Logic, loops and control flow

NENS 230

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Announcements

- Eddy’s office hours this week:
  - Weds 11AM-12:30PM
  - Email to schedule other time(s)

Outline for today

- Review of relational operators
- Logic and branching
- Loops
- Advanced control flow

The cornerstone to programming!

Relational operators

Test if relationship is true or false

• Less than	`2 < 3`	`(true)`
• Greater than	`2 > 3`	`(false)`
• Less than or equal to	`1 <= 1`	`(true)`
• Greater than or equal to	`4 >= 5`	`(false)`
• Exactly equal	`8 == 2^3`	`(true)`
• Not equal	`pi ~= 3.14`	`(true)`

Output is datatype called `logical`

Remember...

<u>“=” means assignment</u>

```
>> x = 5

ans =
      5
```

<u>“==” tests equality</u>

```
>> x = 5;
>> x == 5

ans =
      1
```

One of the most common programming mistakes ever

You will make it. Many times.

Relational operators are *vectorized*

Operate on all members of an array simultaneously

```
>> x = 1:10

ans =
      1    2    3    4    5    6    7    8    9    10

>> x > 5

ans =
      0    0    0    0    0    1    1    1    1    1
```

Relational operators are *vectorized*

Operate on all members of an array simultaneously

```
>> x = 1:10

ans =
     1    2    3    4    5    6    7    8    9    10

>> x > 5

ans =
     0    0    0    0    0    1    1    1    1    1
```

Logical indexing

- Allows selection of any elements meeting criteria
- Criteria usually defined by relational operators

```
>> x = 1:10;
>> idx = x > 5;
>> x(idx)

ans =
      6   7   8   9   10
```

Usually combine in one expression: `x(x > 5)`

Assignment by logical indexing

```
>> x = -2:2;
>> x(x < 0) = 0 % Truncate values at 0

ans =
     0    0    0    1    2


>> x(x < 0) = [] % Remove negatives

ans =
     0    1    2
```

Logical indexing and `find`

`find` returns indices of nonzero elements

```
>> x = 1:10;
>> x > 5

ans =
     0     0     0     0     0     1     1     1     1     1

>> find(x > 5)

ans =
     6     7     8     9    10
```

A comment on the `find` function

```
>> data = [0, 0, 1, 0, 1, ..., 1, 0];
>> ltime = avg_logical_time(data);
>> ftime = avg_find_time(data);
>> ftime / ltime

ans =
      7.5426
```

Logical indexing is faster by an order of magnitude

When to use `find`

- Need the actual indices of a condition
- Need to know only first place condition is satisfied
- Better for arrays with many zeros (sparse)

Everything else should use logical indexing

Other useful logical functions

- `isempty`
- `isnan, isinf`
- `isfinite  % true if not +/-Inf, NaN`
- `isnumeric, ischar, iscell, isstruct`

Our code thus far

```
do_thing1(data);
do_thing2(data);
do_thing3(data);
.
.
.
do_thing73(data);
```

All code executed unconditionally

But what if we only want to `do_thing2()` *if* `data` *meets some criterion?*

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Branching

- Execute blocks of code only if certain conditions are met
- Each possible path is a “branch”

```
if condition1 % keyword to start block
  do_something();
end           % keyword to end block
```

Branching: `if/else`

```
if p_value <= significance_threshold
  % jump here if condition is true
  keep_data();
else
  % jump here if condition is false
  % keep_data is NOT executed!
  ignore_data();
end
```

Branching: multiple conditions

```
if condition1
  do_thing1();
end
if condition2
  do_thing2();
end
if condition3
  do_thing3();
end
```

Branching: `if/elseif`

Test multiple conditions in a single block

```
if condition1
  do_thing1();
elseif condition2
  do_thing2();
elseif condition3
  do_thing3();
...
else
  do_last_thing();
end
```

One and *only* one of these functions will be executed.

Branching with many conditions

- Used `if/elseif` blocks to test many conditions
- Becomes cumbersome and hard to read with a large number of conditions

Branching: `switch`/`case`

```
switch my_var
case 1
   do_thing1();
case 2
   do_thing2();
otherwise
   do_default_thing();
end
```

Equivalent to:

```
if my_var == 1
```

Default code block

Branching: if/elseif

```
if (mod(i, 3) == 0) && (mod(i, 5) == 0)
  fprintf('%d div. by 3 and 5\n', i);
elseif mod(i, 3) == 0
  fprintf('%d div. by 3\n', i);
elseif mod(i, 5) == 0
  fprintf('%d div. by 5\n', i);
else
  fprintf('%d div. by neither\n', i);
end
```

Branching: if/else

```
for i = 1:100
  if mod(i, 2) == 0
    fprintf('%d is even\n', i);
  else
    fprintf('%d is odd\n', i);
  end
end
```

Branching: switch with strings

```
s = input('Are you happy?', 's');
switch s
case {'y', 'yes'}
  awesome();
case {'y', 'yes'}'
  too_bad();
otherwise
  stock_answer();
end
```

Combining logical values

Use “`&`” or “`|`” to combine *arrays* of logicals

```
>> val1 = [0, 1, 1, 0];
>> val2 = [1, 1, 0, 0];
>> result = val1 & val2

result =
     0   1   0   0
```

Compares two arrays of same size, element-wise

Combining logical values

Use "`&&`" or "`||`" to combine *scalar* logicals

```
>> 0 && 1

ans =

     0

>> 0 || 1

ans =

     1
```

What is truth?

Value	(if w) == ?
`w = -1;`	`true`
`x = 0.5;`	`true`
`y = 'a string';`	`true`
`z = Inf;`	`true`
`a = 0;`	`false`
`b = [0, 1];`	`?`

Any scalar value except 0 evaluates to true

Arrays evaluate to true if *all* elements are true

Generally do direct tests:

```
(if w == -1)
```

Our code thus far

```
>> data1 = load_data(file1);
>> process_data(data1);
>> data2 = load_data(file2);
>> process_data(data2)
.
.
.
>> process_data(data87)
>> publish_results();
```

Loops to the rescue

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Loops

Allow repeated execution of a block of code

For loop:

```
for i = N:M
  do_something;
end
```

Index Bounds

While loop:

```
while condition
  do_something;
end
```

Logical condition

Loops

```
>> for i = 1:5
fprintf('"i" is now %d\n', i);
end
"i" is now 1
"i" is now 2
"i" is now 3
"i" is now 4
"i" is now 5
>>
```

Loops

```
>> i = 1;
>> while i <= 5
fprintf('"i" is now %d\n', i);
i = i + 1;
end
"i" is now 1
"i" is now 2
"i" is now 3
"i" is now 4
"i" is now 5
>>
```

Loops: index variables

```
for i = 1:n
  for j = 1:m
    for k = 1:b
      get_grade(i, j, k);
    end
  end
end
```

Difficult to understand code's purpose
from loop variable names

Loops: index variables

```
for si = 1:num_students
  for ai = 1:num_assignments
    for pi = 1:num_problems
       get_grade(si, ai, pi);
    end
  end
end
```

Better

Loops: index variables

```
for student = 1:num_students
  for assgn = 1:num_assignments
    for problem = 1:num_problems
       get_grade(student, assgn, ...
                 problem);
    end
  end
end
```

Best!

Which loop type?

We can use a `for` loop wherever can use a `while` loop, and vice versa.

`for`

- Use to repeat code a predetermined number of times
- Automatic tracking of index variable

`while`

- Use to repeat code as long as condition is true
- Automatic tracking of condition's truth value

Which loop type?

```
start = 10;
fact = 1;
for ni = start:-1:2
  fact = fact * ni;
end
```

```
start = 10;
ni = start;
fact = 1;
while ni > 1
  fact = fact * number;
  ni = ni - 1;
end
```

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Control flow

Methods for fine-grained control of loops

1. Combining loops and branching
2. `continue`: Skip to next loop iteration
3. `break`: Exit loop altogether

Control flow: loops and branching

```
for i = 1:N
  % check condition on each
  % loop iteration
  if condition
    do_this();
  else
    do_that();
  end
end
```

Control flow: loops and branching

```
for i = 1:100
  if is_even(i)
    fprintf('%d is even\n', i);
  else
    fprintf('%d is odd\n', i);
  end
end
```

Control flow: `continue`

Skip to next loop iteration

```
for i = 1:num_datasets
  if (~meets_criteria(i))
    continue;  % skips the rest of
               % the loop, but still
               % increments i
  else
    process_data(i);
  end
end
```

Control flow: `break`

Exit loop altogether

```
for i = 1:num_datasets
  if (meets_criteria(i))
    break; % abort the loop as soon
           % as we find valid data
  end
end
% break moves us here
process_data(i);
```

Control flow: break

Continuous loops

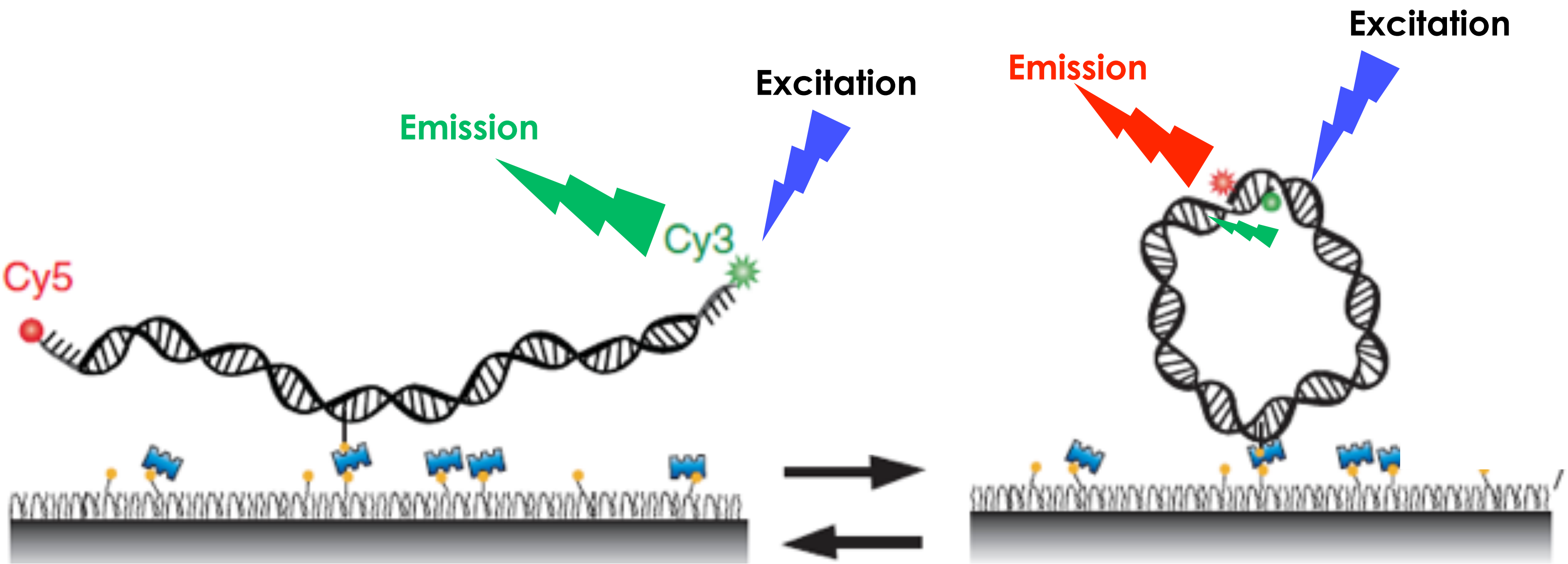
```
while 1 % loop forever
  new_data = get_more_data();
  if isempty(new_data)
    break; % no more data, exit loop
  end
  process_data(new_data);
end
```

Problem set 3

Förster resonance energy transfer (FRET)

1. Two nearby light-sensitive molecules, **chromophores**
2. Excited chromophore may **donate** energy to neighbor
3. Energy transfer proportional to distance

Problem set 3



Modified from: Vafabakhsh R and Ha T. (2012) Extreme Bendability of DNA Less than 100 Base Pairs Long Revealed by Single-Molecule Cyclization. Science, 337: 1097 (2012)

$$\frac{F_A}{F_A + F_D}$$

Review

- Branching
  - `if`: execute code if condition true
  - `else`: execute code if condition false
  - `elseif` & `switch/case`: test multiple statements
- Loops
  - `for`: execute block defined number of times
  - `while`: execute block as long as condition true
- Control flow
  - combine loops and branching
  - `continue`: skip this loop iteration, start next
  - `break`: exit loop altogether

Programming!