嵌入式技术

混合语言程序设计

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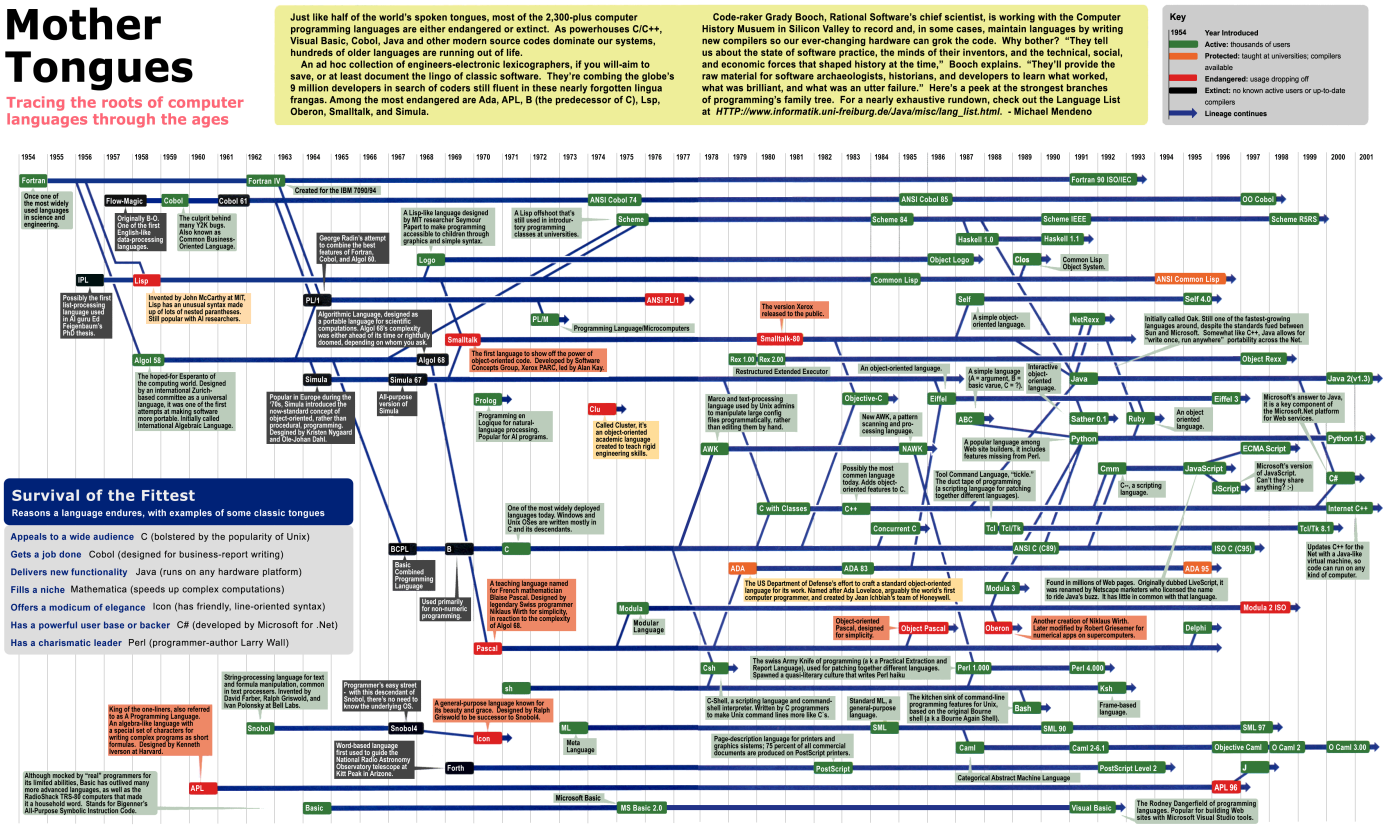
程序设计发展

- 纸带
- 汇编
- 高级语言
  - 函数式语言 (Functional language)：
    - Lisp (LISt Processing)
    - Haskell
    - Caml (Objective Caml)
  - 命令式语言 (Imperative language)：
    - Fortran
    - C
    - Pascal
  - 脚本语言 (Descript language)：
    - HTML
    - Javascript
    - Postscript

程序设计语言列表



Sources: Paul Boutin; Brent Hailpern, associate director of computer science at IBM Research; The Retrocomputing Museum; Todd Proebsting, senior researcher at Microsoft; Gio Wiederhold, computer scientist, Stanford University

混合语言组合与通信

- 组合方式
  - 多个程序
  - 单个程序
- 通信方式
  - 文件
  - 管道
  - 网络
  - 共享库

数据类型与编码

- IEEE 754 float
- Big/Little Endian
- 数组

混合语言编程类型

- 基础
  - C/C++
  - Java
- 扩展/嵌入
  - 汇编
  - Fortran
  - MATLAB/SIMULINK
  - Scilab/Scicos
  - Lua, Python, Perl
  - Lisp, Scheme, Ocaml

语言平台

- Java Platform
  - Java
  - JNI
- .Net Framework
  - C#
  - CLR

C 与 Fortran

- C 调用 Fortran 过程
- Fortran 调用 C 函数

Fortran,main


```
program main
   implicit none
   integer i,j,M,N;
   integer, external:: r2;
   real A(3,3),B(3,3),C(5,3);
   real, allocatable,dimension(:,:)::D;

   A=1;  B=2;  B(1:3:2,1:3:2)=3;
   B(3:2:-1,2:1:-1)=A(1:2,2:3);
   B(int(A(:,1)),1)=(/4,5,6/);
   where(B==3)
       B=5
   endwhere
   C= reshape((/ ((sin(PI/M)*cos(PI/N),
      M=1,5), N=1,3) /),(/5,3/));
   allocate (D(size(C,1),size(C,2)));
   D= reshape((/ ((M+N*10, M=1,5), N=1,3) /),(/5,3/));
   print *, D;
   write(*,*) r2(1)
end program main
```

Fortran, subroutine


```
recursive integer function r2(i) result(r)
integer i
integer r
write(*,*) 'recurseive...',i;
r=r2(i+1);
end function

subroutine s(a)
integer a
a=a+1;
end subroutine
```

Fortran 调用 C 函数


```
PROGRAM MAIN
 use iso_c_binding
INTERFACE
   subroutine fact(n)  bind(C,name="Fact")
      INTEGER(4) n(2,2)
    END subroutine
END INTERFACE
INTEGER(4) n(2,2)
 write(*,*) 'before : ', N
 call fact(N)
 write(*,*) 'after : ', N
END
```

Fortran 调用 C 函数


```
void Fact(int a[2][2])
{
        int i,j;
  /*
  for(i=0;i<4;i++)   *(a[0]+i)=i;
  */
  for(i=0;i<2;i++)for(j=0;j<2;j++) a[i][j]=i*2+j;
  /*
  for(i=0;i<2;i++)for(j=0;j<2;j++) *(a[0]+i*2+j)=1;
  */
}
```

脚本语言编程

- 扩展
  - 速度
  - 系统调用
- 嵌入
  - 灵活
  - 方便

C 与 Lua

- C 调用 Lua 函数
- 回调函数的实现

C 调用 Lua


```
int main (void){
  char buff[256];
  int width,height;
  lua_State *L = lua_open();
  luaL_openlibs(L);
  luaL_loadfile(L,"lua.txt");
  lua_getglobal(L, "width");
  lua_getglobal(L, "height");
  width = (int)lua_tonumber(L, -2);
  height = (int)lua_tonumber(L, -1);
  printf("width is %d,height is %d.\n",width,height);
  lua_getglobal(L, "f"); /* function to be called */
  lua_pushnumber(L, 1.0);
  lua_pushnumber(L, 2.0);
  lua_pcall(L, 2, 2, 0);
  printf("double: %f %f \n",
      lua_tonumber(L, -2), lua_tonumber(L, -1));
  lua_close(L);
  return 0;
}
```

Lua 程序 lua.txt


```
width = 200
height = 300

function f(x1,x2)
return x1,x2
end
```

Callback

```
static int f(lua_State *L){
  double a = lua_tonumber(L, -1);
  lua_pushnumber(L, a);
  return 0;
}
int main(void){
    lua_State *L=lua_open();
    lua_register(L,"f",f);
    double a = 1;
    char *p = "f(a)";
    lua_pushnumber(L,a);
    lua_setglobal(L,"a");
    luaL_loadstring(L,p);
    lua_pcall(L,1,1,0);
    lua_close(L);
    return 0;
}
```

C 与 Scheme

- C 调用 Scheme 函数
- 回调函数的实现

Tinyscheme


```
#include <stdio.h>
#include <stdlib.h>
#include "dynload.h"

int main(int argc, char *argv[])
{
        scheme scmenv;
        scheme_init(&scmenv);
        scheme_set_output_port_file(&scmenv, stdout);
        scheme_load_string(&scmenv,
"(display (+ 1 2 3 4 5 6))(newline)" );
        scheme_deinit(&scmenv);
        exit(EXIT_SUCCESS);
}
```

Foreign Functions

```
pointer square(scheme *sc, pointer args) {
 if(args!=sc->NIL) {
      if(sc->isnumber(sc->pair_car(args))) {
           double v=sc->rvalue(sc->pair_car(args));
           return sc->mk_real(sc,v*v);
      }
 }
 return sc->NIL;
}
```

Foreign functions are defined as closures:

```
sc->interface->scheme_define(
      sc,
      sc->global_env,
      sc->interface->mk_symbol(sc,"square"),
      sc->interface->mk_foreign_func(sc, square));
```

Simplified Wrapper and Interface Generator (SWIG)

- Building more powerful C/C++ programs.
- Rapid prototyping and debugging.
- Systems integration.
- Construction of scripting language extension modules.

Compared with interface definition language (IDL)

- ANSI C/C++ syntax.
- SWIG is not a stub generator.
- SWIG does not define a protocol nor is it a component framework.
- Designed to work with existing C/C++ code.
- Extensibility.

C file

```c
/* File : example.c */
#include <time.h>
double My_variable = 3.0;
int fact(int n) {
    if (n <= 1) return 1;
    else return n*fact(n-1);
}
int my_mod(int x, int y) {
    return (x%y);
}
char *get_time()
{
    time_t ltime;
    time(&ltime);
    return ctime(&ltime);
}
```

Interface file


```
/* example.i */
%module example
%{
/*Put header files here or function declarations*/
extern double My_variable;
extern int fact(int n);
extern int my_mod(int x, int y);
extern char *get_time();
%}

extern double My_variable;
extern int fact(int n);
extern int my_mod(int x, int y);
extern char *get_time();
```

Building a Tcl module

```
unix % swig -tcl example.i
unix % gcc -fpic -c example.c example_wrap.c \
       -I/usr/local/include
unix % gcc -shared example.o example_wrap.o \
       -o example.so
unix % tclsh
% load ./example.so example
% puts $My_variable
3.0
% fact 5
120
% my_mod 7 3
1
% get_time
Sun Feb 11 23:01:07 1996
%
```

Building a Python module

Python module


```
unix % swig -python example.i
unix % gcc -c example.c example_wrap.c \
       -I/usr/local/include/python2.1
unix % ld -shared example.o example_wrap.o \
         -o _example.so
```

We can now use the Python module as follows :

```
>>> import example
>>> example.fact(5)
120
>>> example.my_mod(7,3)
1
>>> example.get_time()
'Sun Feb 11 23:01:07 1996'
>>>
```

Building a Perl module

```
unix % swig -perl5 example.i
unix % gcc -c example.c example_wrap.c \
       `perl -MExtUtils::Embed -e ccopts`
unix % ld -G example.o example_wrap.o \
        -o example.so
unix % perl
use example;
print $example::My_variable,"\n";
print example::fact(5),"\n";
print example::get_time(),"\n";
<ctrl-d>
3.0
120
Sun Feb 11 23:01:07 1996
unix %
```

思考

- 混合语言程序设计有哪些方法？
- 混合语言程序设计有哪些优缺点？