Array Memory Mapping

Charles Aunkan Gomes
Lecturer, Dept. of CSE
United International University
charles@cse.uiu.ac.bd

Arrays

- An array is an **indexed sequence** of components
  - The components of an array are all of the same type (**homogenous**)
- Typically, the array occupies **sequential** storage locations
- Array is a **static** data structure, that is, the length of the array is determined when the array is created, and cannot be changed
- Each component of the array has a **fixed, unique index**
  - Indices range from a lower bound to an upper bound
- Any component of the array can be inspected or updated by using its index
  - This is an efficient operation: ***O*(1) = constant time (will discuss later)**

Representation of Array in Memory

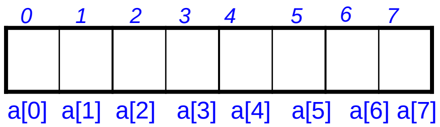
- **Linear (1 D) Arrays:**

A 1-dimensional array a is declared as:

int a[8];

The elements of the array a may be shown as

a[0] a[1] a[2] a[3] a[4] a[5] a[6] a[7]



Representation of Array in Memory

- **2 D Arrays:**

A 2-dimensional array a is declared as:

int a[3][4];

The elements of the array a may be shown as a table

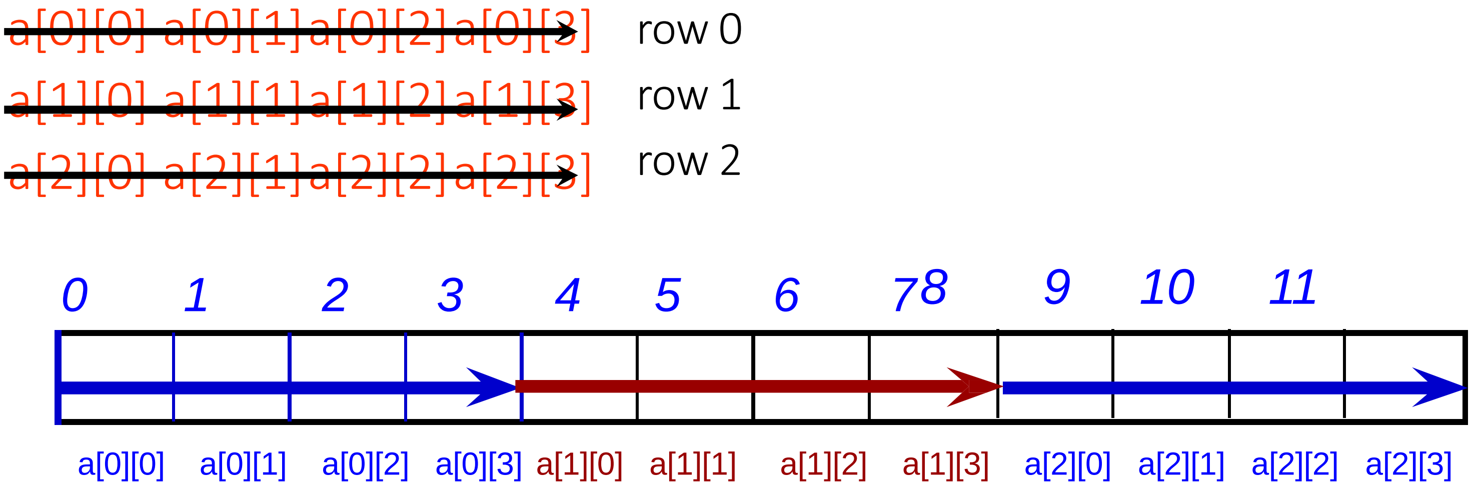
a[0][0]	a[0][1]	a[0][2]	a[0][3]
a[1][0]	a[1][1]	a[1][2]	a[1][3]
a[2][0]	a[2][1]	a[2][2]	a[2][3]

In which order are the elements stored?

- Row major order (C, C++, Java support it)
- Column major order (Fortran supports it)

Representation of Array in Memory

Row Major Order: the array is stored as a sequence of 1-D arrays consisting of rows.



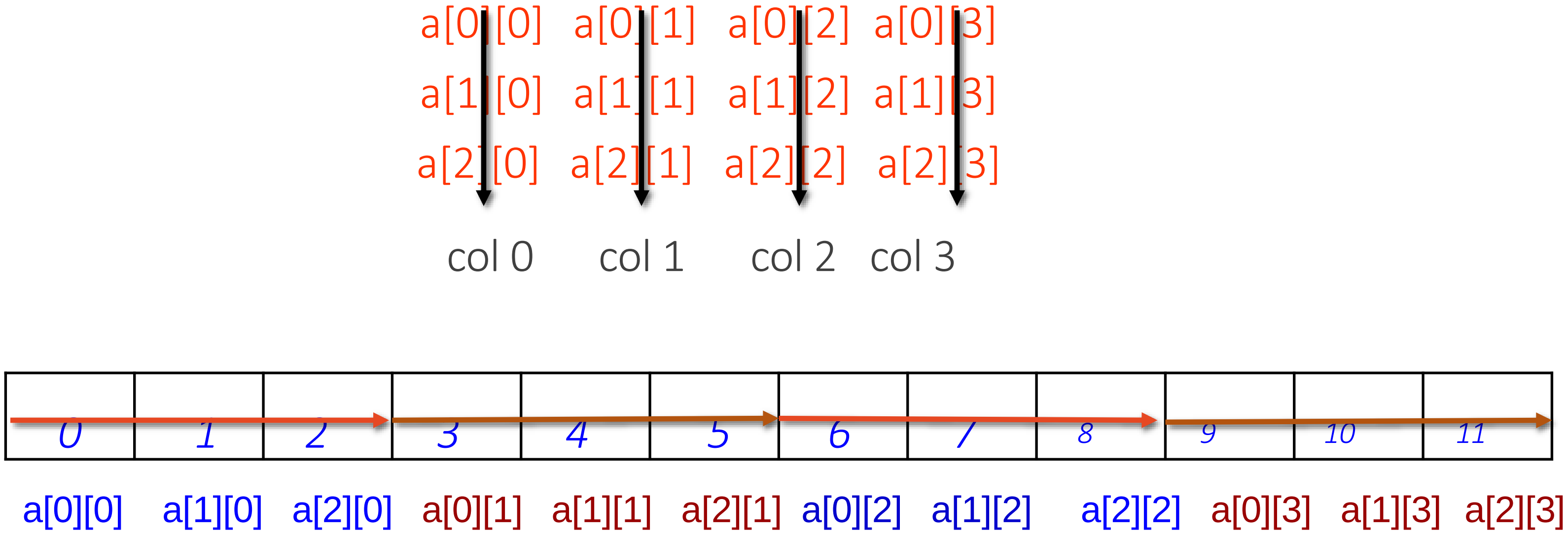
a[0][0] a[0][1] a[0][2] a[0][3] row 0

a[1][0] a[1][1] a[1][2] a[1][3] row 1

a[2][0] a[2][1] a[2][2] a[2][3] row 2

Representation of Array in Memory

Column Major Order: The array is stored as a sequence of arrays consisting of columns instead of rows.



a[0][0]	a[0][1]	a[0][2]	a[0][3]
a[1][0]	a[1][1]	a[1][2]	a[1][3]
a[2][0]	a[2][1]	a[2][2]	a[2][3]
col 0	col 1	col 2	col 3

0	1	2	3	4	5	6	7	8	9	10	11
a[0][0]	a[1][0]	a[2][0]	a[0][1]	a[1][1]	a[2][1]	a[0][2]	a[1][2]	a[2][2]	a[0][3]	a[1][3]	a[2][3]

Representation of Array in Memory

- **Base Address (*b*):** The memory address of the first byte of the first array component.
- **Component Length (*L*):** The memory required to store one component of an array.
- **Upper and Lower Bounds (l_i, u_i):** Each index type has a smallest value and a largest value.
- **Dimension**

Representation of Array in Memory

- **Array Mapping Function (AMF)**
  - AMF converts index value to component address

- **Linear (1D) Arrays:**

a : array $[l_1 \,..\, u_1]$ of element_type

$$\text{Then addr}(a[i]) = b + (i - l_1) \times L$$
$$= c_0 + c_1 \times i$$

Therefore, the time for calculating the address of an element is same for any value of i.

Representation of Array in Memory

- **Array Mapping Function (AMF)**: **2D Arrays**

  Row Major Order:

a : array $[l_1 \,..\, u_1, l_2 \,..\, u_2]$ of element_type

Then addr($a[i, j]$) $= b + (i - l_1)\times(u_2 - l_2 + 1)\times L + (j - l_2)\times L$

$= c_0 + c_1\times i + c_2\times j$

Therefore, the time for calculating the address of an element is same for any value of (i, j).

Representation of Array in Memory

- **Array Mapping Function (AMF): 2D Arrays**

  Column Major Order:

a : array $[l_1 \,..\, u_1,\, l_2 \,..\, u_2]$ of element_type

Then addr$(a[i, j]) = b + (j - l_2)\times(u_1 - l_1 + 1)\times L + (i - l_1)\times L$

$$= c_0 + c_1\times i + c_2\times j$$

Therefore, the time for calculating the address of an element is same for any value of (i, j).

Representation of Array in Memory

- **Array Mapping Function (AMF): 3D Arrays :**

a : array $[l_1 .. u_1, l_2 .. u_2 , l_3 .. u_3]$ of element_type

Then addr($a[i, j, k]$) $= b + (i - l_1)\times(u_2 - l_2 + 1)\times(u_3 - l_3 + 1)\times L +$

$$(j - l_2)\times(u_3 - l_3 + 1)\times L + (k - l_3)\times L$$

$$= c_0 + c_1\times i + c_2\times j + c_3\times k$$

Therefore, the time for calculating the address of an element is same for any value of (i, j , k).

Summary on Array

- Advantages:
  - Array is a random access data structure.
  - Accessing an element by its index is very fast (constant time)
- Disadvantages:
  - Array is a static data structure, that is, the array size is fixed and can never be changed.
  - Insertion into arrays and deletion from arrays are very slow.
- An array is a suitable structure when
  - a lot of searching and retrieval are required.
  - a small number of insertions and deletions are required.

THANK YOU