Argument Arrays & String Tokenization

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ITER, Bhubanewar

Text Books

Kay A. Robbins, & Steve Robbins

Unix™ Systems Programming

Communications, concurrency, and Treads

Pearson Education

Brain W. Kernighan, & Rob Pike

The Unix Programming Environment

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Agenda

- Command line arguments and Argument arrays
- **`strtok()`** & **`strtok_r()`** library functions for string tokenization
- Argument array creation (version-I, version-II, version-III)

Command line arguments and Argument arrays

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Example

Consider the command line input: **`$ mine -c 10 2.0`**

- Four tokens:(1) **`mine`**, (2) **`-c`**, (3) **`10`**, (4) **`20`**
- First token is the name of the **command** or **executable**
- The **`mine`** program might start with the following line

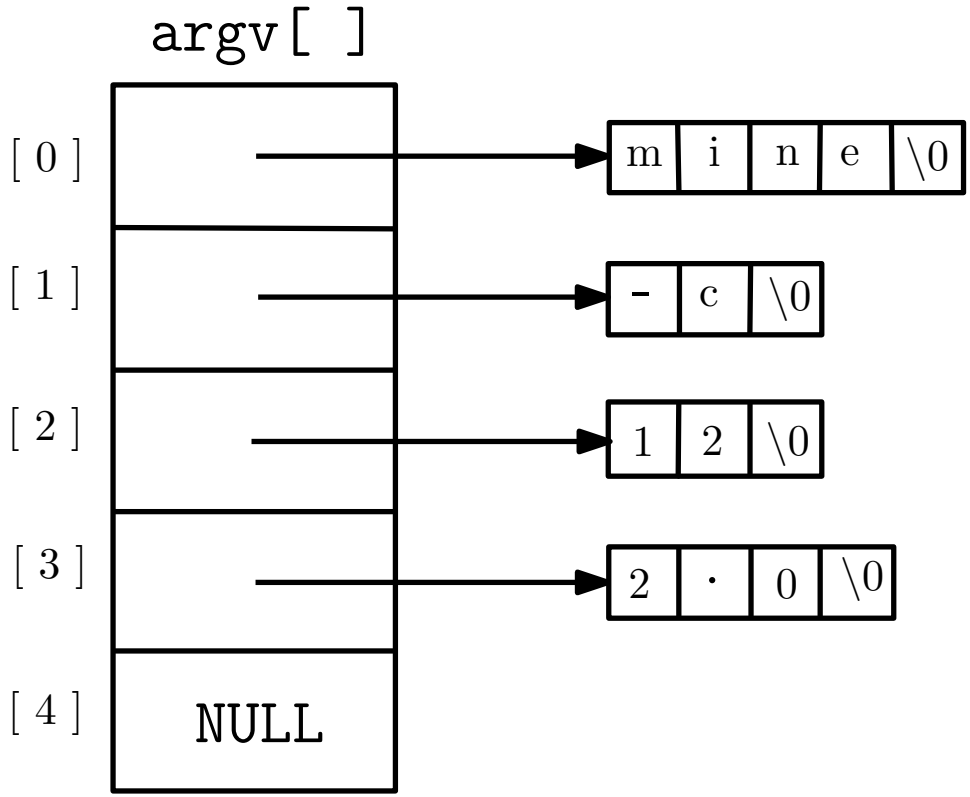
```
int main(int argc, char *argv[])
```

- **`argc`** parameter contains the number of command-line tokens or arguments and **`argv`** is an array of pointers to the command-line tokens.

The **`argv`** is an example of an **argument array**

Argument array structure

An argument array is an array of pointers to strings. The end of the array is marked by an entry containing a `NULL` pointer.



The `argv` array for the call `mine -c 10 2.0`

Argument arrays are also useful for handling a variable number of arguments in calls to **`execvp`** and for handling environment variables.

Printing all command line arguments to standard output

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

Alternative code for the argument processing loop;

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 return 0;
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```

Alternative code for the argument processing loop;

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

C Library Function `strtok()`

```
#include <string.h>

char *strtok(char *str, const char *delim);
```

- **`strtok`** splits a string into tokens.
- On the first call to **`strtok()`** the string to be parsed should be specified in **`str`**.
- In each subsequent call that should parse the same string, **`str`** must be NULL. (i.e. the first call to **`strtok`** is different from subsequent calls)
- The second argument to **`strtok`** is a string of allowed token delimiters.

  A delimiter is one or more characters that separate text strings. Common delimiters are commas (,), semicolon (;), colon (:), quotes (”, ’), braces ({}), pipes (|), hyphen (-), or slashes (/ \) etc.

- Each successive call to **`strtok`** returns the start of the next token and inserts a ’\0’ at the end of the token being returned. The **`strtok`** function returns NULL when it reaches the end of the string, **`str`**.
- **`strtok`** does not allocate new space for the tokens, but rather it tokenizes **`str`** in place. Thus, if you need to access the original **`str`** after calling **`strtok`**, you should save a copy of the string.

Example: `strtok()` function

```
#include<stdio.h>
#include<string.h>
int main()
{
    char str[] ="ITER-IBCS-SHM-SUM-IDS";
    char *token;
    token=strtok(str,"-");
    while (token!=NULL){
        printf("Token=%s\n",token);
        token=strtok(NULL,"-");
    }
    return 0;
}
```

Example: `strtok()` to Count Tokens

```
#include<stdio.h>
#include<string.h>
int main()
{
   char str[]="ITER-IBCS-SHM-SUM-IDS";
   char *delimiters="-";
   int numtokens;
   /* count the number of tokens in str */
   if (strtok(str, delimiters) != NULL)
      for(numtokens = 1; strtok(NULL, delimiters) != NULL;
          numtokens++) ;

  printf("Number of tokens=%d\n",numtokens);
  return 0;
}
```

A case with `strtok()` Function

What will be the output of the given code sample?

```
int main()
{
    char str[] ="ITER-IBCS-SOA-SUM-ids";
    char ptr[] ="iter-ibcs-soa-sum-ids-CSE";
    char *token,*ptoken;
    token=strtok(str,"-");
    ptoken=strtok(ptr,"-");
    while (token!=NULL){
        printf("Token=%s\n",token);
        token=strtok(NULL,"-");
    }
    return 0;
}
```

A case with `strtok()` Function

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int main()
{
    char str[] ="ITER-IBCS-SOA-SUM-ids";
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    char *token,*ptoken;
    token=strtok(str,"-");
    ptoken=strtok(ptr,"-");
    while (token!=NULL){
        printf("Token=%s\n",token);
        token=strtok(NULL,"-");
    }
    return 0;
}
```

The behavior that causes the above code to fail also prevents **strtok** from being used safely in programs with multiple threads. If one thread is in the process of using **strtok** and a second thread calls **strtok**, subsequent calls may not behave properly. POSIX defines a thread-safe function, **strtok_r**, to be used in place of **strtok**. The **_r** stands for reentrant, indicating the function can be reentered (called again) before a previous call finishes.

Reason For Above Behavior of `strtok()`

- Because of **`strtok`** definition, it must use an internal static variable to keep track of the current location of the next token to parse within the string.

- However, when calls to strtok with different parse strings occur in the same program, the parsing of the respective strings may interfere because there is only one variable for the location.

C Library Function `strtok_r()`

```
#include <string.h>

char *strtok_r(char *str, const char *delim, char **saveptr
    );
```

The `strtok()` and `strtok_r()` functions return a pointer to the next token, or `NULL` if there are no more tokens.

- `strtok_r` splits a string into tokens. The `strtok_r` function is a reentrant version `strtok`.
- The `saveptr` argument is a pointer to a `char` variable that is used internally by `strtok_r()` in order to maintain context between successive calls that parse the same string.
- Different strings may be parsed concurrently using sequences of calls to `strtok_r()` that specify different `saveptr` arguments.

Example: `strtok_r()` function

```
#include <stdio.h>
#include <string.h>
int main()
{
   char str[] ="Lesson-plan-USP-DOS-FML-PLC";
   printf("Entered strin:::");
   puts(str);
   char *token;
   char *last;
   token = strtok_r(str, "-", &last);
   while (token!=NULL) {
      printf("Token:%s\n", token);
      printf("\t\tRemaining part of the string:%s\n",last);
      token = strtok_r(NULL, "-", &last);
   }
   return (0);
}
```

strtok() VS strtok_r()

You know the behavior of **strtok()**. An incorrect use of **strtok** to determine the next tokens in the string.

```
int main() {
    char str[] ="ITER-IBCS-SOA-SUM-ids";
    char ptr[] ="iter-ibcs-soa-sum-ids-CSE";
    char *token,*ptoken;
    token=strtok(str,"-");
    ptoken=strtok(ptr,"-");
    while (token!=NULL){
        printf("Token=%s\n",token);
        token=strtok(NULL,"-");
    }    return 0; }
```

Resolving the issues using **strtok_r()**

```
int main() {
    char str[] ="ITER-IBCS-SOA-SUM-ids";
    char ptr[] ="iter-ibcs-soa-sum-ids-CSE";
    char *token,*ptoken,*sptr1,*sptr2;
    token=strtok_r(str,"-",&sptr1);
    ptoken=strtok_r(ptr,"-",&sptr2);
    while (token!=NULL){
        printf("Token=%s\n",token);
        token=strtok_r(NULL,"-",&sptr1);
    }    return 0; }
```

Exercise: `strtok()` vs `strtok_r()`

Develop a program to determine the average number of words per line.

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Sample input to the program: a string of the form `This is a line of text\n It is the second line \n then next line"`. Here, \n is the newline character and *space*(“ ”) is the word separator.

Exercise: `strtok()` vs `strtok_r()`

Develop a program to determine the average number of words per line.

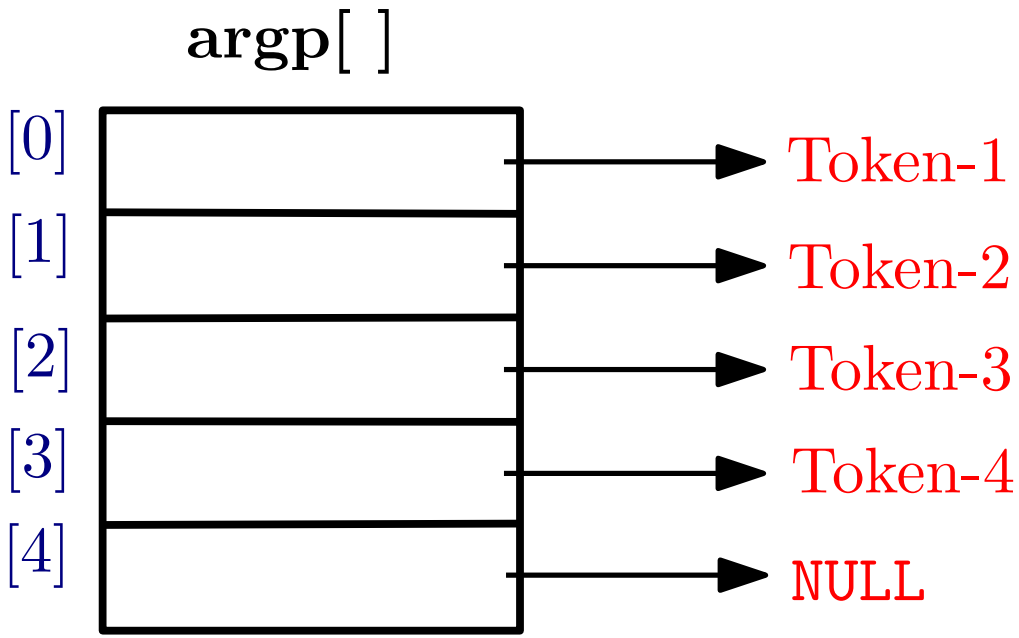
Sample input to the program: a string of the form `This is a line of text\n It is the second line \n then next line"`. Here, \n is the newline character and *space*(" ") is the word separator.

```
#define LINE_DELIMITERS "\n"
#define WORD_DELIMITERS " "
static int wordcount(char *s) {
.....................
return count;}
double wordaverage(char *s) {
int linecount = 1;
char *nextline;
.....................
words = wordcount(nextline);
.....................
return (double)words/linecount;
}
int main(){
  char str[]="This is a line of text\n It is the second line \n
       then next line";
  double wordavg=wordaverage(str);
  printf("Word average=%f\n",wordavg);
  return 0;}
```

Argument Array Creation

Procedure

- Tokenize the input string using **`strtok`** or **`strtok`** or by own logic
- Put the tokens into an array. (i.e array of pointers to string)
- Put the last array pointer pointing to NULL as shown as;



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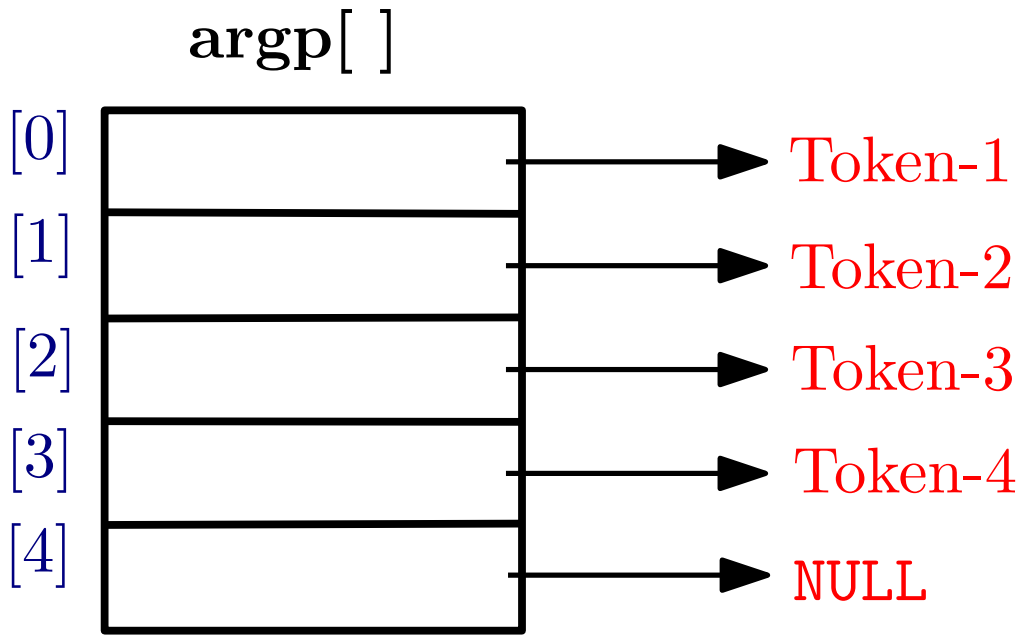

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How to Develop an argument array?

Argument Array Creation Version-I

Development of a function **`makeargv()`** to create an argument array from a string of tokens.

`makeargv` function prototype

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char **makeargv(char *s);
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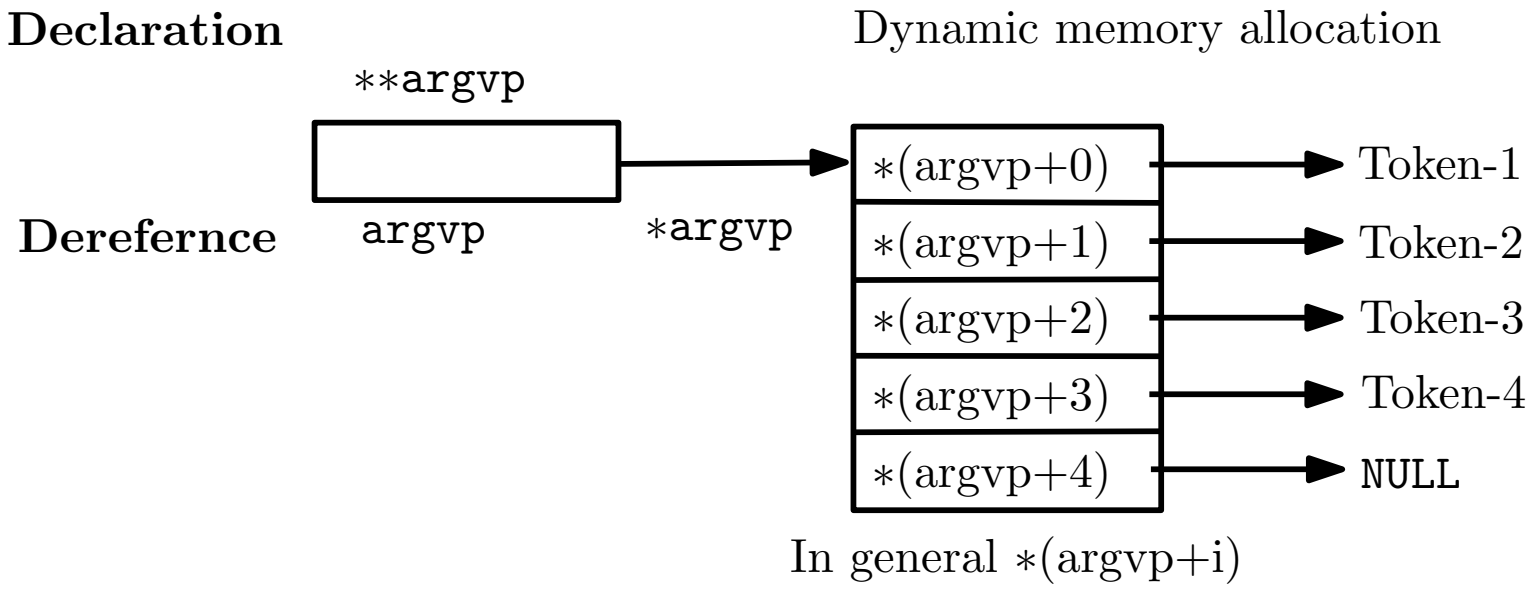
main part to invoke **makeargv** function

```
char **makeargv(char *);
int main()
{
 char s[]="This is a string";
 char **myargv;
 myargv=makeargv(s);
 if(myargv==NULL)
   fprintf(stderr,"Failed to construct an argument array\n");
else{
  for(int i=0;myargv[i]!=NULL;i++)
        printf("Myargv[%d]: %s\n",i,myargv[i]);
 }
 return 0;
}
```

`makeargv` Function Definition for Version I

```
char **makeargv(char *s)
{
 int ntokens,i;
 char *t,**argvp;
 argvp=NULL;
 t=(char *)malloc(sizeof(char)*(strlen(s)+1));
 strcpy(t,s);
 if(strtok(s," ")!=NULL){ /* count the number of tokens in s */
  for(ntokens=1;strtok(NULL," ")!=NULL;ntokens++);
}
 printf("number of tokens=%d\n",ntokens);
 argvp=(char **)malloc((ntokens+1)*sizeof(char *));
 /* insert pointers to tokens into the argument array */
 *argvp=strtok(t," ");
 for(i=1;i<ntokens;i++){
    *(argvp+i)=strtok(NULL," ");
 }
 *(argvp+ntokens)=NULL;   /* put in final NULL pointer */
 return argvp;
 }
```

HOW `argvp` Works in `myargv` Function ?



Argument Array Creation Version-II

The following alternative prototype specifies that **makeargv** should pass the argument array as a parameter. This alternative version of makeargv returns an integer giving the number of tokens in the input string. In this case, **makeargv** returns -1 to indicate an error.

makeargv function prototype

```
int makeargv(char *s, char ***argvp);
```

`main` Part for Version II Argument Array

`main` part to invoke **`makeargv`** function in version II.

```
int makeargv(char *, char ***); /* Function prototype
    for makeargv */
int main()
{
 char mytest[]="This is a test";
 char **myargv;
 int numtokens,i;
 numtokens=makeargv(mytest, &myargv);
 if(numtokens==-1)
    fprintf(stderr, "Failed to construct an argument
        array\n");
 else{
   for (i = 0; i < numtokens; i++)
        printf("myargv[%d]: %s\n", i, myargv[i]);
 }
 return 0;
}
```

Implementation Strategy of `makeargv`

- Use **`malloc`** to allocate a buffer **`t`** for parsing the string in place. The **`t`** buffer must be large enough to contain **`s`** and its terminating '\0'.

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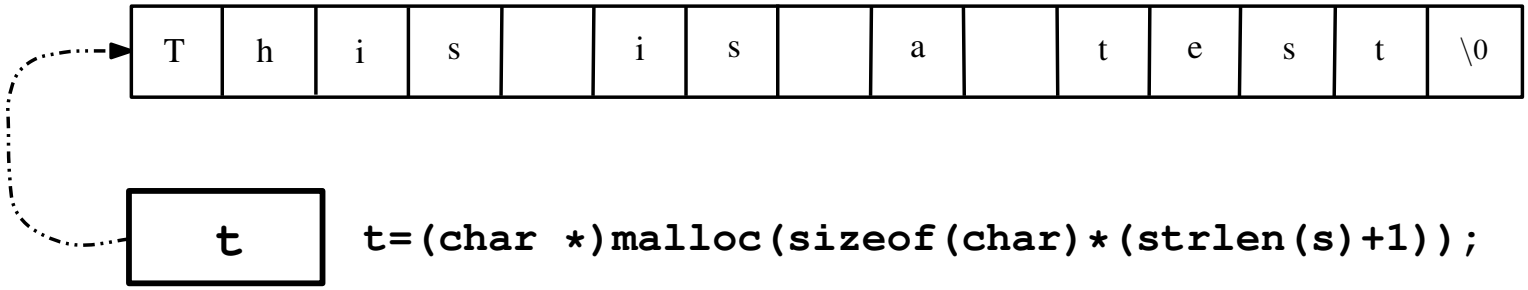


```
t=(char *)malloc(sizeof(char)*(strlen(s)+1));
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The **`makeargv`** function makes a working copy of the string **`s`** in the buffer **`t`**.

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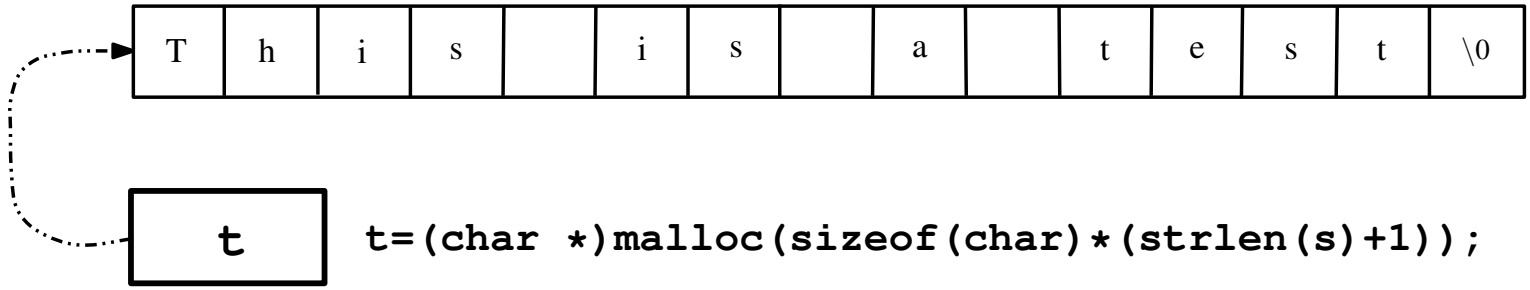


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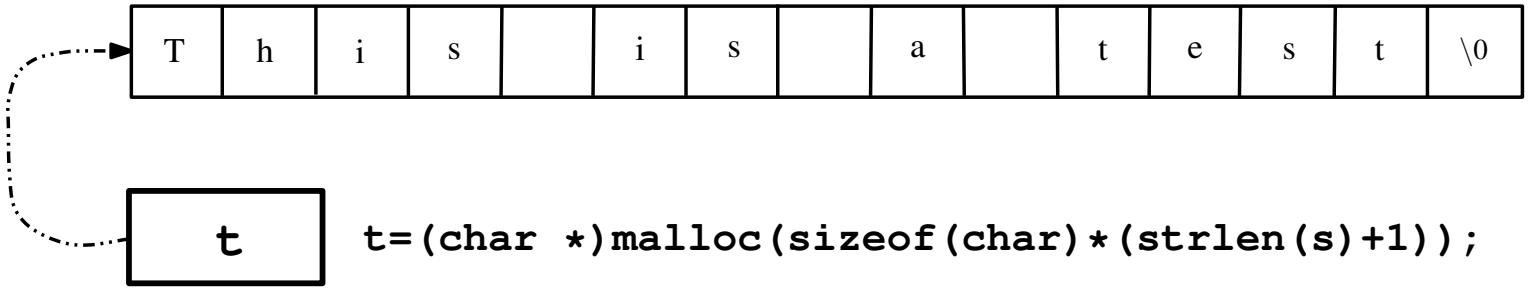

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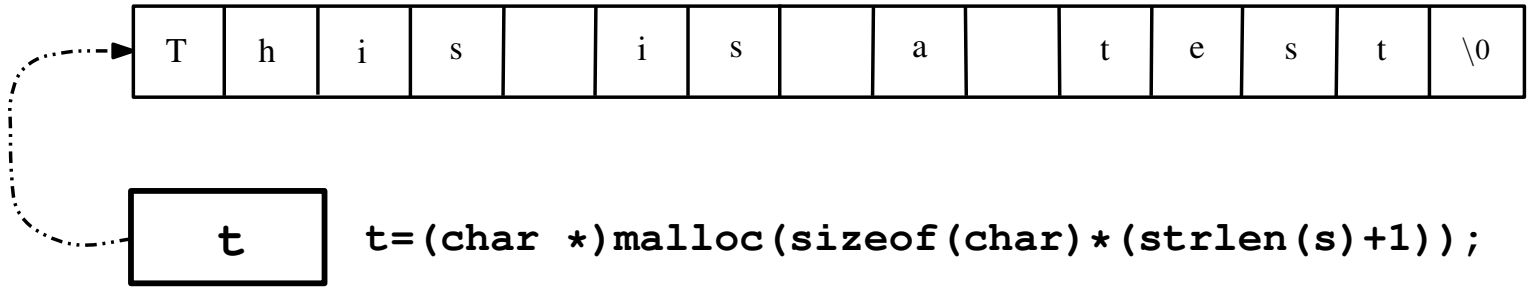

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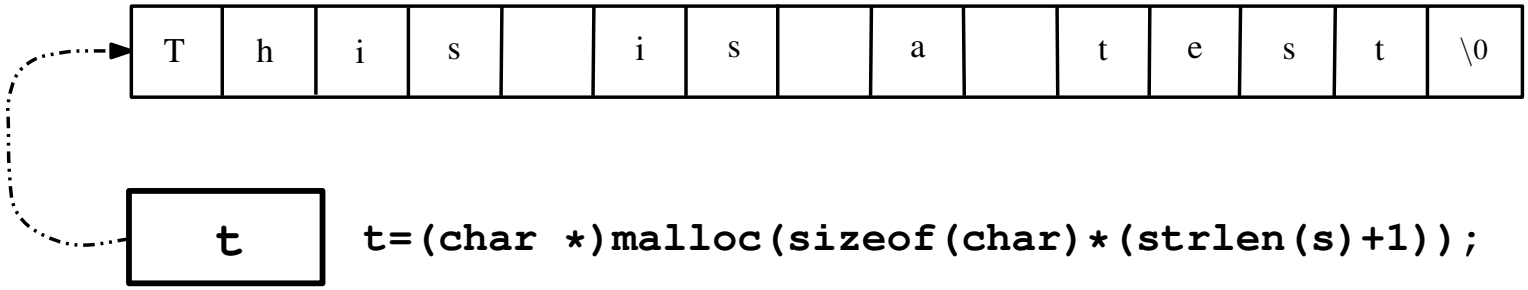

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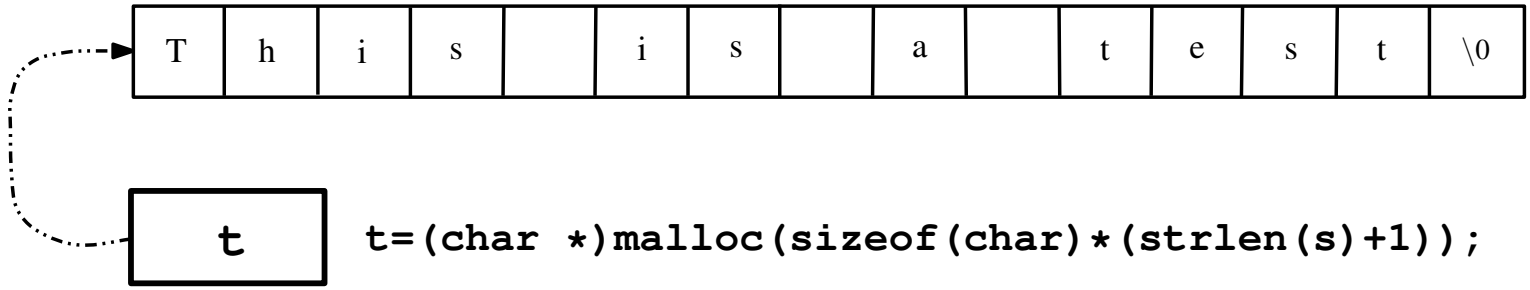

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*argvp=(char **)malloc((numtokens+1)*sizeof(char *));
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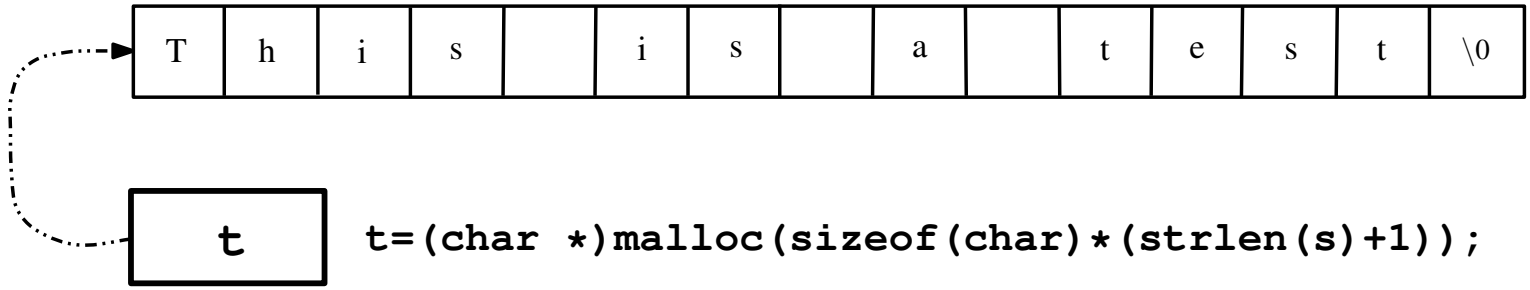

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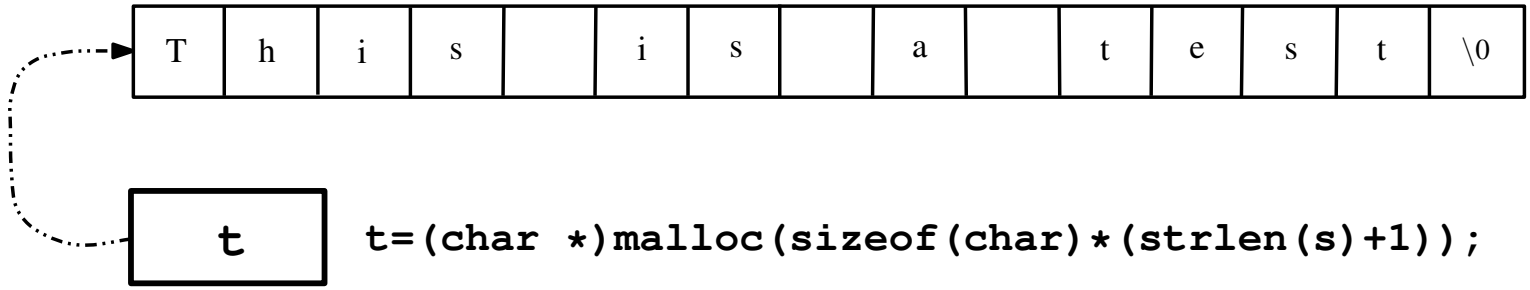

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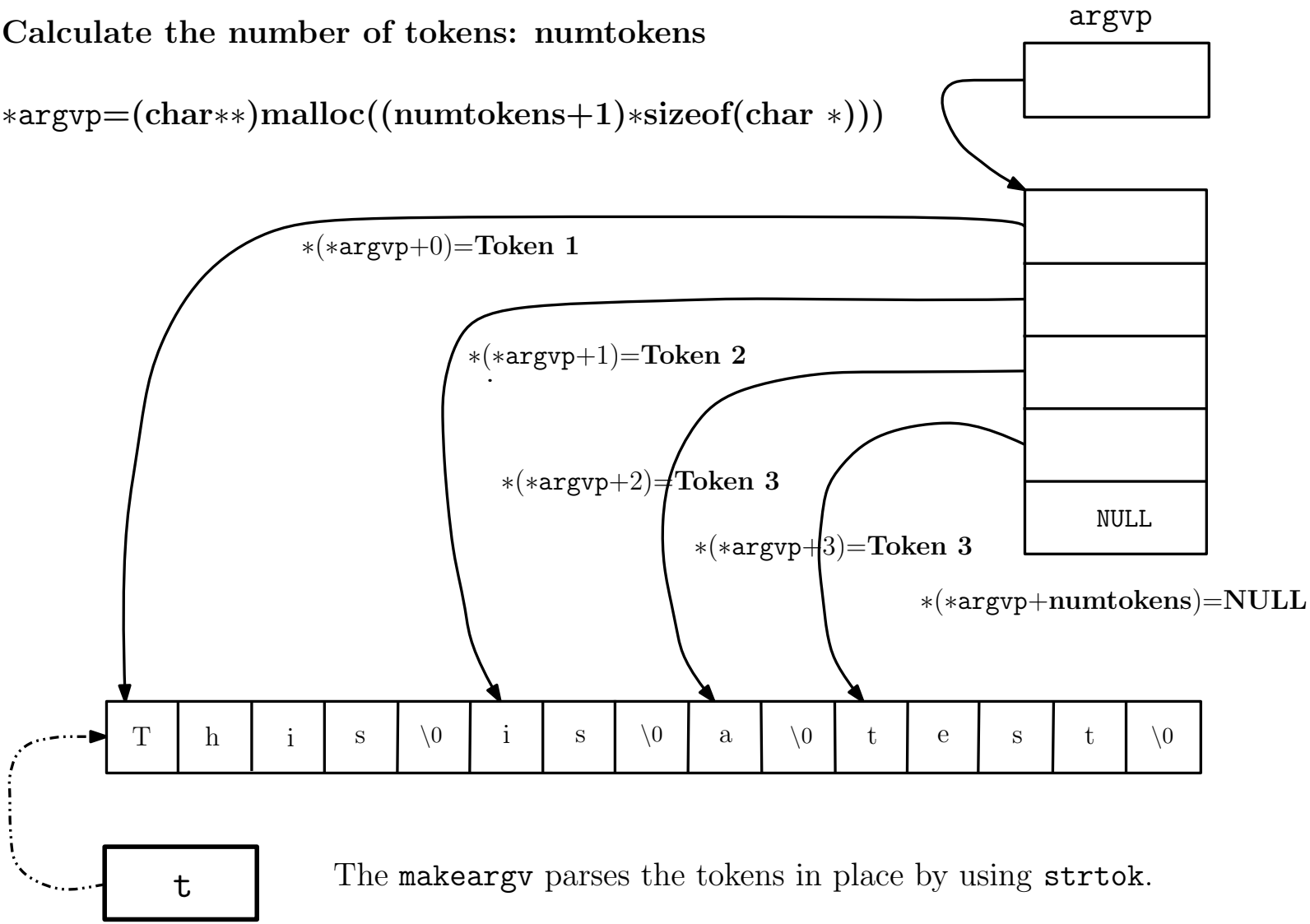
- Copy **`s`** into **`t`** again. `strcpy(t,s);`
- Use **`strtok`** to obtain pointers to the individual tokens, modifying **`t`** and effectively parsing **`t`** in place.

Creating Argument Array for ptrs (`argvp`) to the Tokens

Calculate the number of tokens: numtokens

`*argvp=(char**)malloc((numtokens+1)*sizeof(char *))`



The `makeargv` parses the tokens in place by using `strtok`.

Library Function: `strspn()`

`strspn()` - get length of a prefix substring

```
#include <string.h>

size_t strspn(const char *s, const char *
   accept);

RETURN VALUE:
The  strspn()  function returns the number of
bytes in the initial segment of s which
consist only of bytes from accept.
```

The **`strspn()`** function calculates the length (in bytes) of the initial segment of **`s`** which consists entirely of bytes in **`accept`**.

Example: `strspn()`

`strspn()` - get length of a prefix substring

```
#include<stdio.h>
#include<string.h>
int main()
{
  char *s="--#?This # is a String - ?";
  char *snew;
  size_t len;
  char *accept="----#?";
  printf("Origina string s=%s\n",s);
  len=strspn(s,accept);
  printf("Length of the initial segment of s which
      consists entirely of bytes in accept=%ld\n",len);
  snew=s+len; //shifting base addr of s to len
  printf("Now snew=%s\n",snew);
  return 0;
}
```

makeargv Function Definition for Version II

```
int makeargv(char *s, char ***argvp)
{
  int numtokens=-1,i;
  char *t,*snew;
  *argvp=NULL;
  printf("Original String Length=%ld\n",strlen(s));
  /* To skip over leading delimietrs use strspn() */
  /* For more on strspn() refer $ man strspn */
  snew=s+strspn(s," ");
  printf("Skipping leading delimietrs(If any): String Length=%
      ld\n",strlen(snew));
  t=(char *)malloc(sizeof(char)*(strlen(snew)+1));
  strcpy(t,snew);
  if(strtok(t," ")!=NULL){
     for(numtokens=1;strtok(NULL," ")!=NULL;numtokens++);
  }
  *argvp=(char **)malloc((numtokens+1)*sizeof(char *));
  strcpy(t,snew);
  **argvp=strtok(t," ");
  for(i=1;i<numtokens;i++)
      *(*argvp+i)=strtok(NULL," ");
  *(*argvp+numtokens)=NULL;
  return numtokens;
 }
```

Argument Array Creation Version-III

The following alternative prototype specifies that **makeargv** should pass the argument array and a **delimiter set** as parameters. This third version of **makeargv** returns an integer giving the number of tokens in the input string. In this case, **makeargv** returns -1 to indicate an error.

makeargv function prototype Version III

```
int makeargv(const char *s, const char *
    delimiters, char ***argvp);
```

The **const** qualifier means that the function does not modify the memory pointed to by the first two parameters.

`main` Part for Version III Argument Array

```
int makeargv(const char *s, const char *delimiters, char ***
    argvp);
int main(int argc, char *argv[]) {
char delim[] = " \t";
int i;int numtokens;
char **myargv;
if (argc != 2) {
   fprintf(stderr, "Usage: %s string\n", argv[0]);
   return 1;
}
if ((numtokens = makeargv(argv[1], delim, &myargv)) == -1) {
   fprintf(stderr, "Failed to construct an argument array for %
       s\n", argv[1]);
   return 1;
}
printf("The argument array contains:\n");
for (i = 0; i < numtokens; i++)
   printf("%d:%s\n", i, myargv[i]);
return 0;
}
```

The above program that takes a single string as its command-line argument and calls **`makeargv`** to create an argument array. **TO RUN::** **`$./a.out "This is a test"`**

Implementation of `makeargv`

Implementation of **`makeargv`** based on the prototype as;

```
int makeargv(const char *s, const char *
    delimiters, char ***argvp);
```

The **`makeargv`** function creates an argument array pointed to by **`argvp`** from the string **`s`**, using the delimiters specified by **`delimiters`**. If successful, **`makeargv`** returns the number of tokens. If unsuccessful, makeargv returns -1.

makeargv Function Definition for Version III

```
int makeargv(const char *s, const char *delimiters, char ***
    argvp)
{
  int numtokens=-1,i;
  char *t;
  const char *snew;
  if ((s == NULL) || (delimiters == NULL) || (argvp == NULL)) {
    return -1;
  }
  *argvp=NULL;
  snew=s+strspn(s,"delimiters");
  t=(char *)malloc(sizeof(char)*(strlen(snew)+1));
  strcpy(t,snew);
  if(strtok(t,"delimiters")!=NULL){
     for(numtokens=1;strtok(NULL," ")!=NULL;numtokens++);
  }
  *argvp=(char **)malloc((numtokens+1)*sizeof(char *));
  strcpy(t,snew);
  **argvp=strtok(t,"delimiters");
  for(i=1;i<numtokens;i++)
      *(*argvp+i)=strtok(NULL," ");
  *(*argvp+numtokens)=NULL;
  return numtokens;
 }
```

Summary: Argument Array Version I, II, III

`makeargv` function prototype Version I

```
char **makeargv(char *s);
```

Summary: Argument Array Version I, II, III

`makeargv` function prototype Version I

```
char **makeargv(char *s);
```

`makeargv` function prototype Version II

```
int makeargv(char *s, char ***argvp);
```

Summary: Argument Array Version I, II, III

makeargv function prototype Version I

```
char **makeargv(char *s);
```

makeargv function prototype Version II

```
int makeargv(char *s, char ***argvp);
```

makeargv function prototype Version III

```
int makeargv(const char *s, const char *
   delimiters, char ***argvp);
```