EECS 22: Advanced C Programming

Lecture 15

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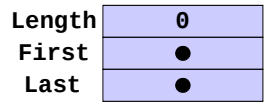
Lecture 15: Overview

- Dynamic Data Structures
  - Double-linked list
  - Element insertion, deletion
  - Example: Student records
    - **`Student.h`**
    - **`StudentList.h`**
      - New **`InsertStudentBefore`**
      - New **`InsertStudentAfter`**
    - **`StudentList.c`**
      - New **`InsertStudentBefore`**
      - New **`InsertStudentAfter`**
    - **`Makefile`**
  - Graphical data structure display in **`ddd`**

Dynamic Data Structures

- Double-Linked List (with header)
  - Example: List of Student Records

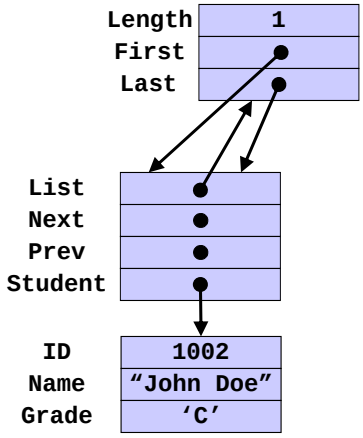
1. Empty list



Dynamic Data Structures

- Double-Linked List (with header)
  - Example: List of Student Records

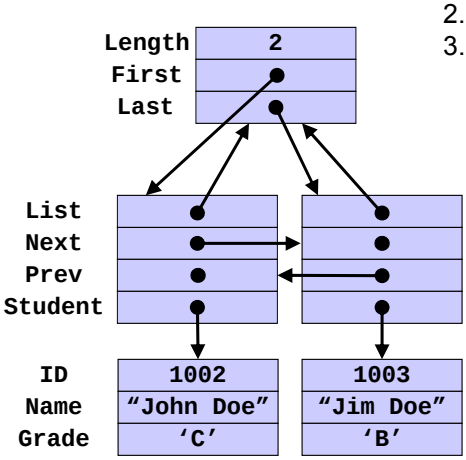
1. Empty list
2. Add a student



Dynamic Data Structures

- Double-Linked List (with header)
  - Example: List of Student Records

1. Empty list
2. Add a student
3. Append a student



Dynamic Data Structures

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  - Example: List of Student Records

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2. Add a student
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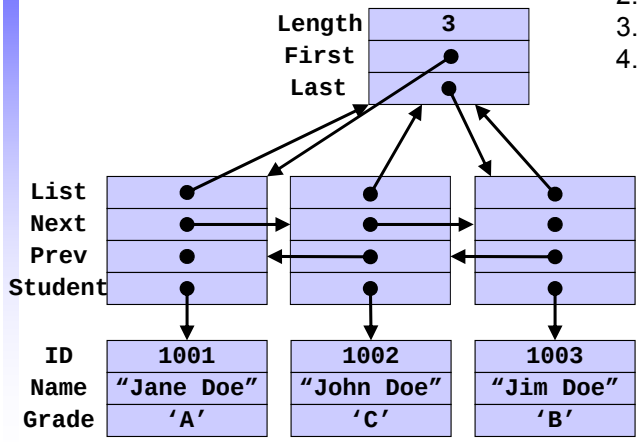
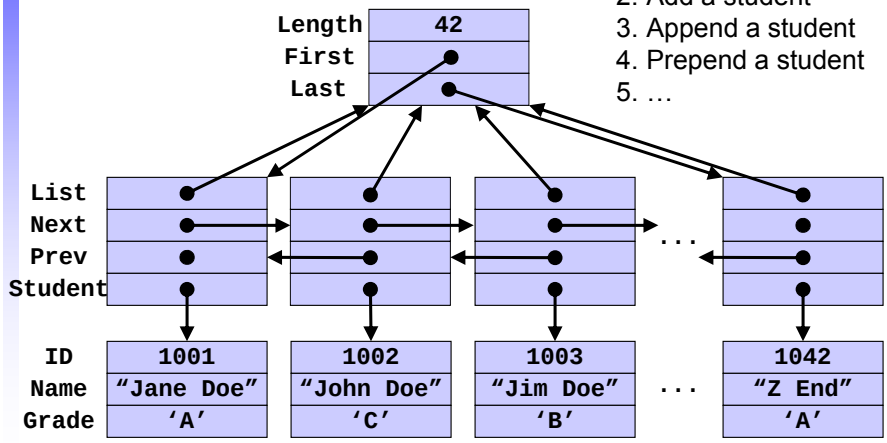


Dynamic Data Structures

- Double-Linked List (with header)
  - Example: List of Student Records

1. Empty list
2. Add a student
3. Append a student
4. Prepend a student
5. …

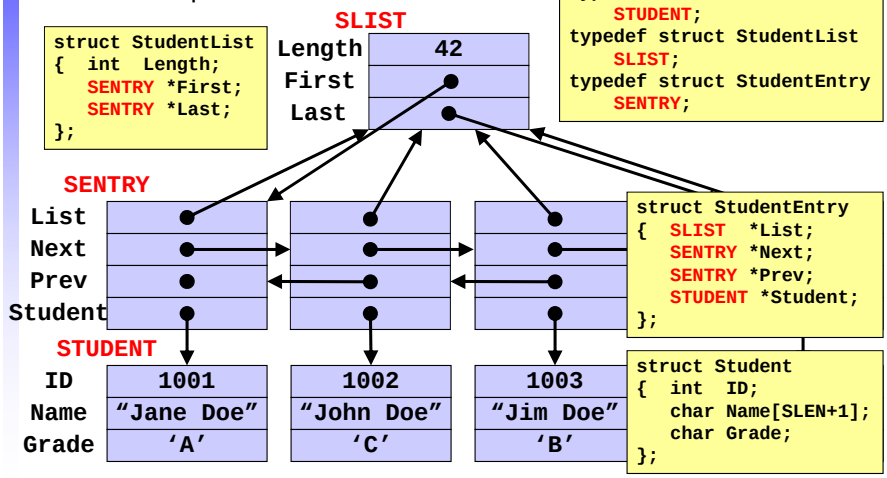


Dynamic Data Structures

- Double-Linked List (with header)
  - Example: List of Student Records

```
struct StudentList
{  int  Length;
   SENTRY *First;
   SENTRY *Last;
};
```

```
typedef struct Student
    STUDENT;
typedef struct StudentList
    SLIST;
typedef struct StudentEntry
    SENTRY;
```




```
struct StudentEntry
{  SLIST  *List;
   SENTRY *Next;
   SENTRY *Prev;
   STUDENT *Student;
};
```

```
struct Student
{  int  ID;
   char Name[SLEN+1];
   char Grade;
};
```

Dynamic Data Structures

- Example **`Student.h`**

```
/* Student.h: header file for student records */

#ifndef STUDENT_H
#define STUDENT_H

#define SLEN 40

struct Student
{  int  ID;
   char Name[SLEN+1];
   char Grade;
};
typedef struct Student STUDENT;

/* allocate a new student record */
STUDENT *NewStudent(int ID, char *Name, char Grade);

/* delete a student record */
void DeleteStudent(STUDENT *s);

/* print a student record */
void PrintStudent(STUDENT *s);

#endif /* STUDENT_H */
```


Dynamic Data Structures

- Example **`StudentList.h`** (part 1/2)

```
/* StudentList.h: header file for lists of student records      */

#ifndef STUDENT_LIST_H
#define STUDENT_LIST_H

#include "Student.h"

typedef struct StudentList SLIST;
typedef struct StudentEntry SENTRY;

struct StudentList
{  int  Length;
   SENTRY *First;
   SENTRY *Last;
};

struct StudentEntry
{  SLIST  *List;
   SENTRY *Next;
   SENTRY *Prev;
   STUDENT *Student;
};

...
```

Dynamic Data Structures

- Example **`StudentList.h`** (part 2/2)

```
...
/* allocate a new student list */
SLIST *NewStudentList(void);

/* delete a student list (and all entries) */
void DeleteStudentList(SLIST *l);

/* prepend/append a student at beginning/end of list */
void PrependStudent(SLIST *l, STUDENT *s);
void AppendStudent(SLIST *l, STUDENT *s);

/* insert a student before/after an existing one */
void InsertStudentBefore(SENTRY *e, STUDENT *s);
void InsertStudentAfter(SENTRY *e, STUDENT *s);

/* remove the first/last student from the list */
STUDENT *RemoveFirstStudent(SLIST *l);
STUDENT *RemoveLastStudent(SLIST *l);

/* print a student list */
void PrintStudentList(SLIST *l);

#endif /* STUDENT_LIST_H */

/* EOF */
```


Dynamic Data Structures

- Example **`StudentList.c`** (part 1/4)

```
/* StudentList.c: maintaining lists of student records  */
/* author: Rainer Doemer                                */
/* modifications:                                       */
/* 11/10/11 RD added InsertStudentBefore, InsertStudentAfter */
/* 11/08/11 RD version for double-linked lists          */
/* 11/03/11 RD initial version                          */

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

/* unmodified functions omitted here for brevity */

...
```

Dynamic Data Structures

- Example **`StudentList.c`** (part 2/4)

```
...

/* insert a student before an existing one */
void InsertStudentBefore(SENTRY *e, STUDENT *s)
{
    SENTRY *New;
    New = NewStudentEntry(s);
    New->List = e->List;
    New->Next = e;
    New->Prev = e->Prev;
    e->Prev = New;
    if (New->Prev)
      { New->Prev->Next = New;
      }
    else
      { assert(New->List->First == e);
        New->List->First = New;
      }
    New->List->Length++;
} /* end of InsertStudentBefore */

...
```


Dynamic Data Structures

- Example **`StudentList.c`** (part 3/4)

```
...

/* insert a student after an existing one */
void InsertStudentAfter(SENTRY *e, STUDENT *s)
{
    SENTRY *New;
    New = NewStudentEntry(s);
    New->List = e->List;
    New->Next = e->Next;
    New->Prev = e;
    e->Next = New;
    if (New->Next)
      { New->Next->Prev = New;
      }
    else
      { assert(New->List->Last == e);
        New->List->Last = New;
      }
    New->List->Length++;
} /* end of InsertStudentAfter */

...
```

Dynamic Data Structures

- Example **`StudentList.c`** (part 4/4)

```
#ifdef MAIN
int main(void)
STUDENT *s = NULL;
    SLIST *l = NULL;
    SENTRY *e = NULL;
    l = NewStudentList();
    s = NewStudent(1001, "Jane Doe", 'A');
    AppendStudent(l, s);
    e = l->First;
    assert(e->Student == s);
    s = NewStudent(1002, "John Doe", 'C');
    InsertStudentAfter(e, s);
    s = NewStudent(1000, "New Kid", 'F');
    InsertStudentBefore(e, s);

    PrintStudentList(l);

    DeleteStudentList(l);
    l = NULL;
    return 0;
} /* end of main */
#endif /* MAIN */
/* EOF */
```


Dynamic Data Structures

- Example **`Makefile`** (part 1/2)

```
# 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

test: all
        valgrind Student
        valgrind StudentList

clean:
        rm -f *.o
        rm -f Student StudentList
...
```

Dynamic Data Structures

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

```
...
# 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) Student.c -o StudentList.o

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

# EOF
```


Dynamic Data Structures

- Example Session

```
% vi StudentList.c
% vi Makefile
% make
gcc -Wall -ansi -g -c Student.c -o Student.o
gcc -DMAIN -Wall -ansi -g StudentList.c Student.o -o StudentList
% valgrind StudentList
==5908== Memcheck, a memory error detector
Student ID:    1000
Student Name:  New Kid
Student Grade: F
Student ID:    1001
Student Name:  Jane Doe
Student Grade: A
Student ID:    1002
Student Name:  John Doe
Student Grade: C
==5908== HEAP SUMMARY:
==5908==     in use at exit: 0 bytes in 0 blocks
==5908==  total heap usage: 7 allocs, 7 frees, 264 bytes allocated
==5908== All heap blocks were freed -- no leaks are possible
==5908== ERROR SUMMARY: 0 errors from 0 contexts
%
```

Graphical Data Structure Display

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

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


Graphical Data Structure Display