



Abstract Data Types

CS 217

1



Structures

stringarray.h

```

#define MAX_STRINGS 128

struct StringArray {
    char *strings[MAX_STRINGS];
    int nstrings;
};

extern void ReadStrings(struct StringArray *stringarray, FILE *fp);
extern void WriteStrings(struct StringArray *stringarray, FILE *fp);
extern void SortStrings(struct StringArray *stringarray);

```

sort.c

```

#include <stdio.h>
#include "stringarray.h"

int main()
{
    struct StringArray *stringarray = malloc( sizeof(struct StringArray) );
    stringarray->nstrings = 0;

    ReadStrings(stringarray, stdin);
    SortStrings(stringarray);
    WriteStrings(stringarray, stdout);

    free(stringarray);
    return 0;
}

```

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Typedef

stringarray.h

```

#define MAX_STRINGS 128

typedef struct StringArray {
    char *strings[MAX_STRINGS];
    int nstrings;
} *StringArray_T;

extern void ReadStrings(StringArray_T stringarray, FILE *fp);
extern void WriteStrings(StringArray_T stringarray, FILE *fp);
extern void SortStrings(StringArray_T stringarray);

```

sort.c

```

#include <stdio.h>
#include "stringarray.h"

int main()
{
    StringArray_T stringarray = malloc( sizeof(struct StringArray) );
    stringarray->nstrings = 0;

    ReadStrings(stringarray, stdin);
    SortStrings(stringarray);
    WriteStrings(stringarray, stdout);

    free(stringarray);
    return 0;
}

```

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Opaque Pointers

stringarray.h

```

typedef struct StringArray *StringArray_T;

extern StringArray_T NewStrings(void);
extern void FreeStrings(StringArray_T stringarray);

extern void ReadStrings(StringArray_T stringarray, FILE *fp);
extern void WriteStrings(StringArray_T stringarray, FILE *fp);
extern void SortStrings(StringArray_T stringarray);

```

sort.c

```

#include <stdio.h>
#include "stringarray.h"

int main()
{
    StringArray_T stringarray = NewStrings();

    ReadStrings(stringarray, stdin);
    SortStrings(stringarray);
    WriteStrings(stringarray, stdout);

    FreeStrings(stringarray);

    return 0;
}

```

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Abstract Data Types

- Module supporting operations on single data structure
 - Interface declares operations, not data structure
 - Implementation is hidden from client (encapsulation)
 - Use features of programming language to ensure encapsulation
- Common practice
 - Allocation and deallocation of data structure handled by module
 - Names of functions and variables begin with <modulename>_
 - Provide as much generality/flexibility in interface as possible
 - Use void pointers to allow polymorphism

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Array ADT - Interface

array.h

```
typedef struct Array *Array_T;

extern Array_T Array_new(void);
extern void Array_free(Array_T array);

extern int Array_getLength(Array_T array);
extern char *Array_getData(Array_T array, int index);
extern int Array_getIndex(Array_T array, char *str);

extern void Array_append(Array_T array, char *str);
extern void Array_insert(Array_T array, int index, char *str);
extern void Array_replace(Array_T array, int index, char *str);
extern void Array_remove(Array_T array, int index);
extern void Array_sort(Array_T array);
```

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Example ADT - Client

client.c

```
#include "array.h"
#include <stdio.h>

int main()
{
    Array_T array;
    int i;

    array = Array_new();

    Array_append(array, "CS217");
    Array_append(array, "IS");
    Array_append(array, "FUN");

    for (i = 0; i < Array_getLength(array); i++) {
        char *str = Array_getData(array, i);
        printf(str);
    }

    Array_free(array);

    return 0;
}
```

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Example ADT - Implementation

array.c (1 of 5)

```
#include "array.h"

#define MAX_ELEMENTS 128

struct Array {
    char *elements[MAX_ELEMENTS];
    int num_elements;
};

Array_T Array_new(void)
{
    Array_T array = malloc(sizeof(struct Array));
    array->num_elements = 0;
    return array;
}

void Array_free(Array_T array)
{
    free(array);
}
```

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Example ADT - Implementation



array.c (2 of 5)

```
int Array_getLength(Array_T array)
{
    return array->num_elements;
}

void *Array_getData(Array_T array, int index)
{
    return array->elements[index];
}

int Array_getIndex(Array_T array, char *str)
{
    int index;
    for (index = 0; index < array->num_elements; index++) {
        if (array->elements[index] == str) {
            return index;
            break;
        }
    }
    return -1;
}
```

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Example ADT - Implementation



array.c (3 of 5)

```
void Array_append(Array_T array, char *str)
{
    int index = array->num_elements;
    array->elements[index] = str;
    array->num_elements++;
}

void Array_replace(Array_T array, int index, char *str)
{
    array->elements[index] = str;
}
```

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Example ADT - Implementation



array.c (4 of 5)

```
void Array_insert(Array_T array, int index, char *str)
{
    int i;

    for (i = array->num_elements; i > index; i--)
        array->elements[i] = array->elements[i-1];

    array->elements[index] = str;
    array->num_elements++;
}

void Array_remove(Array_T array, int index)
{
    int i;

    for (i = index+1; i < array->num_elements; i++)
        array->elements[i-1] = array->elements[i];

    array->num_elements--;
}
```

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Example ADT - Implementation



array.c (5 of 5)

```
void Array_sort(Array_T array)
{
    int i, j;

    for (i = 0; i < array->num_elements; i++) {
        for (j = i+1; j < array->num_elements; j++) {
            if (strcmp(array->elements[i], array->elements[j]) > 0) {
                char *swap = array->elements[i];
                array->elements[i] = array->elements[j];
                array->elements[j] = swap;
            }
        }
    }
}
```

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Summary

- Modularity is key to good software
 - Decompose program into modules
 - Provide clear and flexible interfaces
- Abstract Data Types
 - Modules supporting operations on data structure
 - Well-designed interfaces hide implementations, but provide flexibility
- Advantages
 - Separate compilation
 - Easier to understand
 - Easier to test and debug
 - Easier to reuse code
 - Easier to make changes

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Modularity in C

- Use features of programming language to enhance modularity
 - `struct`
 - `typedef`
 - opaque pointers
 - void pointers
 - function pointers

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Abstract Data Types (ADTs)

- Module supporting operations on single data structure
 - Interface declares operations, not data structure
 - Interface provides access to simple, complete set of operations
 - Interface provides flexibility and extensibility

array.h

```
typedef struct Array *Array_T;

extern Array_T Array_new(void);
extern void Array_free(Array_T array);

extern int Array_getLength(Array_T array);
extern char *Array_getData(Array_T array, int index);
extern int Array_getIndex(Array_T array, char *str);

extern void Array_append(Array_T array, char *str);
extern void Array_insert(Array_T array, int index, char *str);
extern void Array_replace(Array_T array, int index, char *str);
extern void Array_remove(Array_T array, int index);
extern void Array_sort(Array_T array);
```

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Abstract Data Types (ADTs)

- Module supporting operations on single data structure
 - Interface declares operations, not data structure
 - Interface provides access to simple, complete set of operations
 - Interface provides flexibility and extensibility

array.h

```
typedef struct Array *Array_T;

extern Array_T Array_new(void);
extern void Array_free(Array_T array);

extern int Array_getLength(Array_T array);
extern char *Array_getData(Array_T array, int index);
extern int Array_getIndex(Array_T array, char *str);

extern void Array_append(Array_T array, char *str);
extern void Array_insert(Array_T array, int index, char *str);
extern void Array_replace(Array_T array, int index, char *str);
extern void Array_remove(Array_T array, int index);
extern void Array_sort(Array_T array);
```

But this array ADT still only holds strings

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Polymorphism - Void Pointers



array.h

```
typedef struct Array *Array_T;

extern Array_T Array_new(void);
extern void Array_free(Array_T array);

extern int Array_getLength(Array_T array);
extern void *Array_getData(Array_T array, int index);
extern int Array_getIndex(Array_T array, void *datap);

extern void Array_append(Array_T array, void *datap);
extern void Array_insert(Array_T array, int index, void *datap);
extern void Array_replace(Array_T array, int index, void *datap);
extern void Array_remove(Array_T array, int index);
```

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Example ADT - Client 1



string_client.c

```
#include "array.h"
#include <stdio.h>

int main()
{
    Array_T array;
    int i;

    array = Array_new();

    Array_append(array, (void *) "CS217");
    Array_append(array, (void *) "IS");
    Array_append(array, (void *) "FUN");

    for (i = 0; i < Array_getLength(array); i++) {
        char *str = (char *) Array_getData(array, i);
        printf(str);
    }

    Array_free(array);

    return 0;
}
```

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Example ADT - Client 2



int_client.c

```
#include "array.h"
#include <stdio.h>

int main()
{
    Array_T array;
    int one=1, two=2, three=3;
    int i;

    array = Array_new();

    Array_append(array, (void *) &one);
    Array_append(array, (void *) &two);
    Array_append(array, (void *) &three);

    for (i = 0; i < Array_getLength(array); i++) {
        int *datap = (int *) Array_getData(array, i);
        printf("%d ", *datap);
    }

    Array_free(array);

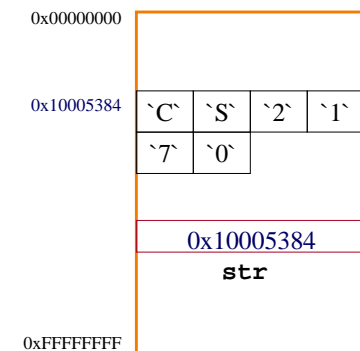
    return 0;
}
```

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Pointers



- Pointers are variables whose value is an address
 - They usually point to a variable of a specific type
 - Example: `char *str = "CS217";`



Memory

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Void Pointers

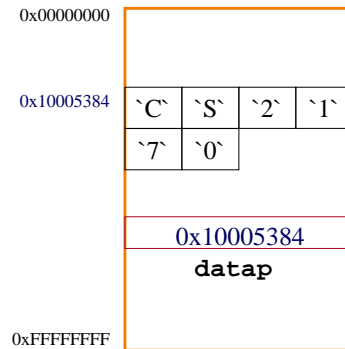
- Void pointers are the same as any other pointer
 - Except they point to a variable **with no specific type**
 - Example: `void *datap = "CS217";`

• Difference:

- Compiler does not check type when dereference

• Common Uses:

- Abstract data types supporting polymorphism
- Pass pointer to function that could be any of several types



Memory



Void Pointer Implementation

array.c (1 of 4)

```
#include "array.h"

#define MAX_ELEMENTS 128

struct Array {
    void *elements[MAX_ELEMENTS];
    int num_elements;
};

Array_T Array_new(void)
{
    Array_T array = malloc(sizeof(struct Array));
    array->num_elements = 0;
    return array;
}

void Array_free(Array_T array)
{
    free(array);
}
```

SAME AS BEFORE EXCEPT ...



Example ADT - Implementation

array.c

```
void Array_sort(Array_T array)
{
    int i, j;

    for (i = 0; i < array->num_elements; i++) {
        for (j = i+1; j < array->num_elements; j++) {
            (strcmp(array->elements[i], array->elements[j]) > 0) {
                char *swap = array->elements[i];
                array->elements[i] = array->elements[j];
                array->elements[j] = swap;
            }
        }
    }
}
```

How do we compare two data elements if we don't know their types?



Function Pointers - Interface

array.h

```
typedef struct Array *Array_T;

extern Array_T Array_new(void);
extern void Array_free(Array_T array);

extern int Array_getLength(Array_T array);
extern void *Array_getData(Array_T array, int index);
extern int Array_getIndex(Array_T array, void *datap);

extern void Array_append(Array_T array, void *datap);
extern void Array_insert(Array_T array, int index, void *datap);
extern void Array_replace(Array_T array, int index, void *datap);
extern void Array_remove(Array_T array, int index);

extern void Array_sort(Array_T array,
    int (*compare)(void *datap1, void *datap2));
```

Pass function pointer to ADT

Function Pointers - Implementation



array.c

```
void Array_sort(Array_T array,
                int (*compare)(void *datap1, void *datap2))
{
    int i, j;

    for (i = 0; i < array->num_elements; i++) {
        for (j = i+1; j < array->num_elements; j++) {
            if ((*compare)(array->elements[i], array->elements[j]) > 0) {
                char *swap = array->elements[i];
                array->elements[i] = array->elements[j];
                array->elements[j] = swap;
            }
        }
    }
}
```

Call function by dereferencing function pointer

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Function Pointers - Client



int_client.c

```
#include "array.h"
#include <stdio.h>

int CompareInts(void *datap1, void *datap2)
{
    int *intp1 = (int *) datap1;
    int *intp2 = (int *) datap2;
    return (*intp1 - *intp2);
}

int main()
{
    Array_T array;
    int one=1, two=2, three=3;

    array = Array_new();
    Array_append(array, (void *) &one);
    Array_append(array, (void *) &two);
    Array_append(array, (void *) &three);
    Array_sort(array, CompareInts);

    etc.
}
```

Every function name (e.g., CompareInts) represents the address of a function (i.e., a pointer to a function).

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Summary



- Module supporting operations on single data structure
 - Interface declares operations, not data structure
 - Interface provides access to simple, complete set of operations
 - Interface provides flexibility and extensibility
- Trick is providing functionality AND generality
 - Take advantage of features of programming language
 - void pointers
 - function pointers
- Advantages
 - Provide complete set of commonly used functions (re-use)
 - Implementation is hidden from client (encapsulation)
 - Can use for multiple types (polymorphism)

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