CS453 Arrays in Java in general

Plan for the day

- *Arrays in general*
- *Array descriptors*
- *Type checking for arrays*
- *Code gen for arrays*

Arrays

An array is a collection of items of the same type

- so that the address of an element can be computed from the start address and the index (efficiency)
- index: int (or int derivative type like unsigned or byte)

Once an array is allocated, the sizes of its dimensions do not change (as opposed to ArrayLists, Lists, …)

Java arrays are one Dimensional

- higher dimensional arrays are arrays of sub-arrays
  these are sometimes called "ragged" arrays, as the lengths of the sub-arrays can differ
- as opposed to rectangular arrays in Fortran and C

Array representations

1. store length with array elements

e.g. at the front of the array

- this is nice for Java arrays

the array is now represented by its start address

- the address of the length field

when allocating and indexing in such arrays this length field must be taken into account (added / skipped over)

2. Have a separate array descriptor with

index ranges for all dimensions

widths in bytes in each dimension

(some representation of) start address

Array descriptors

Sometimes called "dope vectors"

- dope: slang for "the essential information"

The descriptor representation is useful for rectangular arrays, especially when the language allows the creation of sub arrays from arrays.

These sub arrays can be

lower dimensional, e.g. vector (row, column) out of matrix,
or plane out of cube

same dimensional, sometimes called windows or tiles

e.g. median filter:

for all (sliding) windows of 3x3 in an image:
compute the median
from all these medians, build a new image

Rectangular Array declaration and allocation

possible array declarations:

array [1:20, 1:30] of int Im; // by first (lwb) and last (upb) valid indices

// first index (lwb) not necessarily 0 , **why is this useful?**

or

int [20,30] Im; // lengths, first index, lwb, implied: 0

// last index (upb) length-1 C, JAVA

possible array allocations:

row major order (C, JAVA)

array starts with first row allocated consecutively

second row occurs directly after first, etc.

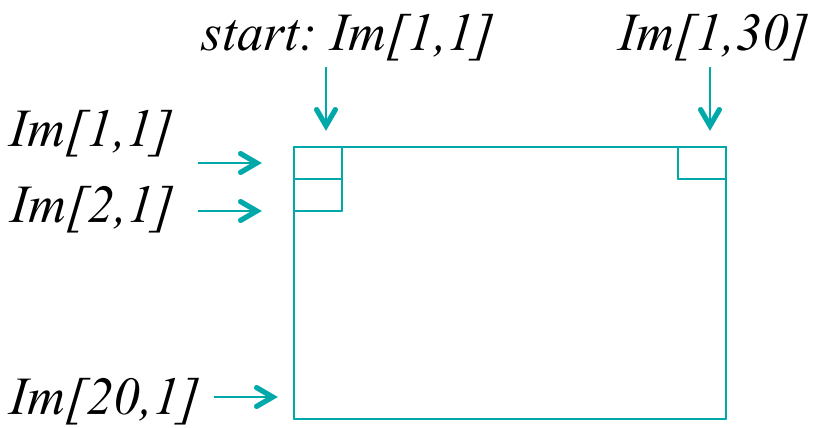
column major order (Fortran)

array starts with first column allocated consecutively

second column occurs directly after first, etc.

Descriptor Example

array [1:20, 1:30] of int Im;



Assume row major order

Im[2,1] directly follows Im[1,30]

Array elements contiguous region allocation:

*start = malloc(20*30*sizeof(int))*

The descriptor should make element address calculation simple:

*&Im[i,j] = start + (i-rowlwb)*rowWidth*

+ (j-collwb) colWidth*

*&Im[i,j] = base + i * rowWidth + j * colWidth*

base = ???

base

dim_1: lwb, upb,width

...

dim_n: lwb,upb,width

DESCRIPTOR IN GENERAL

*start-(30*4 + 4)*

dim_1: 1, 20, 120

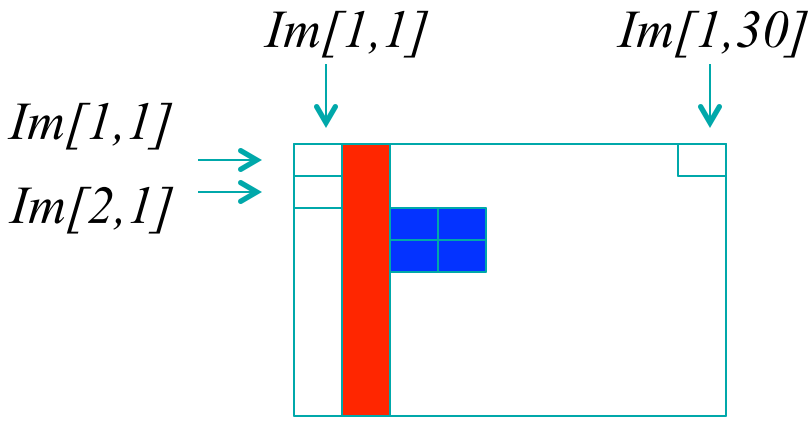
dim_2: 1,30, 4

DESCRIPTOR: im

(sizeof(int) = 4)

Descriptor Exercise

array [1:20, 1:30] of int Im;



Assume row major order:

Im[2,1] directly follows Im[1,30]

Array elements contiguous region allocation

*start = malloc(20*30*sizeof(int))*

The descriptor should make element address calculation simple:

*&Im[i,j] = base + i * rowWidth + j * colWidth*

*start-(30*4 + 4)*

dim_1: 1, 20, 120

dim_2: 1, 30, 4

DESCRIPTOR: Im

(sizeof(int)=4)

Given the descriptor for Im

Create descriptors for

1: array[1:20] of int column = Im[1:20,2]

2: array[1:2,1:2] of int window = Im[3:4,3:4]

assuming start = 1000 (decimal)

Overview of full Meggy Java

Full MeggyJava Grammar

- Array declaration
- Array creation
- Array access and assignment
- Array length
- Meggy.setAuxLEDs

Game of Life Demo

- There is a MeggyJr grid off the resources page

PA6Rainbow example

Rainbow.java

```
class PA6rainbow { public static void main(String[] whatever){{   // display a rainbow on row 5
        new Rainbow().run((byte)5); }}}
class Rainbow {
   Meggy.Color [] p;
   public void run(byte row) {
      p = new Meggy.Color [8];
      p[0] = Meggy.Color.RED;          p[1] = Meggy.Color.ORANGE;
      p[2] = Meggy.Color.YELLOW;   p[3] = Meggy.Color.GREEN;
      p[4] = Meggy.Color.BLUE;        p[5] = Meggy.Color.VIOLET;
      p[6] = Meggy.Color.WHITE;       p[7] = Meggy.Color.DARK;
      Meggy.setPixel((byte)2, (byte)3, p[0]);     Meggy.setPixel((byte)2, (byte)4, p[4]);
      this.displayRow(row, p);
   }
   public void displayRow(byte row, Meggy.Color [] a) {
      int i;  i=0;
      while (i<8) {
         Meggy.setPixel((byte)i, row, a[i]);       i = i+1;
}  }  }
```

Implementing type checking for MeggyJava (Arrays)

Syntax *AST Node(s)*

new int [Exp] NewArrayExp
new Meggy.Color [Exp]

[LINENUM,POSNUM] Invalid operand type for new array operator
// number of elements should be an integer or byte

Exp [Exp] ArrayExp and ArrayAssignStatement

[LINENUM,POSNUM] Array reference to non-array type
[LINENUM,POSNUM] Invalid index expression type for array reference
// index expression should be of type integer or byte
[LINENUM,POSNUM] Invalid expression type assigned into array
// array could be an array of colors or an array of integers

Exp . length LengthExp

[LINENUM,POSNUM] Operator length called on non-array type
// type of the length expression is integer

Dynamically Allocating Arrays

NewArrayExp

- Assume size of array in elements is on stack as an int
- Gen code to calculate number of bytes, numelem * sizeof(elem)
- Gen code to add 2 bytes for lenth int to size of array
- Gen code to call malloc
- Gen code to set the first two bytes of array to numelem
- Gen code to push array's address onto stack

Length Expression

outLengthExp

- Assume array reference/pointer is already on top of stack at runtime.
- Gen code that pops array reference off stack into two registers.
- Gen code that loads integer that array reference points to into two registers.
- Gen code to push that value/length onto the stack.

Array Elements Array Assignment

outArrayExp

- Assume the integer index is at the top of the stack and the array reference/ pointer is directly under it.
- Generate code to pop those off the stack and into registers.
- Generate code to calculate the array element address.
- Generate code that loads the array element and pushes it onto stack.

outArrayAssignStatement

- Assume that rhs expression, index expression, and array reference are on the stack.
- Generate code to pop those of the stack and store them into registers.
- Generate code that calculates the array element address (see previous slide).
- Generate code that stores the rhs expression into the array element memory location.