§5.1-5.5: Arrays
Py 10.1-10.7: Lists

- *Quiz03 (ch4) today*

28 Sep 2007
CMPT14x
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Quiz 03 (ch4): 10 minutes, 20 points

- Define recursion in your own words.
  - Write a short example in Python to illustrate.
    - (It doesn't have to do anything useful.)
- What is the call stack used for?
- What are global variables and why are they bad?
- Write a Python function that returns the value of the sum 1 + 2 + 3 + ... + n.
    - Docstring / comments not necessary but useful for partial credit.

Quiz 03: answers #1-2

- What is recursion?
  - A recursive function invokes itself:

```
def countdown(n):
    if n <= 0:
        return 0
    print n,
    return countdown(n-1)
```

- What is the call stack?
  - Keeps track of which procedures are currently running. Made up of stack frames, recording local variables and parameters for each function invocation.

Quiz 03: answers #3-4

- What are global variables?
  - Accessible everywhere in the module: even inside functions defined in the module
  - Functions can modify global variables and cause unintended side-effects
- Calculate the sum 1 + 2 + ... + n:

```
def sum(n):
    result = 0
    for term in range(1,n+1):
        result += term
    return result
```

What's on today (§5.1-5.5, Py 10.1-10.7)

- 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 (also C)

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

- We could have used CARDINALs instead (and 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) != list:
    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

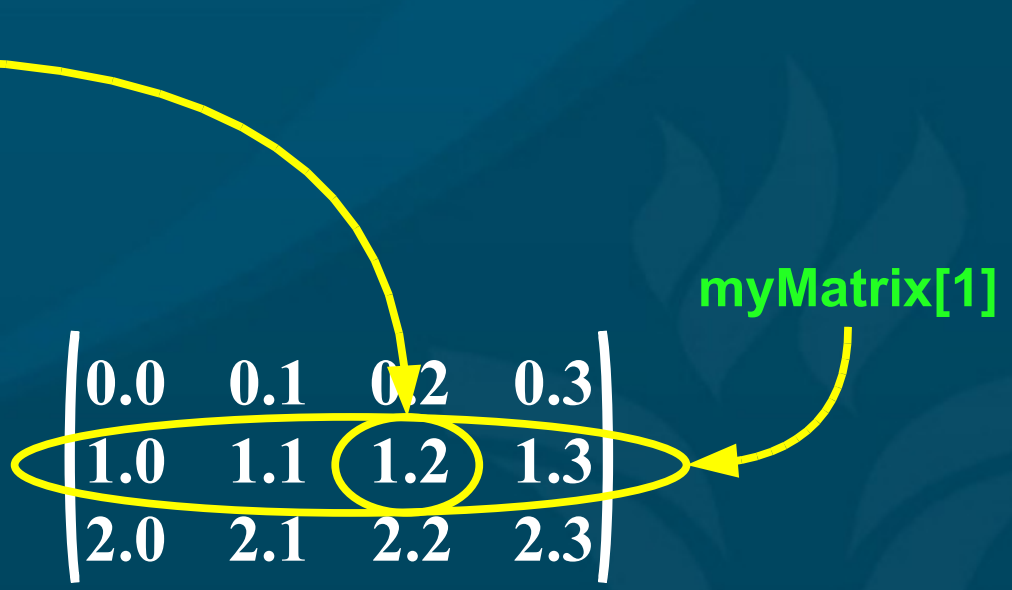
- Multidimensional arrays are simply arrays of arrays:

```
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:



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 specific)

```
myApples = [ "Fuji", "Gala", "Golden 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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TODO

- HW03 due next Mon:
  - M2 ch4 # 7, 18
  - M2 ch5 # 15
- Lab 03 due Wed:
  - M2 ch4 # (23 / 27 / 36)
- Read through M2 ch5 and Py ch7, plus Py ch10

- Midterm ch1-5 next week Fri 5Oct