# C++ Programming

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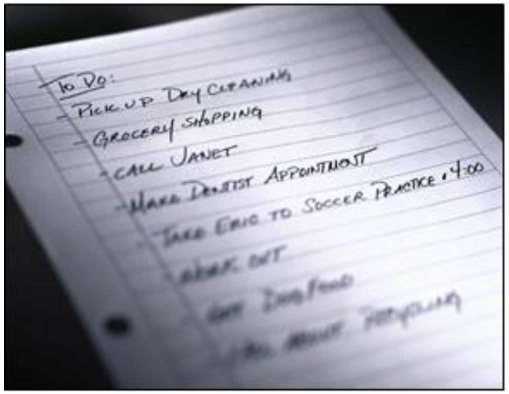
# Mapping zyBooks Chapters

| Topic | zyBooks Chapter |
|---|---|
| Structures | 8.1, 8.2 |
| Arrays of Structures | 8.2 |
| Structures and vectors | 8.3, 8.4 |

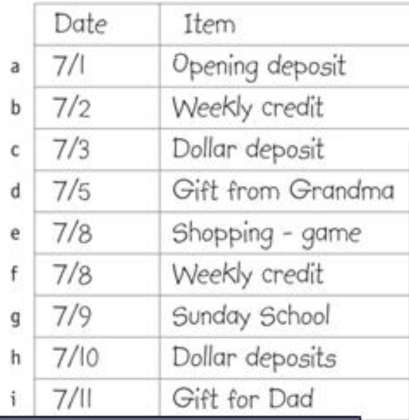
# Struct

# Review - List in Real Life

- It is often the case in computer science that you will process a list of items



To Do:
- Pick up Dry Cleaning
- Grocery Shopping
- Call Janet
- Make Dentist Appointment
- Take Eric to Soccer Practice · 4:00
- Work out
- Get Dog Food
- [illegible] about Recycling



| | Date | Item | In/Out | Balance |
|---|---|---|---|---|
| a | 7/1 | Opening deposit | + 16.00 | $ 16.00 |
| b | 7/2 | Weekly credit | + 3.00 | $ 19.00 |
| c | 7/3 | Dollar deposit | | |
| d | 7/5 | Gift from Grandma | | |
| e | 7/8 | Shopping - game | | |
| f | 7/8 | Weekly credit | | |
| g | 7/9 | Sunday School | | |
| h | 7/10 | Dollar deposits | | |
| i | 7/11 | Gift for Dad | | |

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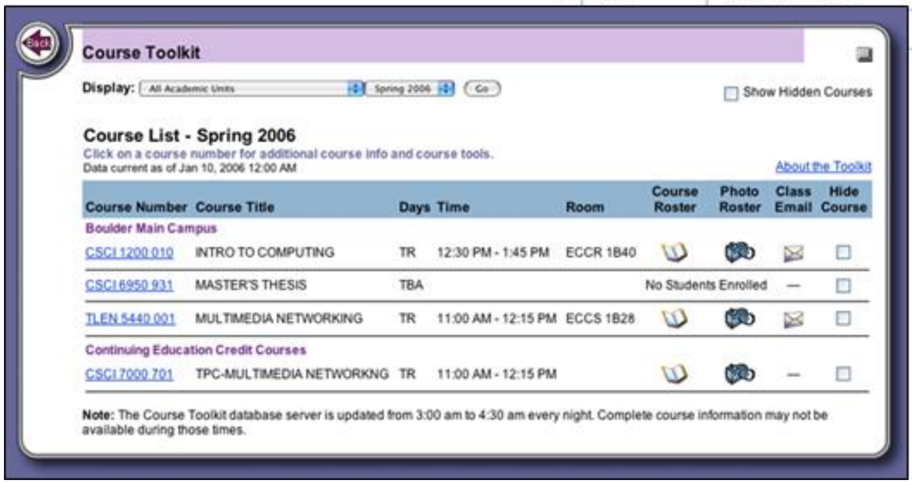

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| CSCI 6950 931 | MASTER'S THESIS | TBA | | | No Students Enrolled | | — | □ |
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| Continuing Education Credit Courses | | | | | | | | |
| CSCI 7000 701 | TPC-MULTIMEDIA NETWORKNG | TR | 11:00 AM - 12:15 PM | | 📖 | 📷 | — | □ |

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# Review - Variables

- Types
  - Specify what kind of data it will hold
  - Basic data types are **integers** (`short`, `int`, `long`), **real numbers** (`float` or `double`), or **characters** (`char`).
  - `int`: hold integer values, i.e., whole numbers such as 7, -11, 0, etc.
    - The largest `int` value is typically 2,147,483,647 but can be as small as 32,767
  - `float`: can store numbers with digits after the decimal point, such as 379.125
    - Slower than `int` in arithmetic operation
    - Is often an approximation of the number. E.g., `0.1` in a float variable might be 0.09999999999999987 stored in the system.
  - **Variables must be declared before they can be used**

# Review - Array

- Array declaration
  - Syntax: `type name[length]`
    - `type` is the data type of the array
    - `name` is the name you use to reference the array
    - `length` is the number of elements in the array, which is always one more than the last index of the array
  - Example, create an array to hold a 1000 integers

    ```
    int a[1000];
    ```

  - Another way to initialize array, which makes your code more maintainable, is to use a preprocessor constant

    ```
    const int SIZE = 1000;
    int a[SIZE];
    ```

  - Like other variables in C, declaring them does not initialize them

# Structures

# Structure and Array

- Array
  - All elements of an array have the same type
  - To select an array element, we specify its position (as an index)
- Structure
  - The elements (members) aren’t required to have the same data type
  - The members of a structure have names; to select a particular member, we specify its name, not its position

# Structure

- Define a structure
  - □ struct *structure_name* {

    ```
    struct structure_name {
      member_type1 member_name1;
      member_type2 member_name2;
      ...
    };
    ```

  - □ Example

    ```
    struct point_t {
      double x;
      double y;
    };
    ```

# Structure

- Declaring a structure variable
  - `struct` *structure_name variable_name*;
  - Example

    ```
    struct point_t pt1;
    struct point_t pt2;
    ```
- Initializing Structure Variables
  - Prepare a list of values to be stored in the structure and enclose it in braces
  - Example:

    ```
    struct point_t pt1 = {200.0, 200.0};
    ```
  - The values in the initializer must appear in the same order as the members of the structure.

# Structure

- Accessing Structure Members
  - Structure member operator: ., also called the dot operator
  - Example:
    `cout << "(" << pt1.x << ", " << pt2.x << ")";`
  - Designated Initializers
    `struct point_t pt1 = {.y = 200.0, .x = 100.0};`
- Where to define structures?
  - Generally defined in a header file along with function prototype
  - Can defined them at the top of `.c` file

https://stackoverflow.com/questions/228684/

# Structure

- Create `point.h` with the following codes

```
#ifndef POINT_H
#define POINT_H

struct point_t {
        double x;
        double y;
};

// function prototypes

#endif
```

# Structures as Arguments and Return Values

- Structures as Arguments
  - Pass a structure to a function require making a copy of all members in the structure
  - Example:

point.c

```
double distance(struct point_t p, struct point_t q)
{
        return sqrt(pow(p.x - q.x, 2) + pow(p.y - q.y, 2));
}
```

pts.c

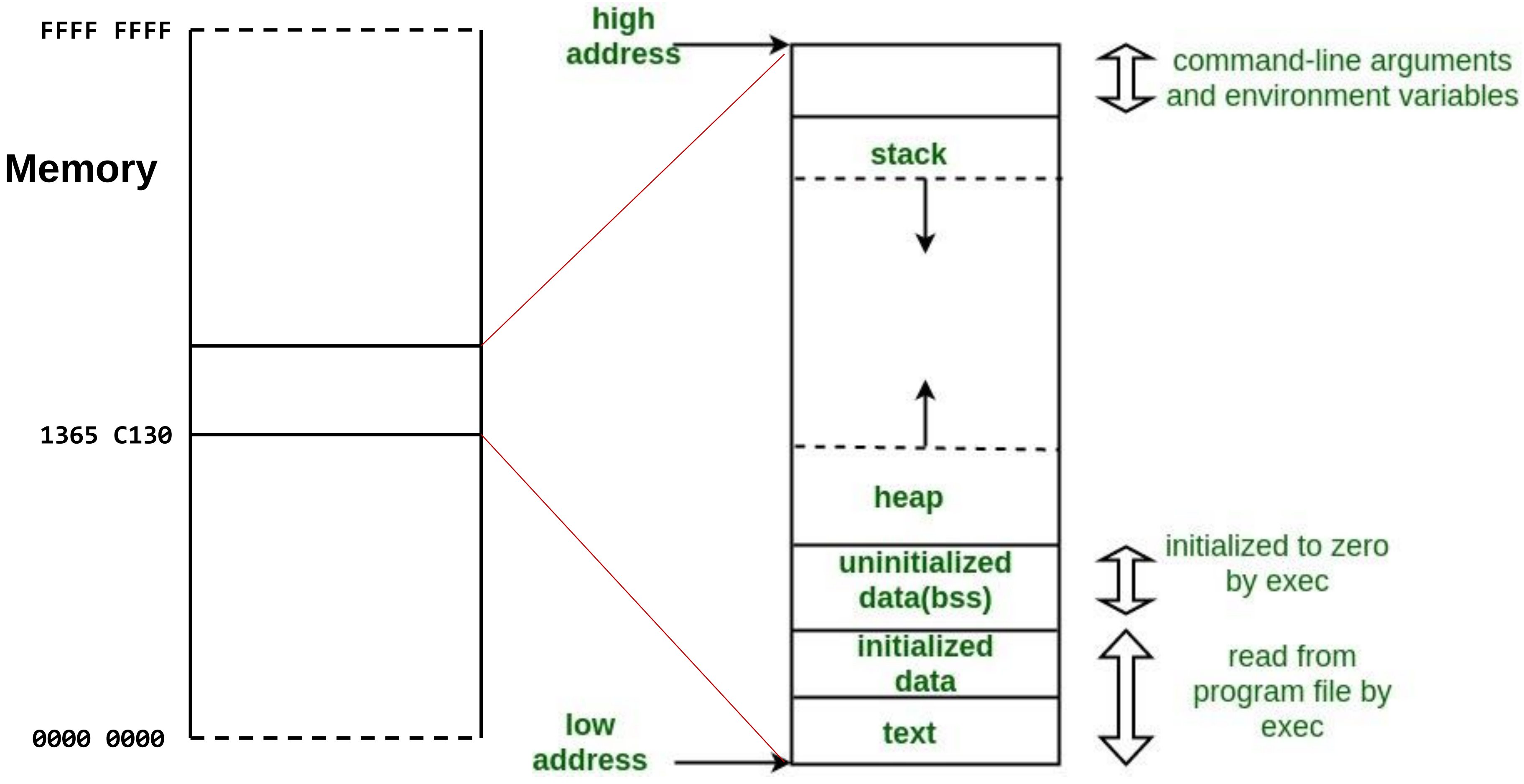
```
int main(void)
{
         struct point_t pt1 = {0.0, 0.0};
         struct point_t pt2 = {3.0, 4.0};
         double d;

         d = distance(pt1, pt2);

         return 0;
}
```

# Review - Memory Layout

- Memory
  - Variables correspond to locations in the computer's memory



https://www.geeksforgeeks.org/memory-layout-of-c-program/

# Structures as Arguments and Return Values

- Structures as Arguments
  - □ Pass a structure to a function require making a copy of all members in the structure
  - □ Example:

point.c

```
double distance(struct point_t p, struct point_t q)
{
        return sqrt(pow(p.x - q.x, 2) + pow(p.y - q.y, 2));
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        double d;

        d = distance(pt1, pt2);

        return 0;
}
```
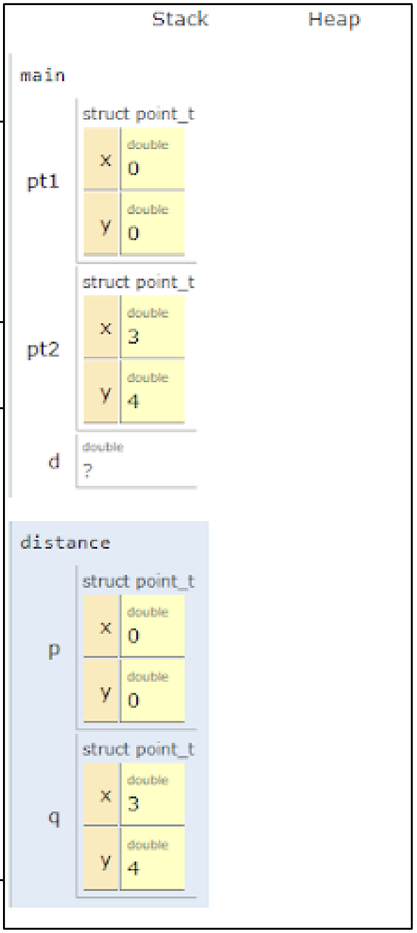



# Structures as Arguments and Return Values

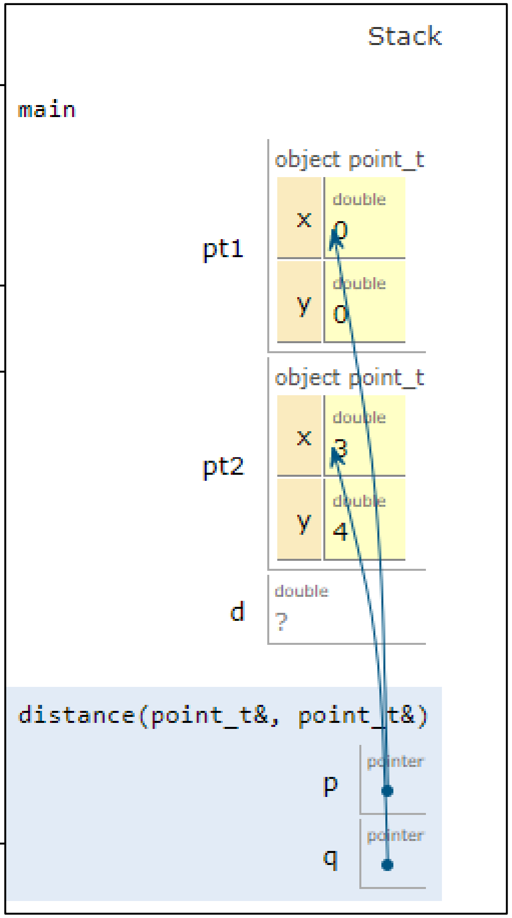
- Structures as Arguments
  - Pass the `struct` parameters by references

point.c

```c
double distance(struct point_t &p, struct point_t &q)
{
        return sqrt(pow(p.x - q.x, 2) + pow(p.y - q.y, 2));
}
```

pts.c

```c
int main(void)
{
         struct point_t pt1 = {0.0, 0.0};
         struct point_t pt2 = {3.0, 4.0};
         double d;

         d = distance(pt1, pt2);

         return 0;
}
```



# Structures as Arguments and Return Values

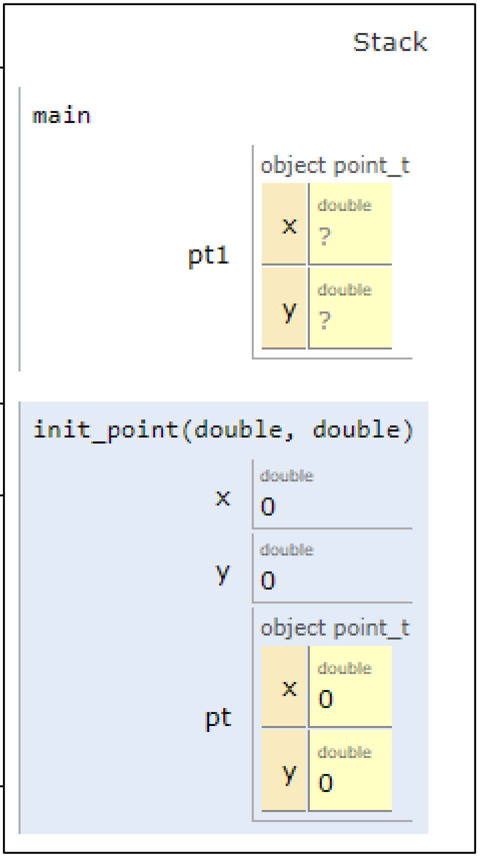
- Structures as Arguments
  - □ Pass a structure to a function require making a copy of all members in the structure
  - □ Example:

point.c

```
struct point_t init_point(double x, double y)
{
        struct point_t pt;
        pt.x = x;
        pt.y = y;
        return pt;
}
```

pts.c

```
int main(void)
{
        struct point_t pt1 = init_point(0.0, 0.0);

        return 0;
}
```



# Structures as Arguments and Return Values

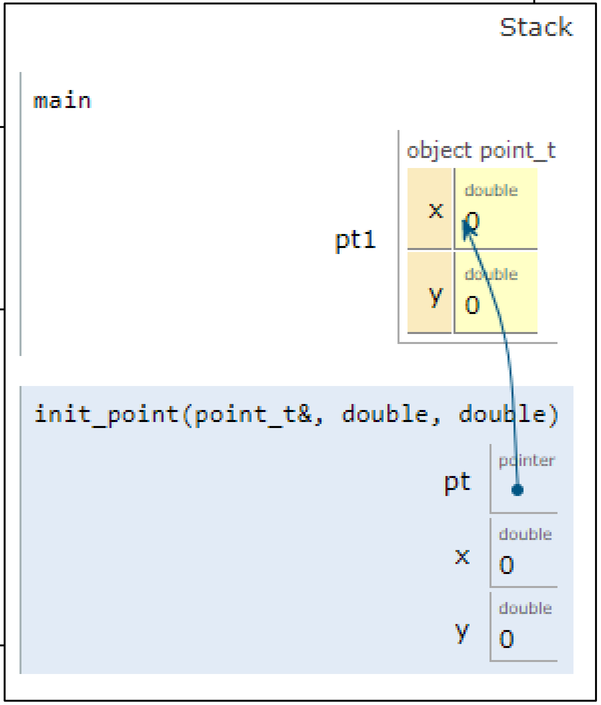
- Structures as Arguments
  - Another way to solve the problem
  - We typically pass `structs` to functions by reference.

point.c

```
void init_point(struct point_t &pt, double x, double y)
{
        pt.x = x;
        pt.y = y;
}
```

pts.c

```
int main()
{
  struct point_t pt1;
  init_point(pt1, 0.0, 0.0);

  return 0;
}
```



# Nested Structure

- Nesting one kind of structure inside another
- Example

```
struct person_name {
  string first;
  char middle_initial;
  string last;
};

struct student {
  struct person_name name;
  int id, age;
  char gender;
};

int main()
{
  struct student std1 = {{"John", 'A', "Doe"}, 32, 21};
  cout << "Student's first name is " << std1.name.first << endl;

  return 0;
}
```

# Arrays of Structures

# Review - Array

- Array declaration
  - Syntax: `type name[length]`
    - `type` is the data type of the array
    - `name` is the name you use to reference the array
    - `length` is the number of elements in the array, which is always one more than the last index of the array
  - Example, create an array to hold a 1000 integers

    ```
    int a[1000];
    ```
  - Another way to initialize array, which makes your code more maintainable, is to use a preprocessor constant

    ```
    const int SIZE = 1000;
    int a[SIZE];
    ```
  - Like other variables in C, declaring them does not initialize them

# struct Arrays

- Declaration
  - □ `struct` *structure_name variable_name*`[`*size*`];`
  - □ Example:

```
struct point_t pts[10];
```

- Visit elements in the struct array
  - □ As same as visiting elements in array with primary data types
  - □ Example:

```
struct point_t origin = {0.0, 0.0};
 for (i = 0; i < 10; i++) {
   cout << "distance to origin: "
        << distance(pts[i], origin) << endl;
 }
```

# struct Arrays

- Example
    - Find the distance of an array of points to the origin

pts.c

```
int main()
{
  const int NPOINTS = 5;
  int i;
  double dist[NPOINTS];
  struct point_t pts[NPOINTS] =
    {{3.5, 7.8}, {3.0, 4.0}, {2.0, 8.5},
     {6.3, 8.9}, {5.0, 5.0}};

  distance_to_origin(pts, NPOINTS, dist);

  for (i = 0; i < NPOINTS; i++)
    cout << dist[i] << "\t";
  cout << endl;

  return 0;
}
```

# struct Arrays

- Example
  - Find the distance of an array of points to the origin

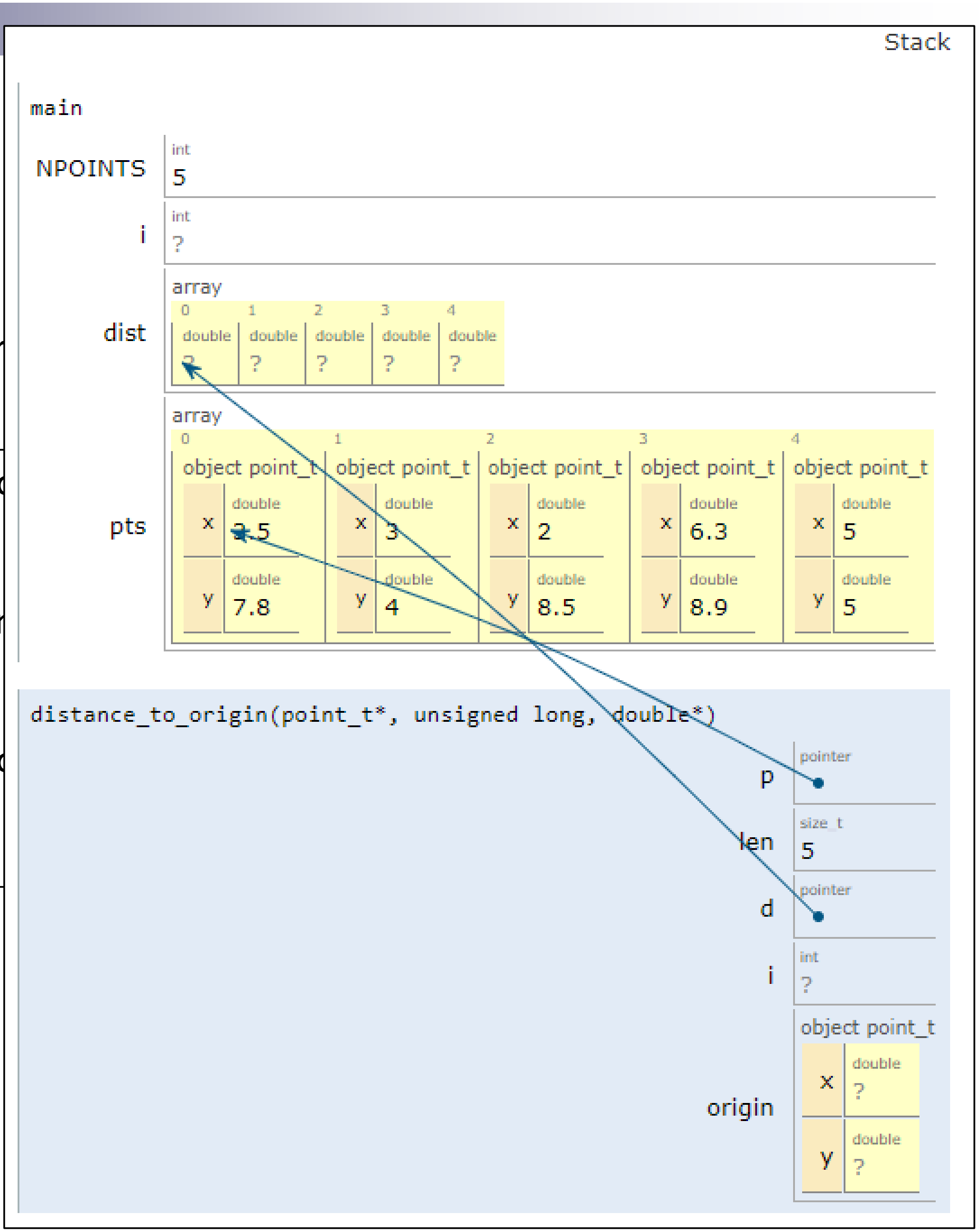
point.c

```
void distance_to_origin(struct point_t p[], size_t len, double d[])
{
        int i;
        struct point_t origin = {0.0, 0.0};

        for (i = 0; i < len; i++) {
               d[i] = distance(p[i], origin);
        }
}
```

# struct Arrays

- Example
  - Find the distance of an ar

```
void distance_to_origin(struc
{
        int i;
        struct point_t origi

        for (i = 0; i < len; 
                d[i] = distanc
        }
}
```



Stack

main

NPOINTS: int 5

i: int ?

dist: array

| 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| double<br>? | double<br>? | double<br>? | double<br>? | double<br>? |

pts: array

|  | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
|  | object point_t | object point_t | object point_t | object point_t | object point_t |
| x | double<br>3.5 | double<br>3 | double<br>2 | double<br>6.3 | double<br>5 |
| y | double<br>7.8 | double<br>4 | double<br>8.5 | double<br>8.9 | double<br>5 |

distance_to_origin(point_t*, unsigned long, double*)

p: pointer

len: size_t 5

d: pointer

i: int ?

origin: object point_t

x: double ?

y: double ?

# Structures and `vectors`

# struct vectors

- Example
  - Find the distance of an array of points to the origin

pts.c

```
int main()
{
  const int NPOINTS = 5;
  int i;
  double dist[NPOINTS];
  vector<struct point_t> pts =
    {{3.5, 7.8}, {3.0, 4.0}, {2.0, 8.5},
     {6.3, 8.9}, {5.0, 5.0}};

  distance_to_origin(pts, NPOINTS, dist);

  for (i = 0; i < NPOINTS; i++)
    cout << dist[i] << "\t";
  cout << endl;

  return 0;
}
```

# struct vectors

- Example
  - Find the distance of an array of points to the origin

point.c

```
void distance_to_origin(vector<struct point_t> &p, size_t len,
                                                          double d[])
{
  int i;
  struct point_t origin = {0.0, 0.0};

  for (i = 0; i < len; i++) {
    d[i] = distance(p.at(i), origin);
  }
}
```

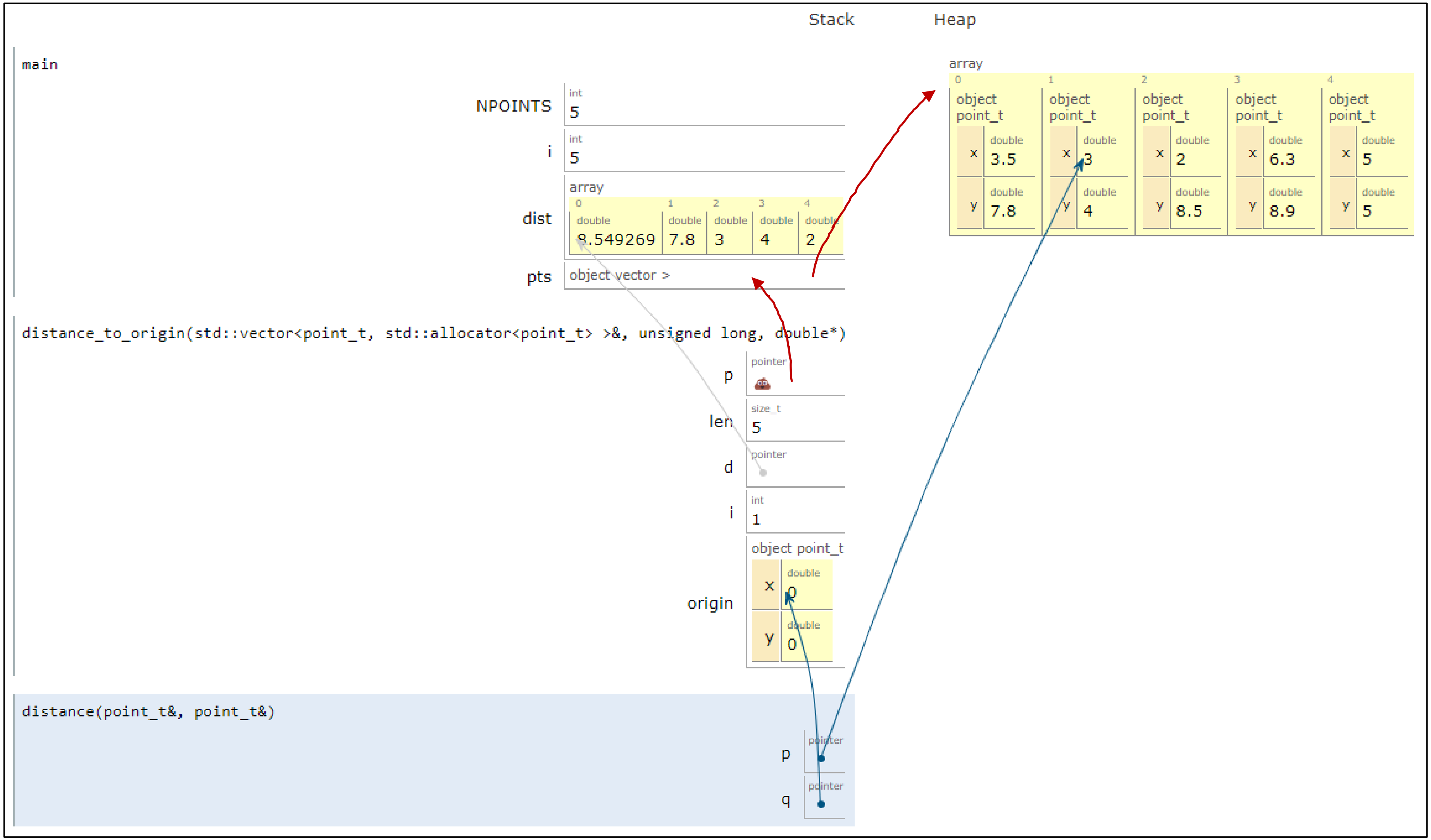
# struct vectors

- Example
  - Find the distance of an array of points to the origin

point.c

```
void distance_to_origin(vector<struct point_t> &p, size_t len,
                                                         double d[])
{
  int i;
  struct point_t origin = {0.0, 0.0};

  for (i = 0; i < len; i++) {
    d[i] = distance(p.at(i), origin);
  }
}
```

# struct vectors



Stack

Heap

main

NPOINTS int 5

i int 5

dist array

| 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| double | double | double | double | double |
| 8.549269 | 7.8 | 3 | 4 | 2 |

pts object vector >

distance_to_origin(std::vector<point_t, std::allocator<point_t> >&, unsigned long, double*)

p pointer

len size_t 5

d pointer

i int 1

origin object point_t

| | |
|---|---|
| x | double<br>0 |
| y | double<br>0 |

distance(point_t&, point_t&)

p pointer

q pointer

array

| 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| object point_t | object point_t | object point_t | object point_t | object point_t |
| x double 3.5 | x double 3 | x double 2 | x double 6.3 | x double 5 |
| y double 7.8 | y double 4 | y double 8.5 | y double 8.9 | y double 5 |

Figure 8.4.1

# struct vectors

- Example: Seat structure

```
#include <iostream>
#include <vector>
#include <string>
using namespace std;

struct Seat {
   string firstName;
   string lastName;
   int amountPaid;
};
```

Figure 8.4.1

# struct vectors

- Example:
  - □ Seat structure

```
#include <iostream>
#include <vector>
#include <string>
using namespace std;

struct Seat {
   string firstName;
   string lastName;
   int amountPaid;
};
```

Figure 8.4.1

# struct vectors

- Example:
  - Seat structure related functions - Seat structure only

```
void SeatMakeEmpty(Seat& seat) {
   seat.firstName   = "empty";
   seat.lastName    = "empty";
   seat.amountPaid  = 0;
}

bool SeatIsEmpty(Seat seat) {
   return(seat.firstName == "empty");
}

void SeatPrint(Seat seat) {
   cout << seat.firstName << " ";
   cout << seat.lastName << ", ";
   cout << "Paid: " << seat.amountPaid << endl;
}
```

Figure 8.4.1

# struct vectors

- Example:
  - □ Seat structure related functions - for Seat vector

```
void SeatsMakeEmpty(vector<Seat>& seats) {
   unsigned int i;
   for (i = 0; i < seats.size(); ++i) {
      SeatMakeEmpty(seats.at(i));
   }
}

void SeatsPrint(vector<Seat> seats) {
   unsigned int i;
   for (i = 0; i < seats.size(); ++i) {
      cout << i << ": ";
      SeatPrint(seats.at(i));
   }
}
```