EECS 22: Advanced C Programming

Lecture 17

Rainer Dömer

doemer@uci.edu

The Henry Samueli School of Engineering
Electrical Engineering and Computer Science
University of California, Irvine

Lecture 17: Overview

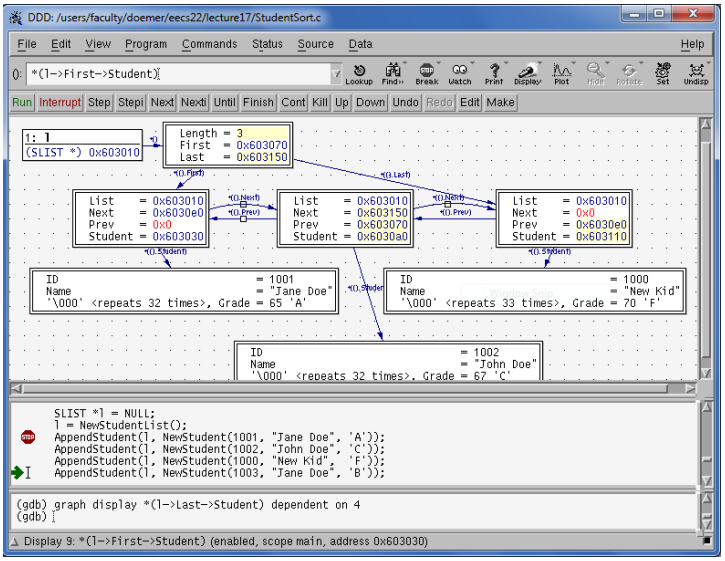
- Data Display Debugger
  - **`ddd`**
- Command Line Arguments
  - **`int main(int argc, char *argv[]);`**
- File Processing
  - Introduction
  - Standard input and output streams
  - File streams, I/O
  - Standard library functions in **`stdio.h`**
- Command Line Example: **`students`**
  - Simple tool to sort student records stored as text files
  - **`students.c`**
  - **`Makefile`**

Data Display Debugger

- Data Display Debugger **ddd**
  - Graphical frontend for GDB
    - Requires X client (e.g. Xming in addition to Putty)
  - Displays separate windows
    - Menu bar and command buttons
    - Graphical display area
    - Source code (and assembly code)
    - Command line interface
  - ➢ Can display data structures built by pointers as graphs
    - Very useful tool to visualize and debug dynamic data structures
  - Example: **`StudentSort.c`**

```
% vi StudentSort.c
% make StudentSort
gcc -DMAIN -Wall -ansi -g StudentSort.c StudentList.o Student.o \
                  -o StudentSort
% ddd StudentSort
```


Data Display Debugger



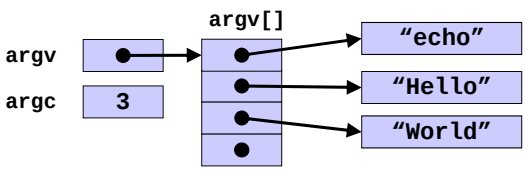
Command Line Arguments

- Operating System
  - passes optional arguments to programs started from the command line
    - **`echo Hello World`**
    - **`gcc HelloWorld.c –ansi –Wall –o HelloWorld`**
- C Programs
  - can opt to ignore the arguments
    - **`int main(void);`**
    - ➢ **`main`** function takes no arguments
  - can receive arguments as parameters to main function
    - **`int main(int argc, char *argv[]);`**
    - ➢ **`main`** function takes two arguments:
      - **`argc`** specifies the number of arguments provided
      - **`argv`** is an array of pointers to the string arguments

Command Line Arguments

- C Programs
  - can receive arguments as parameters to main function
    - **`int main(int argc, char *argv[]);`**
    - **`argc`** specifies the number of arguments provided *including* the program name (!)
    - **`argv`** is an array of pointers to the string arguments
    - **`argv[0]`** is the program name
    - **`argv[argc]`** is a **`NULL`** pointer
  - Example:

```
% echo Hello World
Hello World
%
```



File Processing

- Introduction
  - Up to now, all data processed is available only during program run time
    - At program completion, all data is lost
  - *Persistent data* is stored even after a program exits
  - Persistent data is stored in *files*...
    - ... on the harddisk
    - ... on a removable disk (CD, memory stick, ...)
    - ... on a tape, ...
  - Input and output from/to files is organized as *I/O streams*

File Processing

- I/O Streams
  - Standard I/O streams (opened by the system)
    - **`stdin`** standard input stream (i.e. **`scanf()`**)
    - **`stdout`** standard output stream (i.e. **`printf()`**)
    - **`stderr`** standard error stream (i.e. **`perror()`**)
  - File I/O streams (explicitly opened by a program)
    - Open a file **`fopen()`**
    - Write data to a file **`fprintf()`**, **`fputs()`**, etc.
    - Read data from a file **`fscanf()`**, **`fgets()`**, etc.
    - Close a file **`fclose()`**
  - In C, all I/O functions are ...
    - ... declared in header file **`stdio.h`**
    - ... provided by the standard C library

Standard I/O Functions

- Functions declared in **`stdio.h`** (part 1/4)
  - **`int printf(const char *fmt, ...);`**
  - **`int scanf(const char *fmt, ...);`**
    - formatted output/input to/from stream **`stdin`**/**`stdout`**
  - **`int sprintf(char *s, const char *fmt, ...);`**
  - **`int sscanf(const char *s, const char *fmt, ...);`**
    - formatted output/input to/from a string **`s`**
  - **`int getchar(void);`**
  - **`int putchar(int c);`**
    - input/output of a single character to/from stream **`stdin`**/**`stdout`**
  - **`char *gets(char *s);`**
  - **`int puts(const char *s);`**
    - input/output of strings to/from stream **`stdin`**/**`stdout`**

Standard I/O Functions

- Functions declared in **`stdio.h`** (part 2/4)
  - **`typedef __FILE FILE;`**
    - opaque type for a file handle
  - **`FILE *fopen(const char *n, const char *m);`**
    - open file named **`n`** for input (**`"r"`**), output (**`"w"`**), or append (**`"a"`**)
    - returns a file handle, or **`NULL`** in case of an error
  - **`int fclose(FILE *f);`**
    - closes an open file handle
  - **`int fprintf(FILE *f, const char *fmt, ...);`**
  - **`int fscanf(FILE *f, const char *fmt, ...);`**
  - **`int fgetc(FILE *f);`**
  - **`char *fgets(char *s, int n, FILE *f);`**
  - **`int fputc(int c, FILE *f);`**
  - **`int fputs(const char *s, FILE *f);`**
    - input/output functions from/to stream **`f`**
  - **`int fflush(FILE *f);`**
    - flushes any unwritten data from a buffer into the file

Standard I/O Functions

- Functions declared in **`stdio.h`** (part 3/4)
  - **`typedef unsigned int size_t;`**
    - type for size of a block of memory (number of bytes)
  - **`size_t fread(void *p, size_t s, size_t n, FILE *f);`**
    - binary input to memory location **`p`** for **`n`** times **`s`** bytes from file **`f`**
  - **`size_t fwrite(const void *p, size_t s, size_t n, FILE *f);`**
    - binary output from memory location **`p`** for **`n`** times **`s`** bytes to file **`f`**
  - **`int fseek(FILE *f, long pos, int w);`**
    - move to position **`pos`** in file **`f`** (from beginning/current pos/end)
  - **`long ftell(FILE *f);`**
    - return the current position in file **`f`** (from beginning)
  - **`void rewind(FILE *f);`**
    - move to beginning of file **`f`**
  - **`int feof(FILE *f);`**
    - check if end of file **`f`** is reached

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Standard Library Functions

- Functions declared in **`stdio.h`** (part 4/4)
  - **`int ferror(FILE *f);`**
    - returns the current error status for file **`f`**
  - **`void perror(const char *prg);`**
    - print current error for program **`prg`** to stream **`stderr`**
  - **`int remove(const char *filename);`**
    - delete file **`filename`**
  - **`int rename(const char *old, const char *new);`**
    - rename file **`old`** to new name **`new`**

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Command Line Example: **students**

- In order to practice…
  - Command Line Arguments
  - File Processing
  - Standard I/O streams and functions
- …, let's build a simple command line tool that sorts student records stored in text files
- Example:

```
% students -h
Usage: students [option...]
Option:    Function:
-h         print this usage info
-v         be verbose (default: be quiet)
-i <file>  specify input filename (default: stdin)
-o <file>  specify output filename (default: stdout)
-id        sort student records by ID
-name      sort student records by name (default)
-grade     sort student records by grade
%
```


Command Line Example: **students**

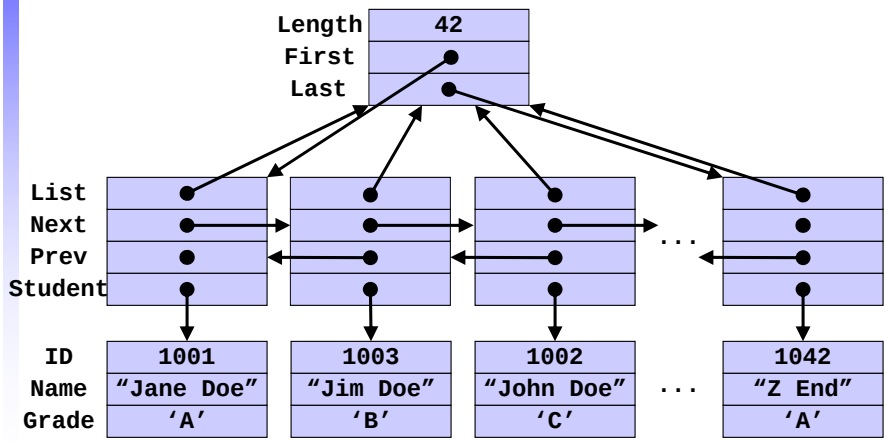
- Example:

```
1001    Jane Doe        A
1002    John Doe        C
1000    New Kid         F
1003    Jane Doe        B
1009    Z End           A
1008    Alice A         A
1007    Bob B           B
1006    Carl C          C
1005    Dave D          D
1004    Eve E           F
```

```
% vi ListOfStudents.txt
% students -i ListOfStudents.txt -name
1008 Alice A                                    A
1007 Bob B                                      B
1006 Carl C                                     C
1005 Dave D                                     D
1004 Eve E                                      F
1001 Jane Doe                                   A
1003 Jane Doe                                   B
1002 John Doe                                   C
1000 New Kid                                    F
1009 Z End                                      A
...
```

Command Line Example: **students**

- Sorted Double-Linked List
  - Example: List of Student Records sorted by ID, Name, or Grade



Command Line Example: **students**

- Example **students.c** (part 1/9)

```
/* students.c: command-line tool to sort student records        */
/* author: Rainer Doemer                                        */
/* 11/21/11 RD initial version                                  */

#include "StudentSort.h"
#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <assert.h>

void PrintUsage(char *ProgramName)
{   fprintf(stderr, "Usage: %s [option...]\n"
          "Option:    Function:\n"
          "-h         print this usage info\n"
          "-v         be verbose (default: be quiet)\n"
          "-i <file>  specify input filename (default: stdin)\n"
          "-o <file>  specify output filename (default: stdout)\n"
          "-id        sort student records by ID\n"
          "-name      sort student records by name (default)\n"
          "-grade     sort student records by grade\n",
          ProgramName);
}
...
```

Command Line Example: **`students`**

- Example **`students.c`** (part 2/9)

```
...
SLIST *ReadStudentFile(char *InFileName, int Verbose,
                       char *ProgramName)
{   SLIST *l = NULL;
    FILE *InFile = stdin;
    int n, ID;
    char FirstName[SLEN], LastName[SLEN], FullName[SLEN*2+1];
    char Grade;
    if (Verbose)
      { fprintf(stderr, "Reading from file %s...\n",
              (InFileName ? InFileName : "stdin"));
      }
    if (InFileName)
      { InFile = fopen(InFileName, "r");
        if (!InFile)
        { fprintf(stderr, "%s: Can't open file \"%s\" to read!\n",
                       ProgramName, InFileName);
          perror(ProgramName);
          exit(10);
        }
      }
...
```


Command Line Example: **`students`**

- Example **`students.c`** (part 3/9)

```
...l = NewStudentList();
    while(1)
      { assert(SLEN >= 20);
        n = fscanf(InFile, " %d %20s %20s %c",
                       &ID, FirstName, LastName, &Grade);
        if (n == EOF)
          { break; }
        if (n != 4)
          { fprintf(stderr, "%s: Read incomplete record!\n",
                       ProgramName);
            exit(10); }
        sprintf(FullName, "%s %s", FirstName, LastName);
        if (Verbose)
          { fprintf(stderr, "Read student ID %d, name \"%s\","
                        "grade %c...\n", ID, FullName, Grade); }
        if (FindStudentID(l, ID))
          { fprintf(stderr, "%s: Found multiple IDs %d!\n",
                       ProgramName, ID);
            exit(10); }
        InsertStudent(l, NewStudent(ID, FullName, Grade),
                         CompareStudentID);
      }...
```

Command Line Example: **students**

- Example **students.c** (part 4/9)

```
...

    if (InFile != stdin)
      { fclose(InFile);
        InFile = NULL;
      }
    if (Verbose)
      { fprintf(stderr, "Successfully read %d student records!\n",
                        l->Length);
      }
    return(l);
} /* end of ReadStudentFile */

...
```


Command Line Example: **students**

- Example **students.c** (part 5/9)

```
...
void WriteStudentFile(char *OutFileName, int Verbose,
                      char *ProgramName, SLIST *l)
{   FILE *OutFile = stdout;
    SENTRY *e;

    if (Verbose)
      { fprintf(stderr, "Writing to file %s...\n",
                (OutFileName ? OutFileName : "stdout"));
      }
    if (OutFileName)
      { OutFile = fopen(OutFileName, "w");
        if (!OutFile)
          { fprintf(stderr, "%s: Can't open file \"%s\""
                                " to write!\n",
                    ProgramName, OutFileName);
            perror(ProgramName);
            exit(10);
          }
      }
...
```

Command Line Example: **students**

- Example **students.c** (part 6/9)

```
...
    e = l->First;
    while(e)
      { assert(e->Student);
        fprintf(OutFile, "%4d %-45s %c\n",
                         e->Student->ID, e->Student->Name,
                         e->Student->Grade);
        e = e->Next;
      }
    if (OutFile != stdout)
      { fclose(OutFile);
        OutFile = NULL;
      }
    if (Verbose)
      { fprintf(stderr, "Successfully wrote %d records!\n",
                    l->Length);
      }
} /* end of WriteStudentFile */

...
```


Command Line Example: **students**

- Example **students.c** (part 7/9)

```
...
int main(int argc, char *argv[])
{   int i, Verbose = 0;
    char *InFileName = NULL, OutFileName = NULL;
    CMP_F *CompareFct = CompareStudentName;
    SLIST *l = NULL;
    for(i=1; i<argc; i++)
      { if (0 == strcmp(argv[i], "-h"))
          { PrintUsage(argv[0]);
            exit(0); }
        else if (0 == strcmp(argv[i], "-v"))
          { Verbose = 1; }
        else if (0 == strcmp(argv[i], "-i"))
          { i++;
            if (i < argc)
              { InFileName = argv[i]; }
             else
              { fputs("Missing argument for -i!\n", stderr);
                PrintUsage(argv[0]);
                exit(10); }
          }
/...
```

Command Line Example: **`students`**

- Example **`students.c`** (part 8/9)

```
...
        else if (0 == strcmp(argv[i], "-o"))
          { i++;
            if (i < argc)
              { OutFileName = argv[i]; }
             else
              { fputs("Missing argument for -o!\n", stderr);
                PrintUsage(argv[0]);
                exit(10); }
          }
        else if (0 == strcmp(argv[i], "-id"))
          { CompareFct = CompareStudentID; }
        else if (0 == strcmp(argv[i], "-name"))
          { CompareFct = CompareStudentName; }
        else if (0 == strcmp(argv[i], "-grade"))
          { CompareFct = CompareStudentGrade; }
        else
          { fprintf(stderr, "Unknown option %s!\n", argv[i]);
            PrintUsage(argv[0]);
            exit(10); }
      }
...
```


Command Line Example: **`students`**

- Example **`students.c`** (part 9/9)

```
...

    l = ReadStudentFile(InFileName, Verbose, argv[0]);

    SortStudentList(l, CompareFct);

    WriteStudentFile(OutFileName, Verbose, argv[0], l);

    DeleteStudentList(l);
    l = NULL;
    return 0;
} /* end of main */

/* EOF */
```

Command Line Example: **`students`**

- Example **`Makefile`** (part 1/3)

```
# Makefile: Student Records

# macro definitions
CC = gcc
DEBUG = -g
#DEBUG = -O2
CFLAGS = -Wall -ansi $(DEBUG) -c
LFLAGS = -Wall -ansi $(DEBUG)
MAIN = -DMAIN

# dummy targets
all: Student StudentList StudentSort students

test: all
        valgrind Student
        valgrind StudentList
        valgrind StudentSort
        valgrind students
clean:
        rm -f *.o
        rm -f Student StudentList StudentSort students
...
```

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Command Line Example: **`students`**

- Example **`Makefile`** (part 2/3)

```
...
# compilation rules
Student.o: Student.c Student.h
        $(CC) $(CFLAGS) Student.c -o Student.o

Student: Student.c Student.h
        $(CC) $(MAIN) $(LFLAGS) Student.c -o Student

StudentList.o: StudentList.c StudentList.h Student.h
        $(CC) $(CFLAGS) StudentList.c -o StudentList.o

StudentList: StudentList.c StudentList.h Student.h Student.o
        $(CC) $(MAIN) $(LFLAGS) StudentList.c Student.o \
                -o StudentList

StudentSort.o: StudentSort.c StudentSort.h StudentList.h Student.h
        $(CC) $(CFLAGS) StudentSort.c -o StudentSort.o

StudentSort: StudentSort.c StudentSort.h StudentList.h Student.h \
                StudentList.o Student.o
        $(CC) $(MAIN) $(LFLAGS) StudentSort.c StudentList.o \
                Student.o -o StudentSort
...
```

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Command Line Example: **students**

- Example **Makefile** (part 3/3)

```
...

students: students.c StudentSort.h StudentList.h Student.h \
                StudentSort.o StudentList.o Student.o
        $(CC) $(MAIN) $(LFLAGS) students.c -o students \
                StudentSort.o StudentList.o Student.o

# EOF
```


Command Line Example: **students**

- Example Session

```
% vi students.c
% vi Makefile
% make students
gcc -Wall -ansi -g -c StudentSort.c -o StudentSort.o
gcc -Wall -ansi -g -c StudentList.c -o StudentList.o
gcc -Wall -ansi -g -c Student.c -o Student.o
gcc -DMAIN -Wall -ansi -g students.c -o students \
                StudentSort.o StudentList.o Student.o
% students -h
Usage: students [option...]
Option:    Function:
-h         print this usage info
-v         be verbose (default: be quiet)
-i <file>  specify input filename (default: stdin)
-o <file>  specify output filename (default: stdout)
-id        sort student records by ID
-name      sort student records by name (default)
-grade     sort student records by grade
...
```

Command Line Example: **`students`**

- Example Session

```
...
% vi ListOfStudents.txt
% students -i ListOfStudents.txt -o List2.txt -v
Reading from file ListOfStudents.txt...
Read student ID 1001, name "Jane Doe", grade A...
Read student ID 1002, name "John Doe", grade C...
Read student ID 1000, name "New Kid", grade F...
Read student ID 1003, name "Jane Doe", grade B...
Read student ID 1009, name "Z End", grade A...
Read student ID 1008, name "Alice A", grade A...
Read student ID 1007, name "Bob B", grade B...
Read student ID 1006, name "Carl C", grade C...
Read student ID 1005, name "Dave D", grade D...
Read student ID 1004, name "Eve E", grade F...
Successfully read 10 student records!
Writing to file List2.txt...
Successfully wrote 10 student records!
...
```


Command Line Example: **`students`**

- Example Session

```
...
% students -i ListOfStudents.txt -name
1008 Alice A                                    A
1007 Bob B                                      B
1006 Carl C                                     C
1005 Dave D                                     D
1004 Eve E                                      F
1001 Jane Doe                                   A
1003 Jane Doe                                   B
1002 John Doe                                   C
1000 New Kid                                    F
1009 Z End                                      A
...
```

Command Line Example: **students**

- Example Session

```
...
% students -i ListOfStudents.txt -id
1000 New Kid                                    F
1001 Jane Doe                                   A
1002 John Doe                                   C
1003 Jane Doe                                   B
1004 Eve E                                      F
1005 Dave D                                     D
1006 Carl C                                     C
1007 Bob B                                      B
1008 Alice A                                    A
1009 Z End                                      A
...
```


Command Line Example: **students**

- Example Session

```
...
% students -i ListOfStudents.txt -grade
1001 Jane Doe                                   A
1008 Alice A                                    A
1009 Z End                                      A
1003 Jane Doe                                   B
1007 Bob B                                      B
1002 John Doe                                   C
1006 Carl C                                     C
1005 Dave D                                     D
1000 New Kid                                    F
1004 Eve E                                      F
%
```