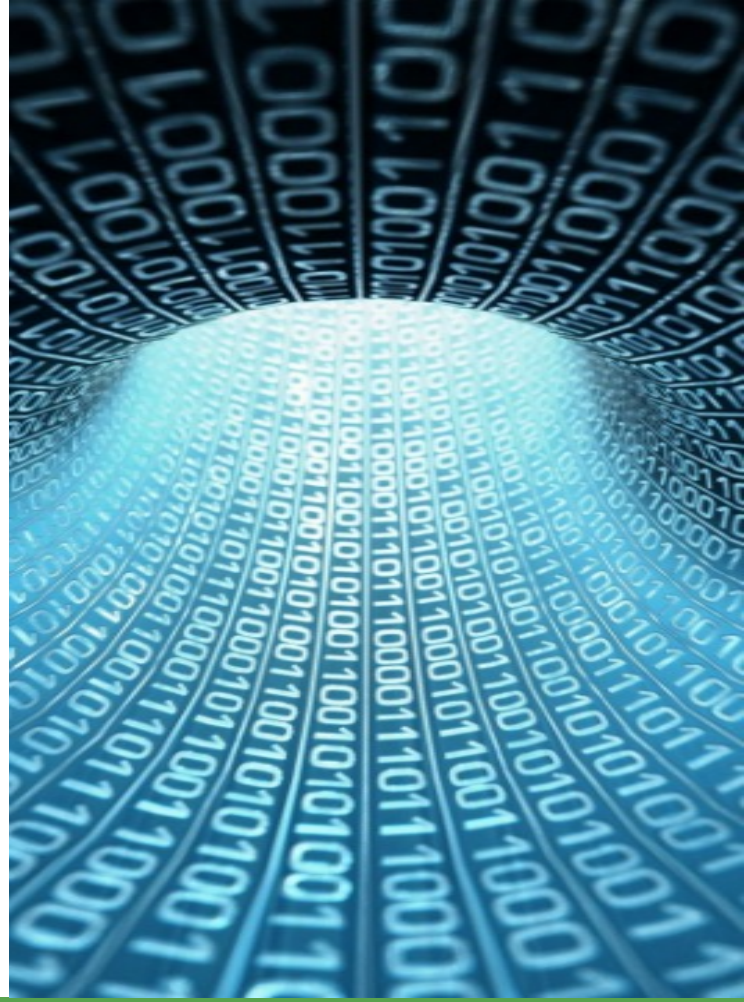
POLITECNICO
DI TORINO
Dipartimento
di Automatica e Informatica

Aggregated data types

DECLARATION AND USE OF ARRAYS, MATRICES AND STRUCT IN C



Arrays (vectors and matrices)

AGGREGATES OF HOMOGENEOUS ELEMENTS, ACCESSIBLE BY INDEXING

Vectors (mono-dimensional arrays)

- Aggregates elements of the same type
- Definition (declaration): `<type> <identifier>[<dimension>];`
  - Examples: `int v[10]; char s[L]; float w[N];`
  - The dimension needs to be CONSTANT (either an integer value or an integer constant, defined with #define or const int)
  - *variable length arrays* are possible in C, but difficult to handle: not suggested
  - Only at the time of the declaration, it is possible to make an explicit initialization:

```
int v[10] = {-2,0,1,10,-7,12,34,9,-3,6};
char s1[6] = {'h','e','l','l','o','\0'};
char s2[6] = "hello"; // Same effect as the previous instruction
```

  - It is possible to have partial initialization or declare implicit dimensions (rules omitted here…)

Vectors (mono-dimensional arrays): usage

- Elements are identified by 0 to N-1 positions (where N is the vector's size):
  - Example: `v[0], v[1], ..., v[N-1]`
- There are NO atomic operations on the whole array
  - Only exception is the optional initialization during the declaration (see previous slide)
  - Atomic operations on strings can be done only with library functions (<string.h>) or IO functions
- There are NO atomic operations on portions of an array (no built-in slicing…)
- Operations need to be done one element at a time:
  - `v[0] = x;`
  - `s[4] = 'a';`
  - `w[i] = w[j];`
  - `s[N-j-1] = s[0];`

Vectors and functions

- When a vector is passed as parameter to a function
  - Formal parameter
    - Name of the vector with [ ]

```
int function(int vett[]);
```

  - Actual parameter
    - Name of the vector, WITHOUT [ ]

```
a = function (vett);
```

- The name of the vector indicates the address of the first element (& is not needed)
  - de-facto, the vector is passed “by reference”
  - The caller and the function share **the same** vector → if you modify the content of the vector in the function, the same modification is seen by the caller

Example

```
int age[20], height[20], i;
float avgAge = 0.0;
float avgHeight = 0.0;

for(i=0; i<20; i++) {
  scanf("%d %d", &age[i], &height[i]);
  avgAge += age[i];
  avgHeight += height[i];
}
avgAge = avgAge/20;
avgHeight = avgHeight /20;

… … …
```

Matrices (multidimensional arrays)

- Arrays with more than one dimension: you just need to add extra sets of [ ]
- Definition (declaration): `<type> <identifier>[<dim1>][<dim2>]`
  - Examples: `int M[10][10]; char s[R][C]; float W[N1][N2];`
  - Dimensions need to be constant integers (same rules as vectors)
  - Only at the time of the declaration, it is possible to make an explicit initialization:

```
int v[5][2] = {{-2,0,1,10,-7},{12,34,9,-3,6}};
char days[7][10] = {"monday","tuesday","wednesday","thursday",
                    "friday","saturday","sunday"};
```

Matrices: usage

- Elements are accessed by indexing each dimension :

```
M[0][j], s[r][c], ..., W[N-1][0]
```

- There are NO atomic operations on the whole matrix except initialization during declaration, same as vectors
- There are NO atomic operations on portions. Nonetheless, it is possible to identify a portion of the matrix (for example, a whole row) by omitting the last index

```
char s[10][10];  → s[r] is the r-th row of the matrix → an array of char!
→ it is possible to do:    fgets(s[r],MAX,fin));   scanf("%s",s[r]);   etc…
```

- We need to access one element at a time (same as with vectors):

```
v[0][0] = x; s[4][1] = 'a'; w[i][j] = w[j][i];
```

- Matrices are passed to functions "by reference", same as vectors
  - You can omit ONLY the first dimension in the formal parameter

Example

```
int matrix_diagonal[3][3] = { { 1, 0, 0 },
                              { 0, 1, 0 },
                              { 0, 0, 1 }  } ;
float M2 [N][M], V[N], Y[M];

/* assignment of values to M2 and V */
...
/* matrix-vector multiplication*/
for (r=0; r<N; r++) {
  Y[r] = 0.0;
  for (c=0; r<M; c++)
    Y[r] = Y[r] + M2[r][c]*V[c];
}
```

Strings

A SPECIAL FORM OF ARRAY

Strings

- They are not a specific data type, just a special vector of `char` elements
  - Example: `char nome[N];`
- They are characterized by a string terminator `'\0'` (ASCII code 0), placed after the last significant character:
  - Usually a vector is over-sized in the declaration, `'\0'` indicates where the string actually ends
- To perform operations on vectors of chars as a whole, it is necessary to use strings (with `'\0'`) as operands:
  - String constants (for example: "hello") are strings: they have a '\0' terminator
  - IO functions: gets/puts, fgets/fputs, formatted IO with %s
  - Functions of the library <string.h>: for example, strlen, strcpy, strcmp, strncmp, strcat

Functions on strings #include <string.h>

Function	What It Does
strcmp()	Compares two strings in a case-sensitive way. If the strings match, the function returns 0.
strncmp()	Compares the first n characters of two strings, returning 0 if the given number of characters match.
strcpy()	Copies (duplicates) one string to another.
strncpy()	Copies a specific number of characters from one string to another.
strlen()	Returns the length of a string, not counting the or NULL character at the end of the string.
strcat()	Appends one string to another, creating a single string out of two.
strncat()	Appends a given number of characters from one string to the end of another.

Examples

```
char words[NP][MAXL], first[MAXL], last[MAXL], firstAndLast[2*MAXL];
// read words from file
int n;
for (n=0; fscanf(fin, "%s", words[n]) != EOF; n++);
// verify order
int i, sorted = 1;
for (i=1, i<n && sorted; i++) {
  if (strcmp(words[i-1],words[i])>0) { // if words[i-1] follows alphabetically words[i]
    sorted = 0;
  }
}
// copy first and last word
strcpy(first,words[0]); // WARNING: first = words[0] is WRONG!
strcpy(last,words[n-1]); // WARNING: last = words[n-1] is WRONG!
// join first and last
strcpy(firstAndLast,first); // copy first
strcat(firstAndLast,last); // append last
```

Strings as vectors of chars

- It is also possible to handle strings as vectors of characters, and perform operations character-by-character
- Examples:
  - Remove '\n' read by fgets

```
fgets(s,MAXL,fin);
if (s[strlen(s)-1]=='\n')
  s[strlen(s)-1] = '\0';
```

  - Convert a word to uppercase (toupper and tolower functions work only for single characters!)

```
void stringToUpper(char s[]) {
  int i, len = strlen(s);
  for (i=0; i<len; i++)
    s[i] = toupper(s[i]);
}
```

struct

AGGREGATES OF HETEROGENEOUS FIELDS, ACCESSIBLE BY THEIR NAME

Struct types

- Heterogeneous aggregated type in C is a struct. Same as records of other programming languages
- A struct is composed by fields:
  - Fields are either basic data types or other structs
  - Each field in a struct can be accessed by means of its identifier (unlike arrays, where elements are accessed by indexing)

Example

```
struct student {
    char surname[MAX], name[MAX];
    int matricola;
    float score;
};
```

```
struct student
{
    char surname[MAX], name[MAX];
    int matricula;
    float score;
};
```

A new data type

- The new type is `struct student`
- Keyword `struct` is mandatory

```
struct student
{
    char surname[MAX], name[MAX];
    int matricola;
    float score;
};
```

Name of the struct

- Same rules as for the names of the variables
- Names of `struct` need to be different from the names of other struct (they can be the same as the name of other variables, but better avoid…

```
struct student
{
    char surname[MAX], name[MAX];
    int matricola;
    float score;
};
```

Fields

- Fields correspond to local variables of the struct
- Each field has a type and an identifier

Declaration schemes

1. Basic scheme

```
struct student
{
   char surname[MAX], name[MAX];
   int matricola;
   float score;
};
...
struct student s, t;
```

Declaration schemes

2. Contextual declaration of the new struct type and of the variables

```
struct student
{
   char surname[MAX], name[MAX];
   int matricola;
   float score;
} s, t;
```

Declaration schemes

3. (very rare): Contextual declaration of the type struct (without identifier) and variables

- The type `struct` is used just to declare the variables that are defined in the same context
- It will NOT be possible to declare more variables of the same struct type anywhere else in the program

```
struct {
    char surname[MAX], name[MAX];
    int matricola;
    float score;
} s, t;
```

`Typedef:` define a new type

- It is possible to associate an identifier to an already existing type:
  - typedef <existing type> <new name for the existing type>;
  - Example:
    typedef int number;
    ...
    number n, m;
- In practice:
  - We can use a name of our choice to refer to a type (it is especially useful to the struct types)
  - Similar to #define of literal constants (…but typedef is NOT a directive to the pre-processor, it is handled by the compiler!)

Declaration schemes

4. Synonym of di `struct student`, with `typedef`

```
typedef struct student
{
   char surname[MAX], name[MAX];
   int matricola;
   float score;
} Student;
...
Student s, t;
```

Declaration schemes

5. Synonym of di `struct student`, with `typedef` → version without the identifier of struct

```
typedef struct
{
   char surname[MAX], name[MAX];
   int matricola;
   float score;
} Student;
...
Student s, t;
```

Accessing fields of a struct

- After declaring a variable of struct type, the individual fields of the variable can be accessed using the operator ‘ . ’

  <identifier of variable of type struct> . <field name>

- Esxample:

```
typedef struct{
   double re;
   double im;
} complex;
...
complex num1, num2;
num1.re = 0.33; num1.im = -0.43943;
num2.re = -0.133; num2.im = -0.49;
```

`struct` vs arrays

- Analogy:
  - They are both aggregated data types
- Differences:
  - Heterogeneous (`struct`) / Homogeneous (arrays)
  - Access by name of the field (`struct`) / by index (arrays)
  - Parameter passing by value (`struct`) / by reference (arrays)
  - Parameterized access NOT allowed (`struct`) / allowed (arrays)

Parameterized access to arrays

- Arrays are frequently used to access numbered data in a parameterized way, especially in iterative constructs
- By "parameterized" we mean "the access to the each element depends on a parameter" (for example, a variable i)

Example

```
for (i=0; i<N; i++) {
   ...
   vett[i] = ...;
   ...
}
```

Parameterized access to a `struct`: NO

- Fields of a `struct` CANNOT be accessed in a parameterized way


```
char field[20];
...
scanf("%s",field);
printf("%s",s.field);
```

Parameterized access to a `struct`: NO

- Fields of a `struct` CANNOT be accessed in a parameterized way


```
char field[20];
...
scanf("%s",field);
printf("%s",s.field);
```

field is a variable!
The fields of the struct s are: surname, name, matricola, score

Parameterized access to a `struct`: NO

- Possible solution: implement a function that takes the name of the field of the structure as argument

```
char field[20];
...
scanf("%s",field);
printField(s,field);
```

The function HIDES the details…

```
/* in the function the access is explicit, not parameterized! */


void printField( struct student s, char id[]) {
  if (strcmp(id,”surname”)==0)
    printf("%s",s.surname);
  else if(strcmp(id,”name”)==0)
    printf("%s",s.name);
  else if(strcmp(id,”matricola”)==0)
    printf("%d",s.matricola);
  ...
}
```

Better a struct or an array?

For homogeneous types (for example, a point in Euclidean space → aggregate of two coordinates x and y, of the same type): better **`p.x, p.y`** or **`p[0], p[1]`**?

Better `struct` or array?

`struct` suggested when:

- Not too many fields
- Fields are better identifiable by name
- We do not need parameterized access
- We would like to treat the `struct` as a whole datum (for ex. in variable assignments, or as a unique argument or a return value of a function)

Better **`p.x, p.y`** !!!

Arrays can be fields of a `struct`

- A `struct` can have arrays as fields
  - Ex: surname and name in `struct` student
- Careful!
  - a `struct` is passed to functions by value, an array is passed by reference
  - If a `struct` has an array of N elements as field, passing the `struct` requires to "copy" the whole array
  - *TRICK: if you want to pass an array by value instead of by reference, you can include it as a field of a struct…*

Arrays of `struct`

We can have arrays whose elements are type struct

- Suggested when we have homogeneous collections of elements, where the individual elements are heterogeneous aggregates
  - Example: to handle a list of students

  struct student vet[N]; → vett[i] is a variable of type struct student!

- Careful!
  - All arrays (even the ones of type `struct`) are passed by reference to functions
  - A function can modify the content of an array of struct

Example

```
int main(void) {
  struct student list[NMAX];
  int i, n;

  printf(”how many students(max %d)? ",NMAX);
  scanf("%d",&n);
  for (i=0; i<n; i++) {
    list[i] = readStudent();
  }
  sortStudents(list,n);
  printf(”students sorted by their score\n");
  for (i=0; i<n; i++) {
    printStudent(list[i]);
  }
}
```

Example

```
int main(void) {
  struct student list[NMAX];
  int i, n;

  printf(”how many students(max %d)? ",NMAX);
  scanf("%d",&n);
  for (i=0; i<n; i++) {
    list[i] = readStudent();
  }
  sortStudents(list,n);
  printf(”students sorted by their score\n");
  for (i=0; i<n; i++) {
    printStudent(list[i]);
  }
}
```

Array of `struct`

Example

```
int main(void) {
  struct student list[NMAX];
  int i, n;

  printf(”how many students(max %d)? ",NMAX);
  scanf("%d",&n);
  for (i=0; i<n; i++) {
    list[i] = readStudent();
  }
  sortStudents(list,n);
  printf(”students sorted by their score\n");
  for (i=0; i<n; i++) {
    printStudent(list[i]);
  }
}
```

Passing by reference

Example

```
int main(void) {
  struct student list[NMAX];
  int i, n;

  printf(”how many students(max %d)? ",NMAX);
  scanf("%d",&n);
  for (i=0; i<n; i++) {
    list[i] = readStudent();
  }
  sortStudents(list,n);
  printf(”students sorted by their score\n");
  for (i=0; i<n; i++) {
    printStudent(list[i]);
  }
}
```

```
void sortStudents(struct student el[],
                  int n) {

  /*
     this function will MODIFY the content
     of the array, by sorting the
     students based on their score.

     We will see how to implement this at
     the end of the chapter(selectionSort)
   */

}
```