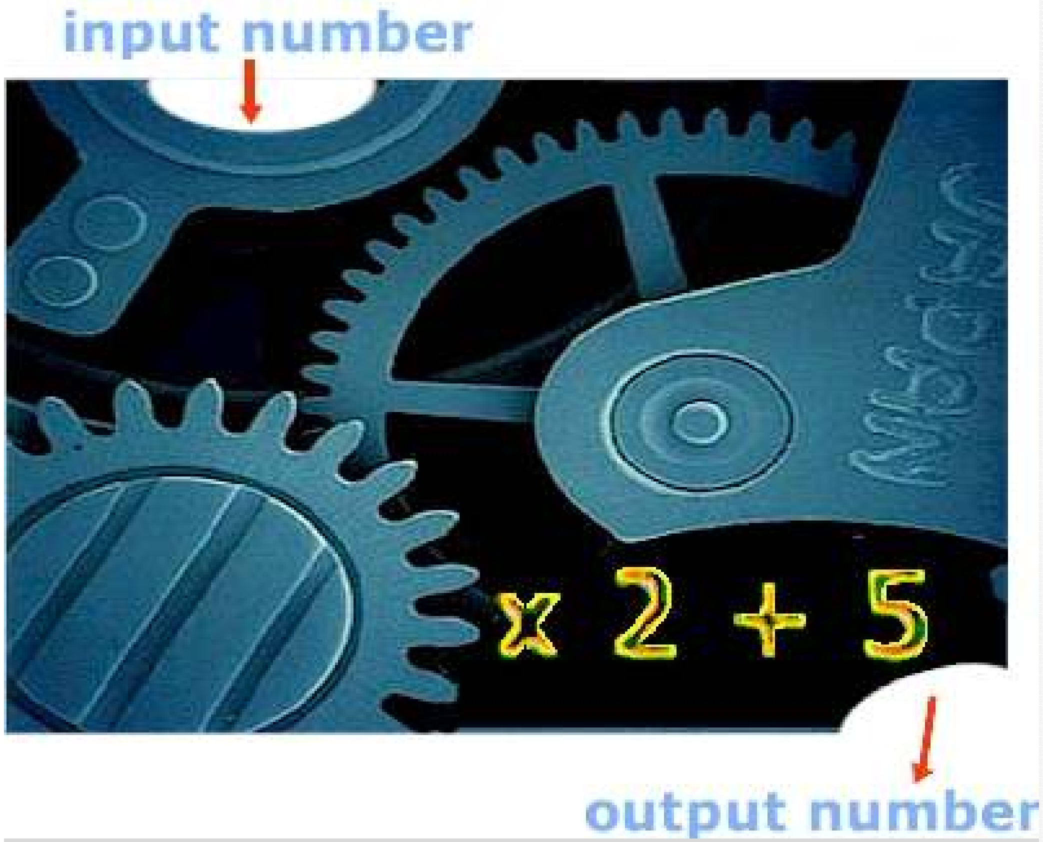
McLab Tutorial
www.sable.mcgill.ca/mclab

Part 2 – Introduction to MATLAB

- Functions and Scripts
- Data and Variables
- Other Tricky "Features"

Functions and Scripts in MATLAB



Basic Structure of a MATLAB function

```
function [ prod, sum ] = ProdSum( a, n )
  prod = 1;
  sum = 0;
  for i = 1:n
    prod = prod * a(i);
    sum = sum + a(i);
  end;
end
```

```
>> [a,b] = ProdSum([10,20,30],3)
a = 6000
b = 60

>>  ProdSum([10,20,30],2)
ans = 200

>> ProdSum(‘abc’,3)
ans =941094

>> ProdSum([97 98 99],3)
ans = 941084
```

Basic Structure of a MATLAB function (2)

```
function [ prod, sum ] = ProdSum( a, n )
  prod = 1;
  sum = 0;
  for i = 1:n
    prod = prod * a(i);
    sum = sum + a(i);
  end;
end
```

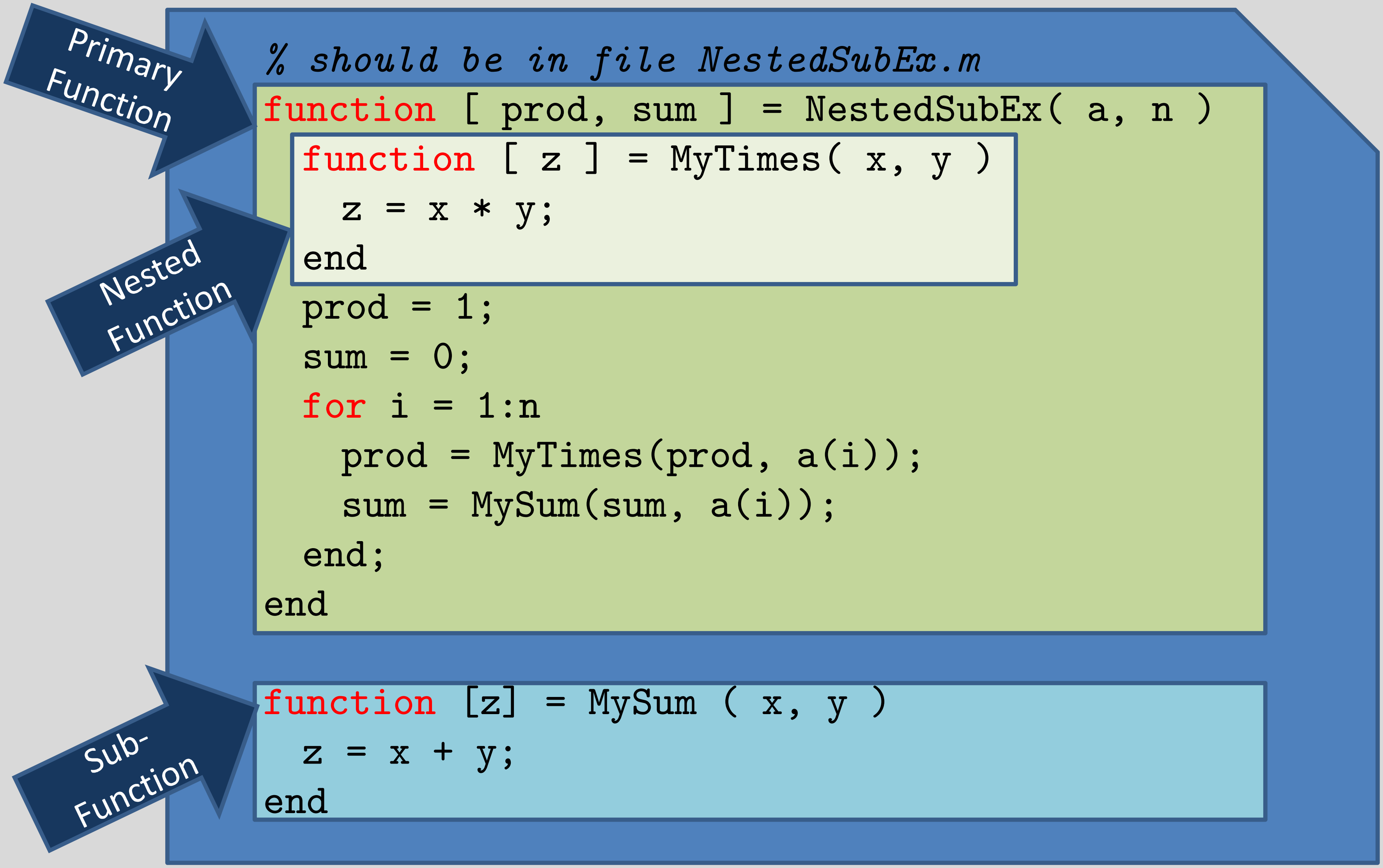
```
>> [a,b] = ProdSum(@sin,3)
a = 0.1080
b = 1.8919

>>  [a,b] = ProdSum(@(x)(x),3)
a = 6
b = 6

>> magic(3)
ans = 8  1   6
      3   5  7
      4   9   2

>>ProdSum(ans,3)
ans=96
```

Basic Structure of a MATLAB function (3)

```
1 function [ prod, sum ] = ProdSum( a, n )
2   prod = 1;
3   sum = 0;
4   for i = 1:n
5     prod = prod * a(i);
6     sum = sum + a(i);
7   end;
8 end
```

```
>> ProdSum([10,20,30],'a')
??? For colon operator with char operands, first and
last operands must be char.
Error in ==> ProdSum at 4
  for i = 1:n

>> ProdSum([10,20,30],i)
Warning: Colon operands must be real scalars.
> In ProdSum at 4
ans =  1

>> ProdSum([10,20,30],[3,4,5])
ans =    6000
```

Primary, nested and sub-functions



Primary Function

Nested Function

Sub-Function

```
% should be in file NestedSubEx.m
function [ prod, sum ] = NestedSubEx( a, n )
  function [ z ] = MyTimes( x, y )
    z = x * y;
  end
  prod = 1;
  sum = 0;
  for i = 1:n
    prod = MyTimes(prod, a(i));
    sum = MySum(sum, a(i));
  end;
end

function [z] = MySum ( x, y )
  z = x + y;
end
```

Basic Structure of a MATLAB script

```
% stored in file ProdSumScript.m
prod = 1;
sum = 0;
for i = 1:n
  prod = prod * a(i);
  sum = sum + a(i);
end;
```

```
>> clear
>> a = [10, 20, 30];
>> n = 3;
>> whos
  Name    Size    Bytes   Class
  a       1x3     24      double
  n       1x1     8       double
>> ProdSumScript()
>> whos
  Name    Size    Bytes   Class
  a       1x3     24      double
  i       1x1      8      double
  n       1x1      8      double
  prod    1x1      8      double
  sum     1x1      8      double
```

Directory Structure and Path

- Each directory can contain:
  - `.m` files (which can contain a script or functions)
  - a `private/` directory
  - a package directory of the form `+pkg/`
  - a type-specialized directory of the form `@int32/`

- At run-time:
  - current directory (implicit 1st element of path)
  - path of directories
  - both the current directory and path can be changed at runtime (`cd` and `setpath` functions)

Function/Script Lookup Order (call in the body of a function f)

```
function f
  …
  foo(a);
  …
end
```

- Nested function (in scope of f)
- Sub-function (in same file as f)
- Function in /private sub-directory of directory containing f.
- 1st matching function, based on function name and type of first argument, looking in type-specialized directories, looking first in current directory and then along path.
- 1st matching function/script, based on function name only, looking first in current directory and then along path.

Function/Script Lookup Order (call in the body of a script s)

```
% in s.m
…
foo(a);
…
```

- Function in /private sub-directory of directory of last called function (not the /private sub-directory of the directory containing s).
- 1st matching function/script, based on function name, looking first in current directory and then along path.

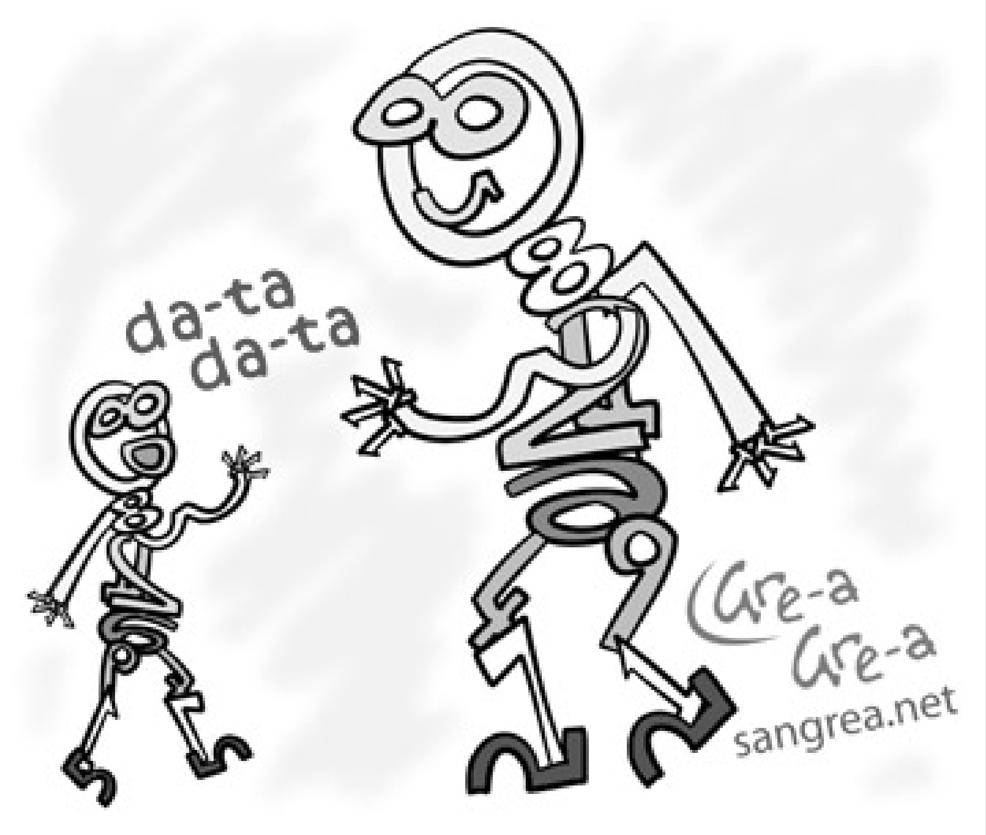
```
dir1/                   dir2/
  f.m                     s.m
  g.m                     h.m
  private/                private/
    foo.m                   foo.m
```

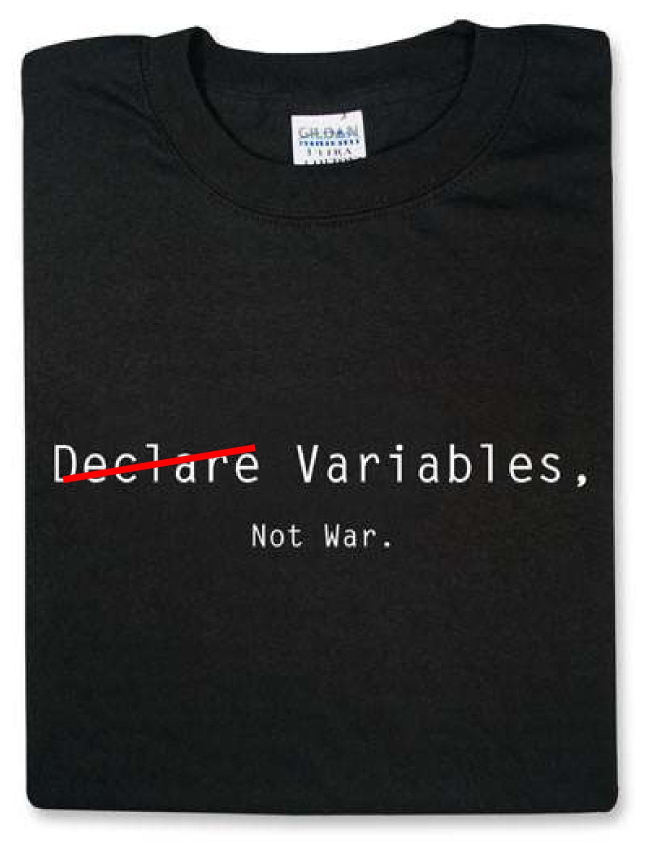
Copy Semantics

```
function [ r ] = CopyEx( a, b )
  for i=1:length(a)
    a(i) = sin(b(i));
    c(i) = cos(b(i));
  end
  r = a + c;
end
```

```
>> m = [10, 20, 30]
m =  10    20    30

>> n = 2 * a
n = 20    40    60

>> CopyEx(m,n)
ans = 1.3210    0.0782   -1.2572

>> m = CopyEx(m,n)
m = 1.3210   0.0782  -1.2572
```

Variables and Data in MATLAB



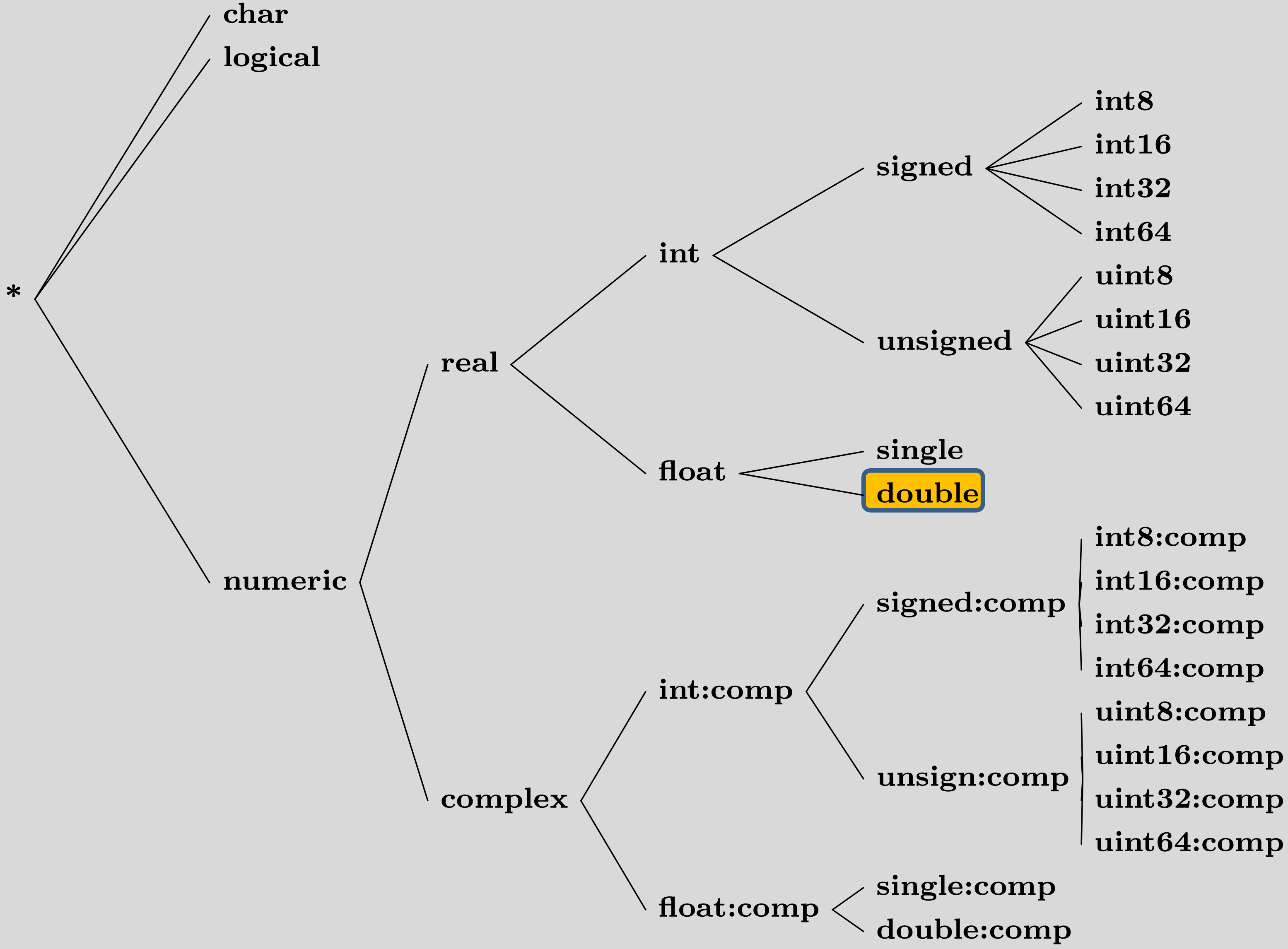


Examples of base types

```
>> clear
>> a = [10, 20, 30]
a = 10    20    30

>> b = int32(a)
b = 10    20    30

>> c = isinteger(b)
c = 1

>> d = complex(int32(4),int32(3))
d = 4 + 3i
```

```
>> whos
Name   Size  Bytes  Class    Attributes
  a     1x3   24    double
  b     1x3   12    int32
  c     1x1    1    logical
  d     1x1    8    int32     complex

>> isinteger(c)
ans = 0
>> isnumeric(a)
ans = 1
>> isnumeric(c)
ans = 0
>> isreal(d)
ans = 0
```

MATLAB base data types



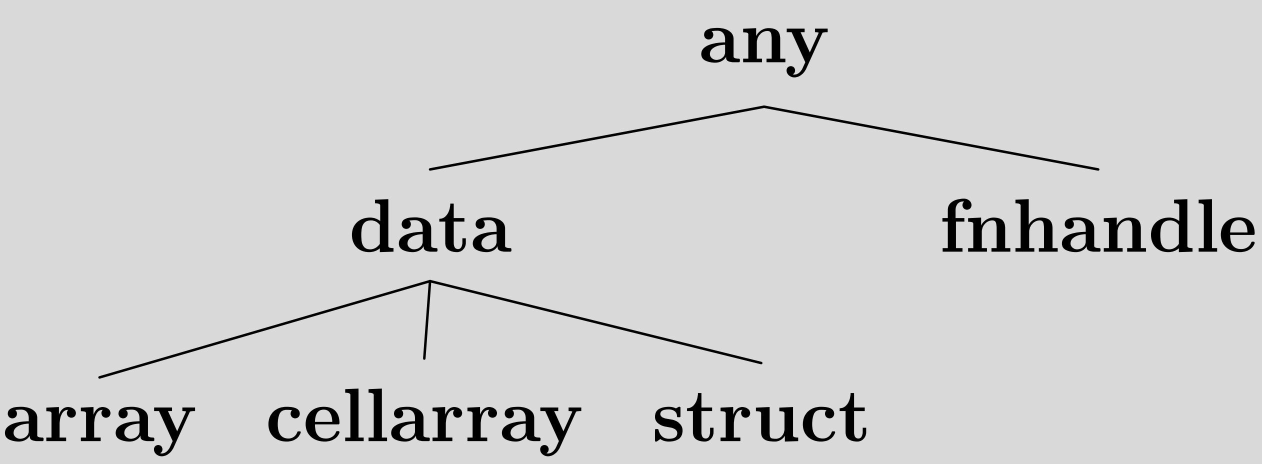
- *
  - char
  - logical
  - numeric
    - real
      - int
        - signed
          - int8
          - int16
          - int32
          - int64
        - unsigned
          - uint8
          - uint16
          - uint32
          - uint64
      - float
        - single
        - double
    - complex
      - int:comp
        - signed:comp
          - int8:comp
          - int16:comp
          - int32:comp
          - int64:comp
        - unsign:comp
          - uint8:comp
          - uint16:comp
          - uint32:comp
          - uint64:comp
      - float:comp
        - single:comp
        - double:comp

Data Conversions

- double + double → double
- single + double → double
- double:complex + double → double:complex
- int32 + double → int32

- logical + double → error, not allowed
- int16 + int32 → error, not allowed
- int32:complex + int32:complex → error, not defined

MATLAB types: high-level



any

data

fnhandle

array

cellarray

struct

Cell array and struct example

```
>> students = {'Nurudeen', 'Rahul', 'Jesse'}
students =  'Nurudeen'   'Rahul'  'Jesse'

>> cell = students(1)
cell =   'Nurudeen'

>> contents = students{1}
contents =Nurudeen

>> whos

 Name          Size      Bytes  Class
 cell           1          128    cell
 contents       1x8         16    char
 students       1x3        372    cell
```

```
>> s = struct('name', 'Laurie',
        'student', students)
s = 1x3 struct array with fields:
       name
       student

>> a = s(1)
a = name: 'Laurie'
     student: 'Nurudeen'

>> a.age = 21
a = name: 'Laurie'
     students: 'Nurudeen'
     age:  21
```

Local variables

- Variables are not explicitly declared.
- Local variables are allocated in the current workspace.
- All input and output parameters are local.
- Local variables are allocated upon their first definition or via a load statement.
  - `x = ...`
  - `x(i) = ...`
  - `load (’f.mat’, ’x’)`
- Local variables can hold data with different types at different places in a function/script.

Global and Persistent Variables

- Variables can be declared to be global.
  - `global x;`
- Persistent declarations are allowed within function bodies only (not allowed in scripts or read-eval-print loop).
  - `persistent y;`
- A persistent or global declaration of x should cover all defs and uses of x in the body of the function/script.

Variable Workspaces

- There is a workspace for global and persistent variables.
- There is a workspace associated with the read-eval-print loop.
- Each function call creates a new workspace (stack frame).
- A script uses the workspace of its caller (either a function workspace or the read-eval-print workspace).

Variable Lookup

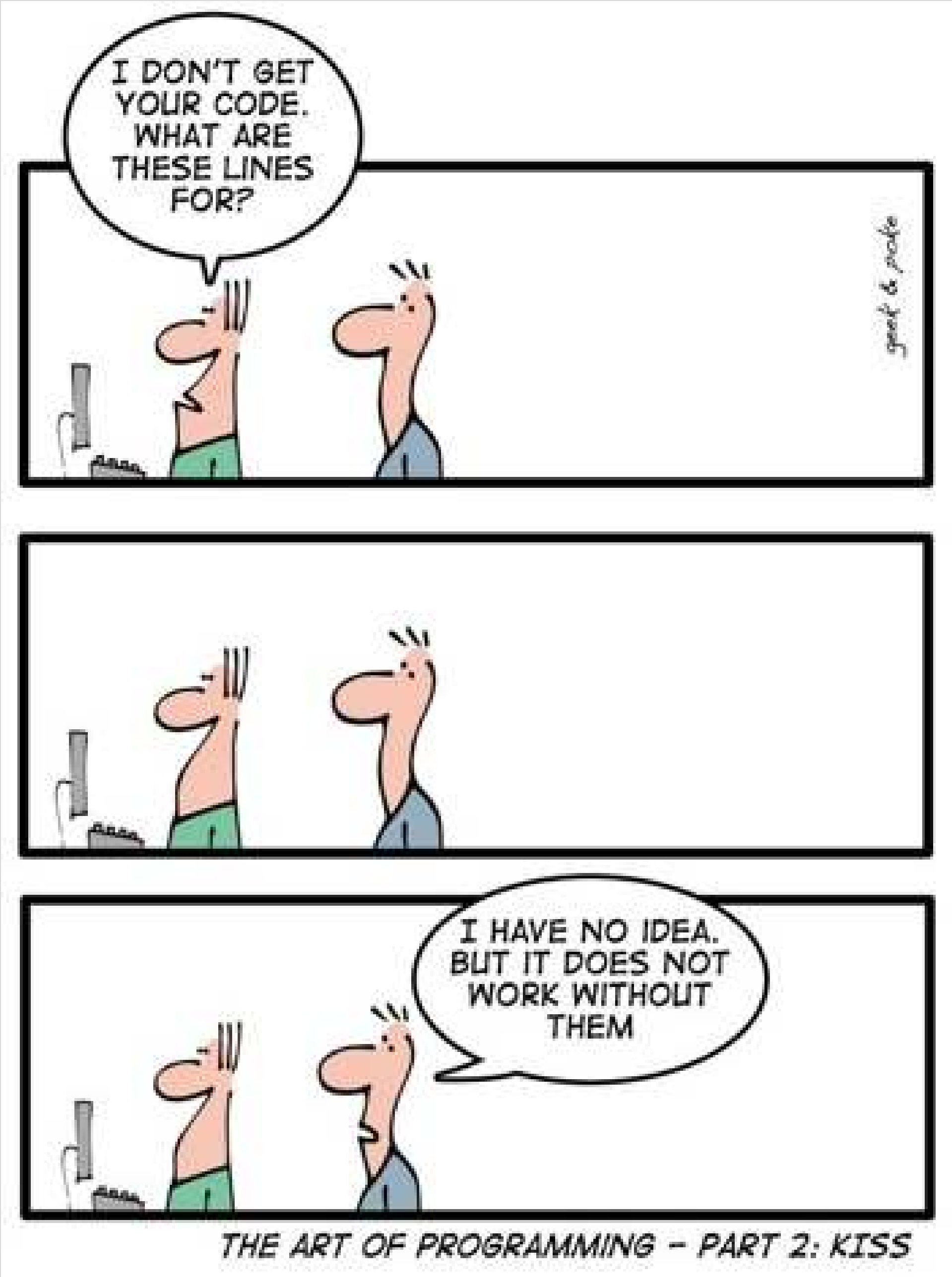
- If the variable has been declared global or persistent in the function body, look it up in the global/persistent workspace.
- Otherwise, lookup in the current workspace (either the read-eval-print workspace or the top-most function call workspace).
- For nested functions, use the standard scoping mechanisms.

Local/Global Example

```
function [ prod ] = ProdSumGlobal( a, n )
  global sum;
  prod = 1;
  for i = 1:n
    prod = prod * a(i);
    sum = sum + a(i);
  end;
end;
```

```
>> clear

>> global sum

>> sum = 0;

>> ProdSumGlobal([10,20,30],3)
ans = 6000

>> sum
sum = 60

>> whos
  Name    Size    Bytes   Class    Attributes
  ans      1x1       8   double
  sum      1x1       8   double      global
```

Other Tricky "features" in MATLAB


I DON'T GET YOUR CODE. WHAT ARE THESE LINES FOR?
geek & poke
I HAVE NO IDEA. BUT IT DOES NOT WORK WITHOUT THEM
THE ART OF PROGRAMMING – PART 2: KISS

Looking up an identifier

Old style general lookup - interpreter

- First lookup as a variable.
- If a variable not found, then look up as a function.

MATLAB 7 lookup - JIT

- When function/script first loaded, assign a "kind" to each identifier. VAR – only lookup as a variable, FN – only lookup as a function, ID – use the old style general lookup.

Kind Example

```
function [ r ] = KindEx( a )
  x = a + i + sum(j)
  f = @sin
  eval('s = 10;')
  r = f(x + s)
end
```

```
>> KindEx (3)
x = 3.0000 + 2.0000i
f = @sin
r = 1.5808 + 3.2912i
ans =  1.5808 + 3.2912
```

- VAR: r, a, x, f
- FN: i, j, sum, sin
- ID: s

Irritating Front-end "Features"

- keyword `end` not always required at the end of a function (often missing in files with only one function).

- command syntax
  - `length('x')` or `length x`
  - `cd('mydirname')` or `cd mydirname`

- arrays can be defined with or without commas:

  [10, 20, 30] or [10 20 30]

- sometimes newlines have meaning:

  -
    ```
    a = [ 10 20 30
          40 50 60 ];  // defines a 2x3 matrix
    ```

  -
    ```
    a = [ 10 20 30 40 50 60];  // defines a 1x6 matrix
    ```

  -
    ```
    a = [ 10 20 30;
          40 50 60 ];  // defines a 2x3 matrix
    ```

  -
    ```
    a = [ 10 20 30;  40 50 60]; // defines a 2x3 matrix
    ```

“Evil” Dynamic Features

- not all input arguments required

```
function [ prod, sum ] = ProdSumNargs( a, n )
  if nargin == 1 n = 1; end;
  ...
end
```

- do not need to use all output arguments
- eval, evalin, assignin
- cd, addpath
- load