§5.1-5.5: Arrays
Py 10.1-10.7: Lists

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CMPT14x
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What's on today

- Python lists vs. M2/C arrays
- Lists as function parameters
- Multidimensional arrays/lists
- Python-specific list operations
  - Membership (in)
  - Concatenate (+), repeat (*)
  - Delete (del), slice ([s:e])
  - Aliasing vs. copying lists

M2 type hierarchy (partial)

- Atomic types
  - Scalar types
    - Real types (REAL, LONGREAL)
    - Ordinal types (CHAR)
      - Whole number types (INTEGER, CARDINAL)
      - Enumerations (§5.2.1) (BOOLEAN)
      - Subranges (§5.2.2)
- Structured (aggregate) types
  - Arrays (§5.3)
    - Strings (§5.3.1)
  - Sets (§9.2-9.6)
  - Records (§9.7-9.12)
- Also can have user-defined types

Python type hierarchy (partial)

- Atomic types
  - Numbers
    - Integers (int, long, bool): 5, 500000L, True
    - Reals (float) (only double-precision): 5.0
    - Complex numbers (complex): 5+2j
- Container (aggregate) types
  - Immutable sequences
    - Strings (str): "Hello"
    - Tuples (tuple): (2, 5.0, "hi")
  - Mutable sequences
    - Lists (list): [2, 5.0, "hi"]
  - Mappings
    - Dictionaries (dict): {"apple": 5, "orange": 8}

Enumeration types in M2 / C

```
TYPE
    DayName = (Sun, Mon, Tue, Wed, Thu, Fri, Sat);
VAR
    today : DayName;
BEGIN
    today := Mon;
```

- We could have used CARDINALs instead (indeed, the underlying implementation does)
  - But the logical semantic of today's type is a DayName type, not a CARDINAL
- Can be thought of as Sun=0, Mon=1, Tue=2, ...
- No explicit enumeration scheme in Python

Lists in Python

- Python doesn't have a built-in type exactly like arrays, but it does have lists:

```
nelliesWages = [0.0, 25.75, 0.0, 0.0, 0.0]
nelliesWages[1]                # returns 25.75
```

- Under the covers, Python often implements lists using arrays, but lists are more powerful:
  - Can change length dynamically
  - Can store items of different type
  - Can delete/insert items mid-list
- For now, we'll treat Python lists as arrays

Using lists

- We know one way to generate a list: range()

```
range(10)       # returns [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

- Or create directly in square brackets:

```
myApples = ["Fuji", "Gala", "Red Delicious"]
```

- We can iterate through a list:

```
for idx in range(len(myApples)):
    print "I like", myApples[idx], "apples!"
```

- Even easier:

```
for apple in myApples:
    print "I like", apple, "apples!"
```

Lists as parameters

```
def average(vec):
    """Return the average of the vector's values.
    pre: vec should have scalar values (float, int)
      and not be empty.
    """
    sum = 0
    for elt in vec:
        sum += elt
    return sum / len(vec)

myList = range(9)
print average(myList)                  # prints 4
```

- What happens when we pass an empty array? An atomic value?

Type-checking list parameters

- Since Python is dynamically-typed, the function definition doesn't specify what type the parameter is, or even that it needs to be a list
  - Easy way out: state expected type in precondition
  - Or do type checking in the function:

    ```
    if type(vec) != type([]):
        print "Need to pass this function a list!"
        return
    ```

  - May also want to check for empty lists:

    ```
    if len(vec) == 0:
    ```

- for, len(), etc. don't work on atomic types

Array parameters in M2/C/etc.

- In statically-typed languages like M2, C, etc., the procedure declaration needs to specify that the parameter is an array, and the type of its elements:
  - M2:

```
PROCEDURE Average(myList: ARRAY of REAL) :
  REAL;
```

  - C:

```
float average(float* myList, unsigned int len) {
```

- In M2, HIGH(myList) gets the length
- In C, length is unknown (pass in separately)

Multidimensional arrays

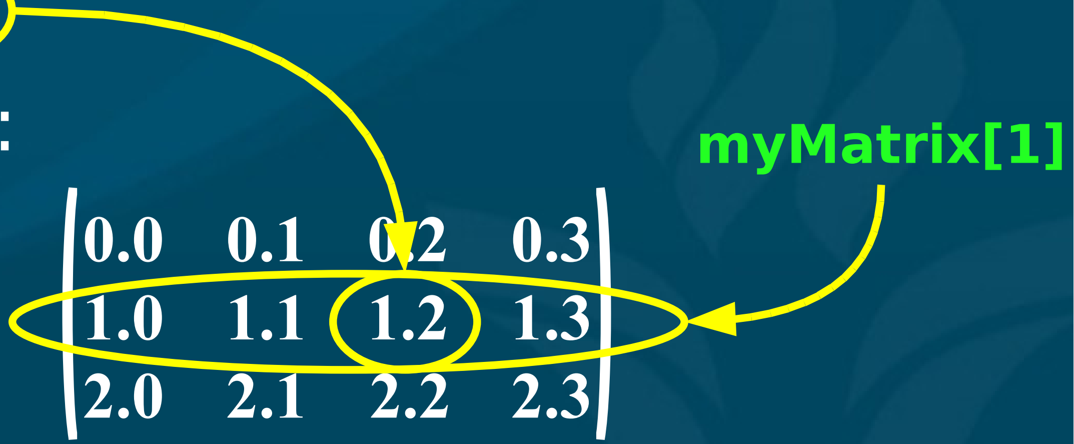
- Multidimensional arrays are simply arrays of arrays:

```
myMatrix = [ [0.0, 0.1, 0.2, 0.3],
             [1.0, 1.1, 1.2, 1.3],
             [2,0, 2.1, 2.2, 2.3] ]
```

- Accessing:

```
myMatrix[1][2] = 1.2
```

- Row-major convention:



$$\begin{vmatrix} 0.0 & 0.1 & 0.2 & 0.3 \\ 1.0 & 1.1 & 1.2 & 1.3 \\ 2.0 & 2.1 & 2.2 & 2.3 \end{vmatrix}$$

Iterating through multidim arrays

```
def matrix_average(matrix):
    """Return the average value from the 2D
      matrix.
    Pre: matrix must be a non-empty 2D array of
      scalar values."""
    sum = 0
    num_entries = 0
    for row in range(len(matrix)):
        for col in range(len(matrix[row])):
            sum += matrix[row][col]
        num_entries += len(matrix[row])
    return sum / num_entries
```

- What if rows are not all equal length?

List operations (Python)

```
myApples = [ "Fuji", "Gala", "Red Delicious" ]
```

- Test for list membership:

```
if "Fuji" in myApples:                  # True
```

- Concatenate:

```
[ 'a', 'b', 'c' ] + [ 'd', 'e' ]
```

- Repeat:

```
[ 'a', 'b', 'c' ] * 2
```

- Modify list entries (mutable):

```
myApples[1] = "Braeburn"
```

- Convert a string to a list of characters:

```
list("Hello World!")     # ['H', 'e', 'l', 'l', 'o', ...]
```

More list operations

- Delete an element of the list:

```
del myApples[1]        # [ "Fuji", "Golden Delicious" ]
```

- List slice (start:end):

```
myApples[0:1]      # [ "Fuji", "Gala" ]
```

- Assignment is aliasing:

```
yourApples = myApples      # points to same array
```

- Use a whole-list slice to copy a list:

```
yourApples = myApples[:]
    # [:] is shorthand for [0:-1] or [0:len(myApples)-1]
```

Summary of today (§5.1-5.5, Py 10.1-10.7)

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Sieve of Eratosthenes

- Problem: list all the prime numbers between 2 and some given big number.
  - You had a homework that was similar: test if a given number is prime, and list its factors
  - How did you solve that?
    - Procedure is_prime() (pseudocode):

```
Iterate for factor in 2 .. sqrt(n):
    If (n % factor == 0), then
        We've found a factor!
```

- But this is wasteful: really only need to test prime numbers for potential factors

Listing all primes

- We could tackle this problem by repeatedly calling is_prime() on every number in turn:

```
for num in range(2, max):
    if is_prime(num) ...
```

- But this could be really slow if max is big
- Is there a smarter way to eliminate non-prime (composite) numbers?

Sieve of Eratosthenes

- The sieve works by a process of elimination: we eliminate all the non-primes by turn:

~~1~~	2	3	~~4~~	5	~~6~~	7	~~8~~	~~9~~	~~10~~
11	~~12~~	13	~~14~~	~~15~~	~~16~~	17	~~18~~	19	~~20~~
~~21~~	~~22~~	23	~~24~~	~~25~~	~~26~~	~~27~~	~~28~~	29	~~30~~
31	~~32~~	~~33~~	~~34~~	~~35~~	~~36~~	37	~~38~~	~~39~~	~~40~~
41	~~42~~	43	~~44~~	~~45~~	~~46~~	47	~~48~~	~~49~~	~~50~~
~~51~~	~~52~~	53	~~54~~	~~55~~	~~56~~	~~57~~	~~58~~	59	~~60~~
61	~~62~~	~~63~~	~~64~~	~~65~~	~~66~~	67	~~68~~	~~69~~	~~70~~
71	~~72~~	73	~~74~~	~~75~~	~~76~~	~~77~~	~~78~~	79	~~80~~
~~81~~	~~82~~	83	~~84~~	~~85~~	~~86~~	~~87~~	~~88~~	89	~~90~~
~~91~~	~~92~~	~~93~~	~~94~~	~~95~~	~~96~~	97	~~98~~	~~99~~	~~100~~

Prime sieve: pseudocode

1) Create an array of booleans and set them all to true at first. (true = prime)

2) Set array element 1 to false. Now 2 is prime.

3) Set the values whose index in the array is a multiple of the last prime found to false.

4) The next index where the array holds the value true is the next prime.

5) Repeat steps 3 and 4 until the last prime found is greater than the square root of the largest number in the array.

Prime sieve: Python code

```
"""Find all primes up to a given number, using
   Eratosthenes' prime sieve."""
import math                              # sqrt
size = input("Find all primes up to: ")


# Initialize: all numbers except 0, 1 are prime
primeFlags = range(size+1)          # so pF[size] exists
for num in range(size+1):
    primeFlags[num] = True

primeFlags[0] = False
primeFlags[1] = False
```

Prime sieve: Python code (p.2)

```
# Computation: eliminate all non-primes
for num in range(2, int(math.sqrt(size))+1):
    if primeFlags[num]:           # got a prime
        # Eliminate its multiples
        for multiple in range(num**2, size+1, num):
            primeFlags[multiple] = False

# Output
print "Your primes, sir/madam:",
for num in range(2, size+1):
    if primeFlags[num]:
        print num,
```

http://twu.seanho.com/python/primesieve.py