Why should I use pointers when I can access objects directly?

```
typedef struct pair{
        int x[512];
        int y[512];
} pair;
```

Consider a large compound data type ‘pair’

```
. . .
pair add1(pair a, pair b){
        pair temp;
        int i;
        for(i=0; i<512; i++){
                temp.x[i] = a.x[i]+b.x[i];
                temp.y[i] = a.y[i]+b.y[i];
        }
        return temp;
}
int main(){
        int i;
        pair a, b, c;
        …
        //approach1
        c = add1(a, b);
        …
}
```

Approach 1:
Compute c by passing objects

```
. . .
void add2(pair *p0, pair *p1, pair *p2){
      int i;
        for(i=0; i<512; i++){
          p2->x[i] = p0->x[i] + p1->x[i];
          p2->y[i] = p0->y[i] + p1->y[i];
        }
      return;
}
int main(){
      int i;
      pair a, b, c;
      pair *p0, *p1, *p2;
      p0 = &a; p1=&b; p2=&c;
      …
      add2(p0, p1, p2);
      …
}
```

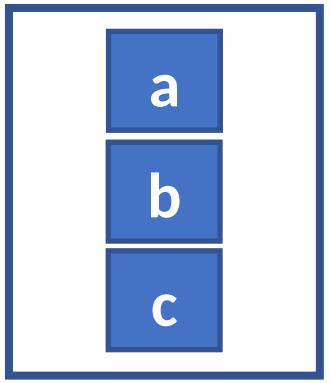
Approach 2:
Compute c by passing pointers

Both approaches compute the same result.

Question:
Which one would be better for a system?

```
. . .
pair add1(pair a, pair b){
        pair temp;
        int i;
        for(i=0; i<512; i++){
                temp.x[i] = a.x[i]+b.x[i];
                temp.y[i] = a.y[i]+b.y[i];
        }
        return temp;
}
int main(){
        int i;
        pair a, b, c;
        …
        //approach1
        c = add1(a, b);
        …
}
```

Approach 1:
Compute c by passing objects

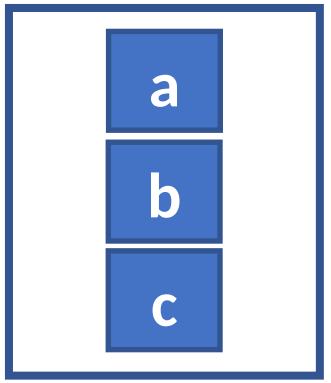


Stack frame of main()

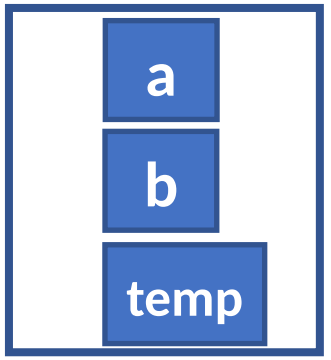
Initially large objects a, b, c are in stack frame of main()

```
. . .
pair add1(pair a, pair b){
        pair temp;
        int i;
        for(i=0; i<512; i++){
                temp.x[i] = a.x[i]+b.x[i];
                temp.y[i] = a.y[i]+b.y[i];
        }
        return temp;
}
int main(){
        int i;
        pair a, b, c;
        …
        //approach1
        c = add1(a, b);
        …
}
```

Approach 1:
Compute c by passing objects



Stack frame of main()

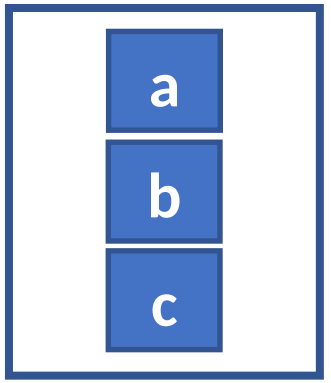


Stack frame of add1()

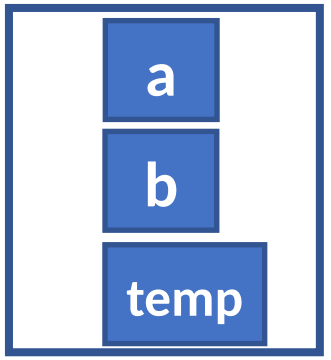
add1() is called and then **large** a and b are passed.
✉ they are **copied**.

```
. . .
pair add1(pair a, pair b){
        pair temp;
        int i;
        for(i=0; i<512; i++){
                temp.x[i] = a.x[i]+b.x[i];
                temp.y[i] = a.y[i]+b.y[i];
        }
        return temp;
}
int main(){
        int i;
        pair a, b, c;
        …
        //approach1
        c = add1(a, b);
        …
}
```

Approach 1:
Compute c by passing objects



Stack frame of main()



Stack frame of add1()

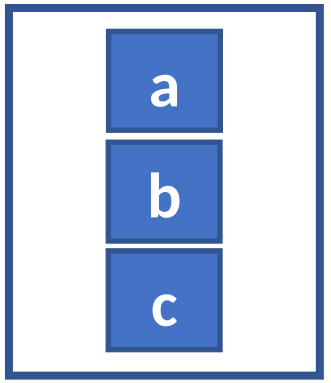
In the end add1() returns **large** ‘temp’.

✉ It is copied into c

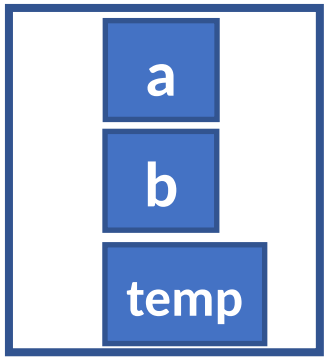
```
. . .
pair add1(pair a, pair b){
        pair temp;
        int i;
        for(i=0; i<512; i++){
                temp.x[i] = a.x[i]+b.x[i];
                temp.y[i] = a.y[i]+b.y[i];
        }
        return temp;
}
int main(){
        int i;
        pair a, b, c;
        …
        //approach1
        c = add1(a, b);
        …
}
```

Lots of big-data copy happen.

Approach 1:
Compute c by passing objects



Stack frame of main()

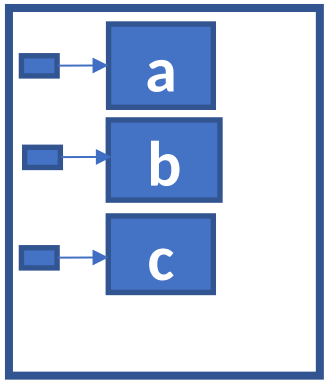


Stack frame of add1()

In the end add1() returns **large** 'temp'.
✉ It is copied into c

```
. . .
void add2(pair *p0, pair *p1, pair *p2){
      int i;
        for(i=0; i<512; i++){
          p2->x[i] = p0->x[i] + p1->x[i];
          p2->y[i] = p0->y[i] + p1->y[i];
        }
      return;
}
int main(){
      int i;
      pair a, b, c;
      pair *p0, *p1, *p2;
      p0 = &a; p1=&b; p2=&c;
      …
      add2(p0, p1, p2);
      …
}
```

Approach 2:
Compute c by passing pointers

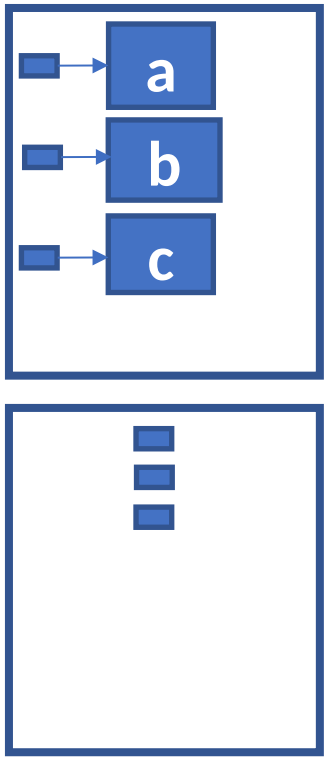


Stack frame of main()

Initially large objects a, b, c and 8-byte pointers are in stack frame of main()

```
. . .
void add2(pair *p0, pair *p1, pair *p2){
      int i;
        for(i=0; i<512; i++){
          p2->x[i] = p0->x[i] + p1->x[i];
          p2->y[i] = p0->y[i] + p1->y[i];
        }
      return;
}
int main(){
      int i;
      pair a, b, c;
      pair *p0, *p1, *p2;
      p0 = &a; p1=&b; p2=&c;
      …
      add2(p0, p1, p2);
      …
}
```

Approach 2:
Compute c by passing pointers



Stack frame of main()

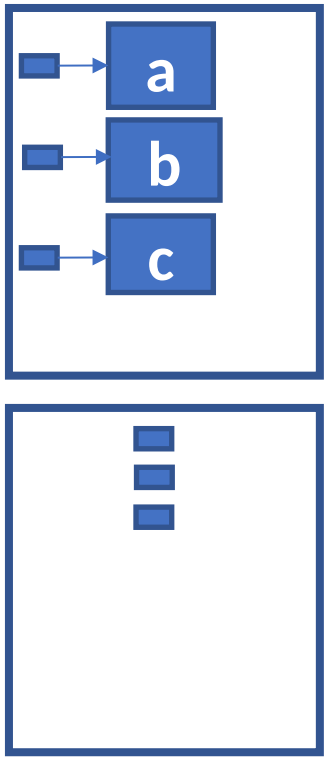
Stack frame of add2()

add2() is called and then pointers are passed.

- **Small** 8-byte pointers are **copied**

```
. . .
void add2(pair *p0, pair *p1, pair *p2){
      int i;
        for(i=0; i<512; i++){
          p2->x[i] = p0->x[i] + p1->x[i];
          p2->y[i] = p0->y[i] + p1->y[i];
        }
      return;
}
int main(){
      int i;
      pair a, b, c;
      pair *p0, *p1, *p2;
      p0 = &a; p1=&b; p2=&c;
      …
      add2(p0, p1, p2);
      …
}
```

Approach 2:
Compute c by passing pointers



Stack frame of main()

Stack frame of add2()

add2() updates c directly

So, overall only 3 pointers are copied!

Conclusions: pass-by-value vs pass-by-pointer

- Pass-by-value copies objects from one stack frame to other
- Pass-by-pointer copies only pointers

Thus, pass-by-pointer is more efficient for large data objects

Other standard input/output functions in C

Standard Input/Output functions in C

So far, we have extensively used two input/output functions

```
scanf("%format", &variable_name);
printf("%format", variable_name);
```

There are several other functions in C to perform input/output operations.

Standard Input/Output functions in C: getchar() and putchar()

- getchar() gets a character from standard input.

- putchar() writes a character to standard output.

```
int main () {
   char c;

   printf("Enter a character: ");
   c = getchar();

   printf("Character entered: ");
   putchar(c);

   return(0);
}
```

Program output
Enter a character: B
Character entered: B

Standard Input functions in C: getline

- getline () reads an entire line.

```
int main(){

   char *str = NULL;
   size_t n;
   int res;
   printf("Enter a string: ");
   res = getline (&str, &n, stdin);
   if (res != -1) {
      printf ("%s", str);
   }

   return 0;
}
```

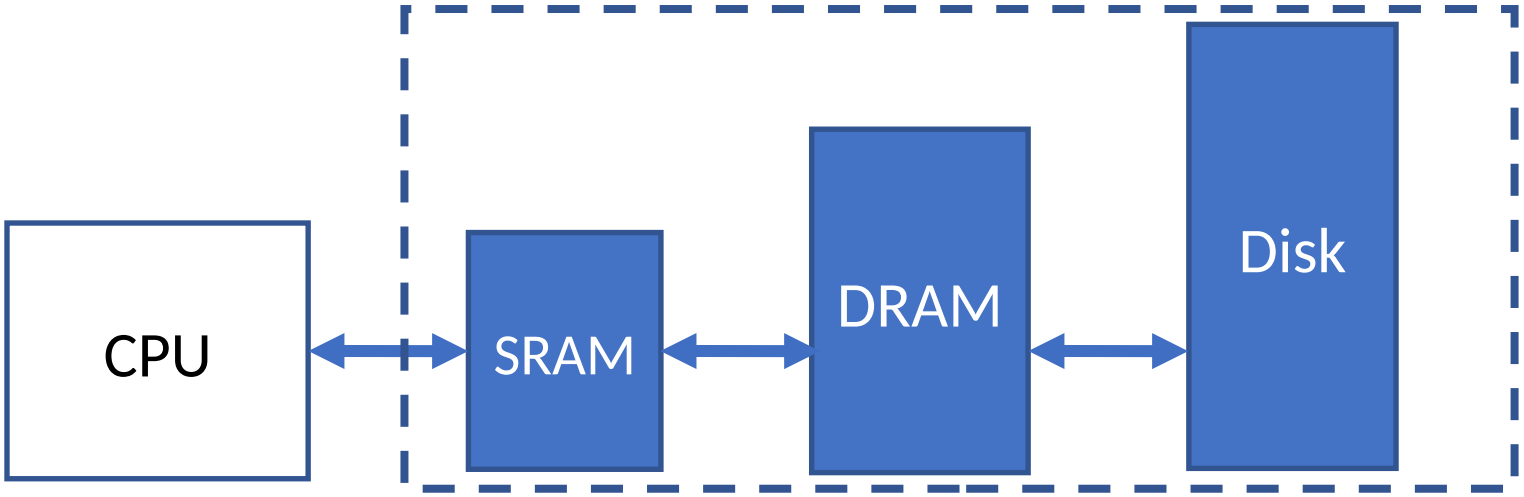
Program output
Enter a string: ABC DEF
ABC DEF

File handlining in C

Use of files in program

- Large data volumes

- E.g. data from statistics, experiments, human genome, population records etc.



File resides in Disk

✉ File read/write are slow

Opening file from a C program

- For opening a file, fopen() function is used with the required access modes.

```
FILE *fp;  /*variable fp is pointer to type FILE*/

fp = fopen("filename", "mode");
/*opens file with name filename , assigns identifier to fp */
```

fopen() returns NULL, if it is unable to open the specified file.

- File pointer fp points to the 'file' resource
  - contains all information about file
  - Communication link between system and program

- An opened file is closed by passing the file pointer to fclose()

```
fclose(fp);
```

Different modes

- Reading mode (**r**)
  - if the file already exists then it is opened as *read-only*
  - sets up a pointer which points to the first character in it.
  - else error occurs.

- Writing mode (**w**)
  - if the file already exists then it is *overwritten* by a new file
  - else a new file with specified name created

- Appending mode (**a**)
  - if the file already exists then it is opened
  - else new file created
  - sets up a pointer that points to the last character in it
  - any new content is appended after existing content

Additional modes

- r+ opens file for both reading/writing an *existing* file
  - doesn't delete the content of if the *existing* file

- w+ opens file for reading and writing a *new* file
  - Overwrites if the specified file already exists

- a+ open file for reading and writing from the last character in the file

Functions for reading or writing: getc() and putc()

There are several functions to read from and write to a file.

- getc() – read a char from a file.
- putc() – write a char to a file

Functions for reading or writing: getc() and putc()

```
int main(){
        char ch;
        FILE *fp0, *fp1;
        fp0 = fopen("infile.txt", "r");
        fp1 = fopen("outfile.txt", "w");
        if (fp0==NULL || fp1==NULL){
         printf("Cannot open files\n");
         exit(-1);
        }

        ch = getc(fp0); // reads one char from first file
        while (ch != EOF){      // EOF is 'end of file'
                printf("%c", ch); // Displays on screen
                putc(ch, fp1); // writes to second file
                ch = getc(fp0);     // reads another char from first file
        }
        fclose(fp0);
        fclose(fp1);
        return 0;
}
```

Functions for reading or writing: fprintf() and fscanf()

- Similar to printf() and scanf()
- in addition the file pointer is provide as an input
- Examples:

To read one int from a file with file pointer fp0

```
int i;
fp0=fopen("some_file", "r");
fscanf(fp0, "%d", &i);
```

To write one int to a file with file pointer fp1

```
int i=4;
fp1=fopen("some_file", "w");
fprintf(f1, "%d", i);
```

Functions for reading or writing: fprintf() and getline()

```
int main(){
        char *line = NULL;
        size_t n;
        FILE *fp0, *fp1;
        int res;

        fp0 = fopen("infile.txt", "r");
        fp1 = fopen("outfile.txt", "w");
        if (fp0==NULL || fp1==NULL){
                printf("Cannot open files\n");
                exit(1);
        }

        while((res = getline(&line, &n, fp0)) != -1) {
          fprintf (fp1, "%s", line);
        }
        fclose(fp0);
        fclose(fp1);
        return 0;
}
```

Typical file errors

Typically, errors happen when a program

- tries to read beyond end-of-file (EOF)
- tries to use a file that has not been opened
- performs operation on file not permitted by ‘fopen’ mode
  Example:

```
fp=fopen("filename", "r");
...
fprintf(fp, "%d", i);
```

- opens file with invalid filename
- writes to write-protected file
  Example: files with read-only permission

Handling these errors

Programmer can perform the following checks

- feof(fp) returns a non-zero value when End-of-File is reached, else it returns zero

```
fp = fopen("somefile", "somemode");
. . .
if(feof(fp)){
      printf("End of file\n");
}
```

- ferror(fp) returns nonzero value if error detected else returns zero

```
fp = fopen("somefile", "somemode");
. . .
if(ferror(fp) !=0)
      printf("An error has occurred\n");
```

Random access to file

Data in a file is basically a collection of bytes.

We can ***directly*** jump to a target byte-number in a file without reading previous data using fseek()

- Syntax: fseek(file-pointer, offset, position);
- position: 0 (beginning), 1 (current), 2 (end)
- offset: number of locations to move from specified position

```
Examples:
fseek(fp, -m, 1); // move back by m bytes from current
fseek(fp, m, 0); // move to (m+1)th byte in file
```

- ftell(fp) returns current byte position in file
- rewind(fp) resets position to start of file

Random access to file

```
int main () {
   FILE *fp;

   fp = fopen("file.txt","w+");
   fprintf(fp,"%s", "This is something");

   fseek( fp, 7, 0);
   fprintf(fp,"%s"," C Language");
   fclose(fp);

   return(0);
}
```

The program
1. writes “This is something”
2. then moves to 7 byte-positions after beginning (i.e., 8th position)
3. writes " C Language“ (overwriting any data that exists)

Thus, the final content is “This is C Language”

Command line arguments in C

Command line arguments in C

We can modify a program to receive arguments from command line.

```
Example
./a.out  string1 string2 string3
```

Syntax is

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

- argc (Argument Count) is int and *automatically* stores the number of command-line arguments passed by the user including name of program.

- argv(Argument Vector) is array of char pointers listing all the arguments.
  argv[0] is the name of the program
  argv[1] is the first command-line argument etc.

Command line arguments in C

```
int main(int argc, char *argv[]){
    int i;
    printf("You have entered %d arguments:\n", argc);

    for (int i = 0; i < argc; ++i)
        printf("%s\n", argv[i]);

    return 0;
}
```

```
$./a.out how are you?
You have entered 4 arguments:
a.out
how
are
you?
```

Another example: Command line arguments in C

```c
#include <stdio.h>
#include <stdlib.h>
#define PI 3.1416
int main (int argc, char *argv[]){
  double r, area, circ;

  char *a = argv[1];
  int diameter = atoi(a);

  if(argc>1)
    printf("You have entered %d\n",diameter);
  else{
    printf("Enter diameter:");
    scanf("%d", &diameter);
  }
  r= diameter/2;
  area = PI*r*r;
  circ= 2*PI*r;

  printf ("Circle with diameter %d\n", diameter);
  printf ("has area of %f\n", area);
  printf ("and circumference of %f\n", circ);
```

atoi() converts a string to an integer.

```
$./a.out
Enter diameter:2
Circle with diameter 2
has area of 3.141600
and circumference of 6.283200

$./a.out 2
You have entered 2
Circle with diameter 2
has area of 3.141600
and circumference of 6.283200
```