CS100
Introduction to Programming

Lecture 5. Strings & Text Files

String Constants

- A **string** is an array of characters terminated by a NULL character '\0', e.g. "Hello World";
- **String constant**: a set of characters in double quotes
  - data type: array of char
  - Automatically terminated with the **NULL** character **'\0'**
  - Define a string constant

    e.g. `#define SHTU "ShanghaiTech University"`
  - As arguments of functions like printf():

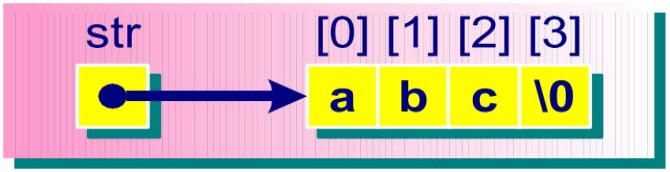
    e.g. `printf("Hello, how are you?");`
  - `char *str = "C Programming";`

    `/* str is a pointer variable */`

String Variables

- **String and Array**

  char str[] = “some text”; // string
  char str[10] = “yes”; // legal
  char str[4] = “four”; // incorrect: space for null character?
  char str[] = {‘a’, ‘b’, ‘c’, ‘\0’}; equivalent to: **char str[] = “abc”;**



- **Note: ‘\0’ differentiates a string from an array of characters**

- Just like other kinds of arrays, the array name **str** gives the **address** of the 1st element of the array:

```
str == &str[0]                  // true
*str == ‘a’                     // true
*(str+1) == str[1] == ‘b’       // true
```

String and Pointer

- Can you tell the difference between

```
char str1[] = “\n how are you?”; //using array
```

and

```
char *str2 = “\n how are you?”;  //using pointer
```

- **str1**: **address constant**; **str2**: **pointer variable**.

Therefore,

```
++str1;            // not allowed
++str2;            // allowed
str1 = str2;       // not allowed
str2 = str1;       // allowed
```

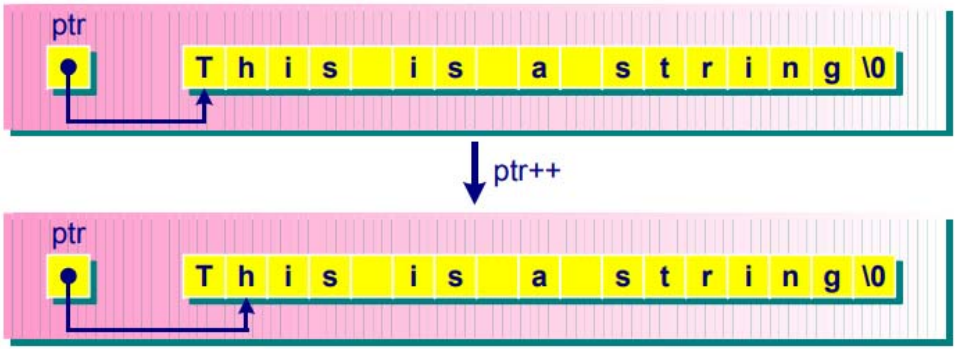
String and Pointer

- Assign a string constant to a pointer that points to a char:

```
char *ptr;
ptr = “This is a string”;
```

- When a string constant is assigned to a pointer variable, the C compiler will:
  - allocate memory space to hold the string constant,
  - store the starting address of the string in the pointer variable, and
  - terminate the string with a ‘\0’ character.
- Hence, the **expression value of a string**, e.g. “This is a string”, is an **address**.
- For the statement:

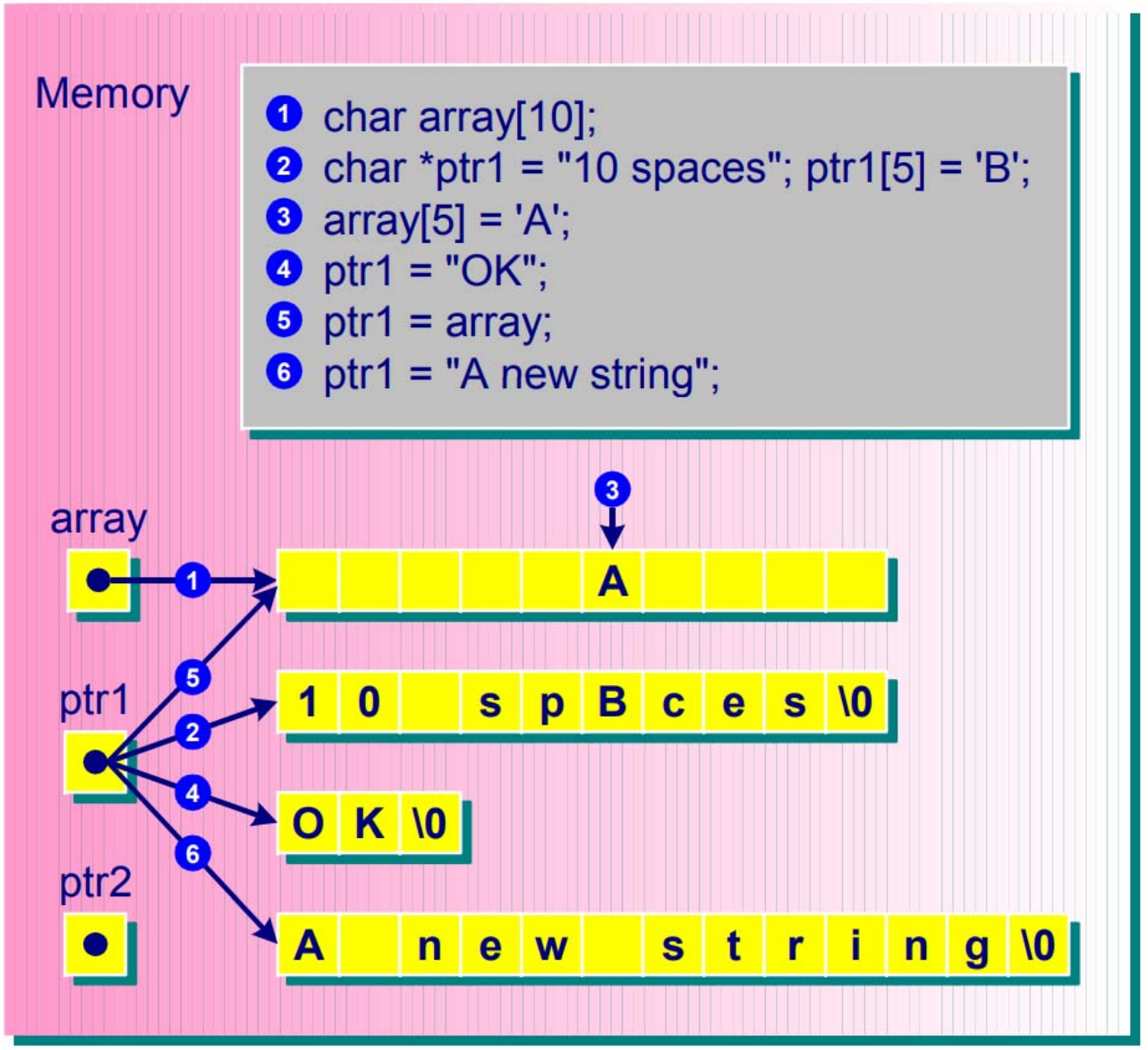
```
ptr++;
```



String and Pointer: Example 1

```
int main(void)
{
   char array[10];
   char *ptr1 = “10 spaces”, *ptr2;
   ptr1[5] = ‘B’;          // OK
   ptr1 = “OK”;            // OK
   ptr1[5] = ‘D’;          /* not OK, ptr1 points to a 3-char-
                              long string constant */
   ptr2[5] = ‘C’;          // not OK, ptr2 points to nowhere
   *ptr2 = “not OK”;       // not OK, type mismatch
   array = “not OK”;       /* not OK. C does not support this.
                              Also, right hand side (RHS) is an
                              address while left hand side (LHS)
                              is a constant pointer */
   array[5] = ‘A’;         // OK
   ptr1 = array;           // OK
   ptr1 = “A new string”; // OK, the array is unchanged
   return 0;
}
```

String and Pointer: Example 1



String and Pointer: Example 2

```
#include <stdio.h>
int main(void)
{
    char *mesg = “Don’t be a fool!”;
    char *copy;

    copy = mesg;
    printf(“%s\n”, copy);
    printf(“mesg=%s; &mesg=%p; value=%p\n”,
                mesg, &mesg, mesg);
    printf(“copy=%s; &copy=%p; value=%p\n”,
                copy, &copy, copy);
    return 0;
}
```

Output:

Don’t be a fool!

mesg=Don’t be a fool!; &mesg=00AA; value=00AC

copy=Don’t be a fool!; &copy=038E; value=00AC

String Input: gets()

- **gets()** returns NULL if it fails; otherwise a pointer to the string is returned.
- Make sure enough memory space is allocated to hold the input string, e.g. **name**.

```
#include <stdio.h>
int main(void)
{
   char name[20];     /* string */
   /* read name */
   printf("Hi, what is your name?\n");
   gets(name);
   /* display name */
   printf("Hello, %s.\n", name);
   return 0;
}
```

Output:

Hi, what is your name?

Xiaoming

Hello, Xiaoming.

String Output: puts()

```
#include <stdio.h>
int main(void)
{
   char str[80];   // string with allocated memory
   printf("Enter a line of string: ");
   if (gets(str) == NULL) {
      printf("Error\n");
   }
   puts(str);
   return 0;
}
```

Input: **0123456789 OK**

Output: **0123456789 OK**

String Input/Output: scanf() and printf()

- scanf()
  - The scanf() function reads the string up to the next white-space character.
  - scanf() returns **the number of items read** by scanf(), otherwise **EOF** is returned if it fails.
  - Make sure that enough memory space is allocated for input string.
- printf()
  - The printf() function returns **the number of characters transmitted**, otherwise **a negative value** will be returned if it fails.

String Input/Output: scanf() and printf()

```
#include <stdio.h>
int main(void)
{
    char name1[20], name2[20];
    int count;
    printf("Please enter your strings.\n");
    count = scanf("%s %s", name1, name2);
    printf("I read the %d strings %s %s.\n",
           count, name1, name2);
    return 0;
}
```

Output:

Please enter your strings.

C programming

I read the 2 strings C programming.

Length of a String

using array notation

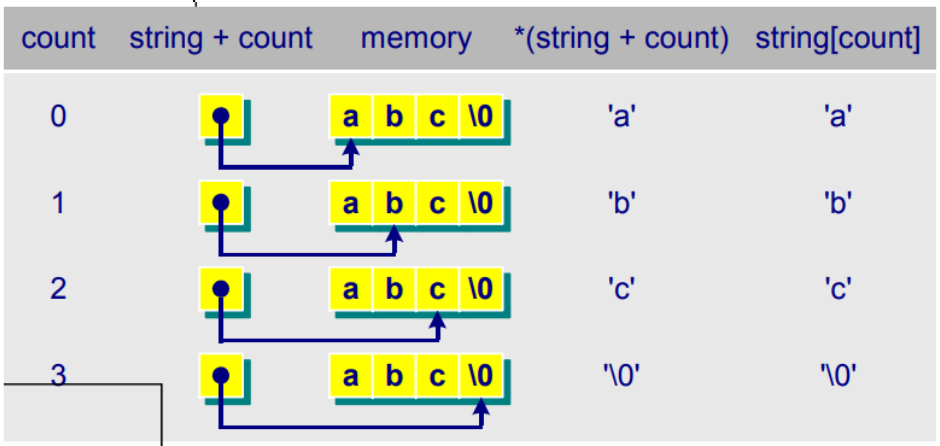
```
#include <stdio.h>
int length1(char []);
int length2(char *);
int main(void)
{
    char word[] = “abc”;
    char *greeting = “hello”;
    printf(“The lengths are %d, %d\n”,
       length1(word), length2(greeting));
    return 0;
}
int length1(char string[])
{
    int count = 0;
    while (string[count] != ‘\0’)
        count++;
    return count;
}
```

Output:

The lengths are 3, 5

using pointer notation

```
int length2(char *string)
{
    int count = 0;
    while (*(string+count))
        count++;
    return count;
}
```



Lengths of a String v.s an Array

- **Length of an array**
  - Usually the number of elements in the whole array allocated in the memory

```
float array[10];
int len=10;
int size=len*sizeof(float);
```

- **Length of a string**
  - Can be smaller than the array containing it

```
char str[64];
scanf(“%s”, str);
int len = 0;
while(str[len] != ‘\0’)
    len++;
printf(“string length = %d”, len);
```

String Functions

Must add `#include <string.h>`

Some standard string functions are:

strcat()	appends one string to another
strncat()	appends a portion of a string to another string
strchr()	finds the first occurrence of a specified character in a string
strrchr()	finds the last occurrence of a specified characters in a string
strcmp()	compares two strings
strncmp()	compares two strings up to a specified number of characters
strcpy()	copies a string to an array
strncpy()	copies a portion of a string to an array

String Functions

strcspn()	computes the length of a string that does not contain specified characters
strerror()	maps an error number with a textual error message
strlen()	computes the length of a string
strpbrk()	finds the first occurrence of any specified characters in a string
strtok()	breaks a string into a sequence of tokens

String Functions

- The function prototype of **strlen** is

```
unsigned strlen(const char *str);
```

- strlen() computes and returns the length of the string pointed to by **str**, i.e. the number of characters that precede the terminating **NULL character '\0'**.
- The function prototype of **strcat** is

```
char *strcat(char *s1, const char *s2);
```

- strcat() appends a copy of the string pointed to by **s2** to the end of the string pointed to by **s1**. The initial character of **s2** **overwrites** the NULL character at the end of **s1**.
- strcat() returns the value of s1.

- The function prototype of **strcpy** is

```
char *strcpy(char *s1, const char *s2);
```

- strcpy() copies the string pointed to by s2 into the array pointed to by s1. It returns the value of s1.

- The function prototype of **strcmp** is

```
int strcmp(const char *s1, const char *s2);
```

- strcmp() compares the string pointed to by s1 to the string pointed to by s2. It returns an integer >, =, or < zero, according to if the string pointed to by s1 is >, =, or < the string pointed to by s2 alphabetically:

0	if the two strings are equal
> 0	if the first string follows the second string alphabetically, i.e. the first string is larger
< 0	if the first string comes first alphabetically, i.e. the first string is smaller

strlen(): Example

```
#include <stdio.h>
#include <string.h>

int main(void)
{
    char line[81] = “This is a string”;
    printf(“The length of the string is %d.\n”,
           strlen(line));
    return 0;
}
```

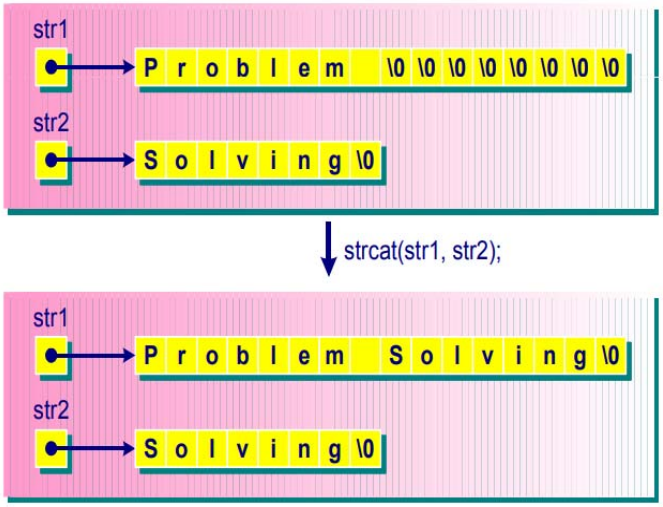
Output:
The length of the string is 16.

strcat(): Example

```
#include <stdio.h>
#include <string.h>

int main(void)
{
   char str1[40] = “Problem ”;
   char *str2 = “Solving”;

   printf(“The first string: %s\n”, str1);
   printf(“The second string: %s\n”, str2);
   strcat(str1, str2);
   printf(“The combined string: %s\n”, str1);
   return 0;
}
```



Output:

The first string: Problem
The second string: Solving
The combined string: Problem Solving

```c
#include <stdio.h>
#include <string.h>

int main(void)
{
   char str[81], str2[81];
   int result;

   printf("String Comparison:\n");
   str1[0] = 'A';
   while (str1[0]) {
      printf("Enter the first string: ");
      gets(str1);
      printf("Enter the second string: ");
      gets(str2);
      result = strcmp(str1, str2);
      printf("The comparison result:
               %d\n\n", result);
   }
   return 0;
}
```

strcmp(): Example 1

Output:

String Comparison:
Enter the first string: ***A***
Enter the second string: ***B***
The comparison result: −1

Enter the first string: ***ABa***
Enter the second string: ***ABA***
The comparison result: 1

Enter the first string: ***A0***
Enter the second string: ***A1***
The comparison result: −1

strcmp(): Example 2

```
/* Read a few lines from standard input
and write each line to standard output
with the characters reversed. The input
terminates with the line “ZZZ” */
#include <stdio.h>
#include <string.h>
Void reverse(char *);
int main(void)
{
    char line[132];
    gets(line);
    while (strcmp(line, “ZZZ”) != 0) {
        reverse(line);
        printf(“%s\n”, line);
        gets(line);
    }
    return 0;
}
```

```
void reverse(char *s)
{
    char c, *end;
    end = s + strlen(s) – 1;
    while (s < end) {
    // 2 ends approach center
        c = *s;

        *s++ = *end;
        // or *s = *end; s++;

        *end-- = c;
        // or *end = c; end--;
    }
}
```

Output:

How are you

uoy era woH

ZZZ

strcpy(): Example

```
#include <stdio.h>
#include <string.h>

int main(void)
{
   char target[40] = “This is the target string.”;
   char *source = “This is the source string.”;

   puts(target);
   puts(source);
   strcpy(target, source);
   puts(target);
   puts(source);

   return 0;
}
```

Output:

This is the target string.
This is the source string.
This is the source string.
This is the source string.

String Copy

- **Implementing strcpy(…)**

```
char * strcpy(char *str_dest, const char *str_src)
{
    char *str_ret=str_dest;
    if((str_dest!=NULL) && (str_src!=NULL))
    {
        while(*str_src!='\0')
            *str_dest++=*str_src++;

        *str_dest='\0';
    }

    return str_ret;
}
```

String Concatenation

- **Implementing strcat(…)**

```
char * strcat(char *str_dest, const char *str_src)
{
    char *str_ret=str_dest;
    if((str_dest!=NULL) && (str_src!=NULL))
    {
        while(*str_dest!='\0')
            str_dest++;

        while(*str_src!='\0')
            *str_dest++=*str_src++;

        *str_dest='\0';
    }

    return str_ret;
}
```

ctype.h Functions

Name	*True If Argument is*
Isalnum	Alphanumeric (alphabetic or numeric)
isalpha	Alphabetic
iscntrl	A control character, e.g. Control-B
isdigit	A digit
isgraph	Any printing character other than a space
islower	A lowercase character
isprint	A printing character
ispunct	A punctuation character (any printing character other than a space or an alphanumeric character)
Isspace	A whitespace character: space, newline, formfeed, carriage return, etc.
Isupper	An uppercase character
Isxdigt	A hexadecimal-digit character

- Return ***true*** (non-zero) if the character belongs to a particular class;
- Return ***false*** (zero) otherwise.
- Must add

#include <ctype.h>

ctype: Character Conversion Functions

- **toupper()** – maps lowercase character to uppercase;
- **toupper()** – maps uppercase character to lowercase.

```
void modify(char* str)
{
   while (*str != NULL)
   {
      if (isupper(*str))
         *str = tolower(*str);
      else if (islower(*str))
         *str = toupper(*str);
      str++;
   }
}
```

Output:
This is a test.
tHIS IS A TEST.

String to Number Conversions

atof()

- **Prototype**: double atof(const char *ptr);
- **Functionality**: converts the string pointed to by the pointer ptr into a double precision floating number.
- **Return value**: converted value.

atoi()

- **Prototype**: int atoi(const char *ptr);
- **Functionality**: converts the string pointed to by the pointer ptr into an integer.
- **Return value**: converted value.

String to Number Conversions: Example

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
int main(void)
{
   char ar[80];
   int i;
   double f;

   scanf("%s", ar);
   for (i=0; isdigit(ar[i]); i++);
   if (ar[i] != NULL)
      printf("The input is not a number\n");
   else {
      f = atof(ar);
      printf("Input is %f\n", f);
   }
   return 0;
}
```

Output:

123

Input is 123.000000

Formatted String I/O

sscanf()

- The function *sscanf()* is similar to *scanf()*. The only difference is that *sscanf()* takes input characters from a **string** instead of from the keyboard.
- sscanf() can be used **to transform numbers represented in characters/strings**, i.e. “123”, into numbers, e.g. 123, 123.0, of data types int, float, double, etc.

sprintf()

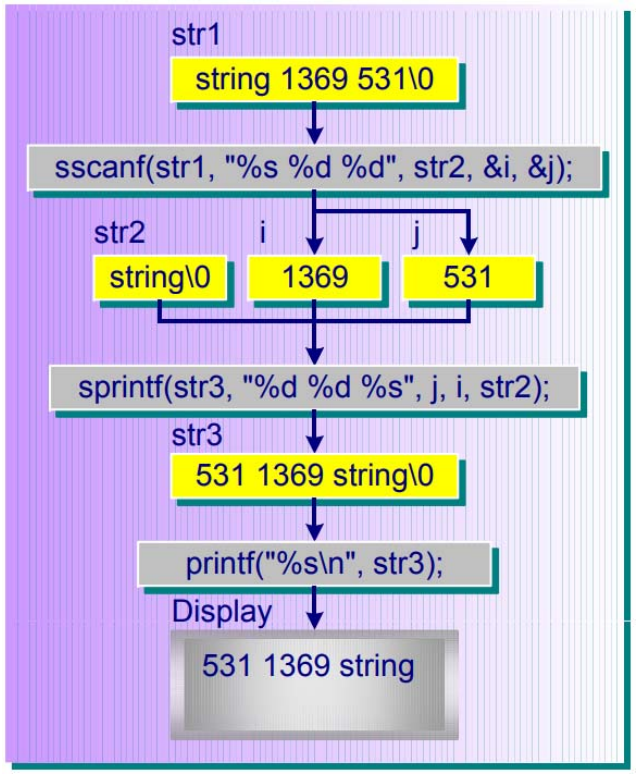
- The function *sprintf()* is similar to *printf()*. The only difference is that *sprintf()* prints output to a string.
- sprintf() can be used **to transform numbers into strings**.

Formatted String I/O – Example

```
#include <stdio.h>
#define MAX_CHAR 80

int main(void)
{
   char str1[MAX_CHAR] = “string 1369 531”;
   char str2[MAX_CHAR], str3[MAX_CHAR];
   int i, j;

   sscanf(str1, “%s %d %d”, str2, &i, &j);
   sprintf(str3, “%d %d %s”, j, i, str2);
   printf(“%s\n”, str3);
   return 0;
}
```



Output:

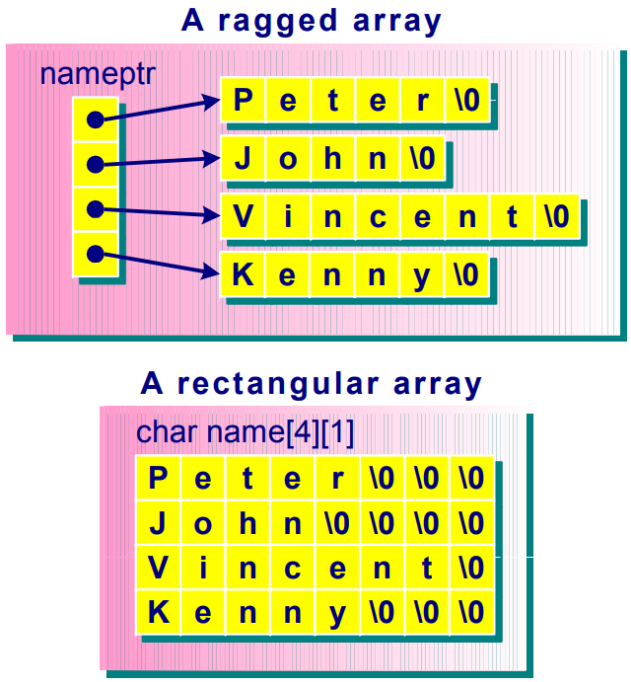
531 1369 string

Array of Character Strings

- Arrays of Character Strings

```
char *nameptr[4] = {“Peter”,
    “John”, “Vincent”, “Kenny”};
for (i=0; i < 4; i++)
    printf(“nameptr[%d]=%s\n”, i,
           nameptr[i]);
```

=> **nameptr** is a *ragged array*, i.e. an array of pointers (to save storage)



- Compare **nameptr** with

```
char name[4][8] = {“Peter”,
    “John”, “Vincent”, “Kenny”};
```

=> **name** is a *rectangular array*

Array of Strings: Example

```
#include <stdio.h>
int main(void)
{
   char *nameptr[4] = {“Peter”, “John”, “Vincent”, “Kenny”};
   char name[4][10] = {“Mary”, “Victoria”, “Susan”, “May”};
   int i, j;

   printf(“Ragged Array:\n”);
   for (i=0; i < 4; i++) {
      printf(“nameptr[%d] = %s\n”, i,
         nameptr[i]);
   }
   printf(“Rectangular Array: \n”);
   for (j=0; j < 4; j++) {
      printf(“name[%d] = %s\n”, j, name[j]);
   }
   return 0;
}
```

Output:

Ragged Array:
nameptr[0] = Peter
nameptr[1] = John
nameptr[2] = Vincent
nameptr[3] = Kenny
Rectangular Array:
name[0] = Mary
name[1] = Victoria
name[2] = Susan
name[3] = May

Command Line Arguments

- The **command line** is the line you type to run your program. Arguments can be given to commands as options. For example, `$cat file1 file2 file3 …`, where file1, file2, file3, …, are the arguments for cat.
- User can also supply arguments to his program, i.e.

```
a.out argument1 argument2 …
```

- Arguments to main() function. The syntax to receive these arguments is:

```
main(int argc, char *argv[])  { … }
```

  where **argc** is the **argument counter** which reports how many words are there in the command line. The command itself, e.g. a.out, ls, cat, …, is also counted.
- **argv** is the **argument value** represented by an array of pointers pointing to the input strings.

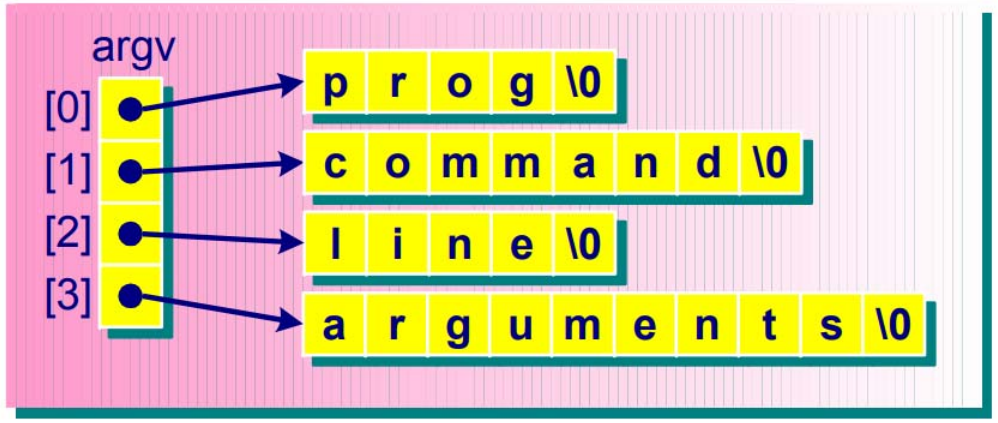
Command Line Arguments: Example

- For example:
  $prog command line arguments

```
#include <stdio.h>
int main(int argc, char *argv[])
{
   int count;
   printf("Command Line Arguments:\n");
   printf("argc = %d\n", argc);
   for (count=0; count < argc; count++) {
      printf("argv[%d] = %s\n", count,
         argv[count]);
   }
   return 0;
}
```

Output:

argc = 4
argv[0] = prog
argv[1] = command
argv[2] = line
argv[3] = arguments



Dynamic Strings

- **Problem with previous string construction**
  - They are all static: constructed in compilation
  - Hard to adapt to run-time string construction

- **Solution**
  - String with dynamic memory (array) allocation
  - Make sure the array end with ‘\0’

Dynamic Strings

- **How to construct dynamic strings?**

```
#include <stdio.h>
#include <cstring>

int main(void)
{
    int len=64;
    char* name_str=(char*)malloc(sizeof(char)*len);
    memset(name_str,0,sizeof(char)*len);

    scanf("Input your name: %s", name_str);
    printf("Your name is: %s", name_str);

    free(name_str);

    return 0;
}
```

Dynamic String Concatenation

- **How to concatenate two strings?**

```
char * strcat(const char *str1, const char *str2)
{
    char *str_ret=NULL;
    if((str_dest!=NULL) && (str_src!=NULL))
    {
        int cat_len=strlen(str1)+strlen(str2);
        str_ret=(char *)malloc(sizeof(char)*(cat_len+1));

        while(*str1!='\0')
            *str_ret++=*str1++;
        while(*str2!='\0')
           *str_ret++=*str2++;

        *str_ret='\0';
    }

    return str_ret;
}
```

Array of Strings

- **Array of statically allocated strings**
  - Basically a 2D array

```
char str_array[10][64]; //an array of 10 strings

for(int i=0;i<10;i++)
   memset(str_array[i],0,sizeof(char)*64);

for(int i=0;i<10;i++)
   scanf("%s", str_array[i]);

for(int i=0;i<10;i++)
   printf("String %d: %s", str_array[i];
```

Array of Strings

- **Array of dynamically allocated strings**

```
char** str_array=NULL;
int str_num=10, str_len=32;

str_array=(float**)malloc(sizeof(float*)*str_num);
for(int i=0;i<str_num;i++)
    str_array[i]=(float*)malloc(sizeof(float)*str_len);

for(int i=0;i<str_num;i++)
    scanf("%s", str_array[i]);

for(int i=0;i<str_num;i++)
    printf("String %d: %s", str_array[i]);

for(int i=0;i<str_num;i++)
    free(str_array[i]);
free(str_array);
```

What is a file?

- **A computer resource for recording data**
  - E.g., a file on hard disk drive
- **Types of files**
  - Text file: data all saved with ANSIC characters
  - Binary file: data saved with binary code
- **File properties**
  - Read/Write only files
  - Read&Write files

Open/Close a Text File

- **File pointer**
  - A pointer which points to a memory containing the information of a file

- **Open/close a file with file pointer**

```
FILE* file=fopen(“E:\\code.txt”, “wt”);
if(file==NULL)
{
    printf(“unable to open the file!\n”;
    exit(1);
}
...
fclose(file);
```

Writing Strings to a Text File

- **Two ways of writing strings**
  - General way
    - Using fwrite(…) function in C standard library

```
FILE* file=fopen(“E:\\code.txt”, “wt”);
...
char *str=“This is what I wrote to a file”;
int bytes_to_write=sizeof(char)*(strlen(str)+1);
if(fwrite(file,str,bytes_to_write)!=bytes_to_write)
    printf(“string writing error!\n”);

fclose(file);
```

Writing Strings to a Text File

- **Two ways of writing strings**
  - Formatted way
    - Using fprintf(…) function in C standard library

```
FILE* file=fopen(“E:\\code.txt”, “wt”);
...
int score=98;
...
fprintf(file, “The score I got is: %d”, score);

fclose(file);
```

Writing Strings with Limited Memory

- **Fix a constant memory with multiple writes**

```
FILE* file=fopen(“E:\\code.txt”, “wt”);
...
char str_line[128];
do{
     memset(str_line,0,sizeof(char)*128);
     scanf(“%s”, str_line);
     int bytes_to_write=sizeof(char)*(strlen(str_line)+1);
     if(fwrite(file, str_line, bytes_to_write)!=bytes_to_write)
        printf(“unable to write the line to the file.\n”);
}while(strcmp(str_line, “!q”)!=0);

fclose(file);
```

Reading Strings from a Text File

- **Two ways of reading strings**
  - General way
    - Using fread(…) function in C standard library

```
FILE* file=fopen(“E:\\code.txt”, “rt”);
...
char str[128];
memset(str,0,sizeof(char)*128);

if(fread(file,str,128)<0)
    printf(“string reading error!\n”);

fclose(file);
```

Reading Strings from a Text File

- **Two ways of reading strings**
  - Formatted way
    - Using fscanf(…) function in C standard library

```
FILE* file=fopen(“E:\\code.txt”, “rt”);
...
char lines[10][128];
for(int i=0;i<10;i++)
    memset(&lines[i][0], 0, sizeof(char)*128);
...
for(int i=0;i<10;i++)
    fscanf(file, “%s”,&lines[i][0]);

fclose(file);
```

Reading Strings with Limited Memory

- **Fix a constant memory with multiple reads**

```
FILE* file=fopen(“E:\\code.txt”, “rt”);
...
char str_line[128];
do{
     memset(str_line,0,sizeof(char)*128);
     fscanf(“%s”, str_line);
     printf(“%s”,str_line);
}while(strcmp(str_line, “”)!=0);

fclose(file);
```

Reading Strings with Dynamic Memory

- **When you do not know the total size of the strings to be read?**

```
FILE* file=fopen("E:\\code.txt", "rt");
...
char c;
int num=0;
while(!feof(file))
{
    if(fread(file,&c,sizeof(char))==1)
        num++;
}
fseek(file, 0, SEEK_SET);

char *str=(char *)malloc(sizeof(char)*num);
memset(str,0,sizeof(char)*num);

if(fread(file, str, sizeof(char)*num)!=sizeof(char)*num)
    printf("failed in string reading.\n");
...
free(str);
fclose(file);
```