

Lecture 22

While Loops

Announcements for This Lecture

Assignments

- A6 due on **Wednesday**
 - First classes should be done
 - Finish Encoder over weekend
- A7 will be last assignment
 - Will talk about next week
 - Posted on Thursday
 - Some deadline flexibility
- There is lab next week
 - **No lab** week of Turkey Day

Prelim 2

- **Prelim, Nov 21st at 7:30**
 - Same rooms as last time
- **Material up to Nov. 12**
 - Recursion + Loops + Classes
 - Study guide is now posted
 - Review Sun. 5pm in Statler
- **Conflict with Prelim?**
 - Prelim 2 Conflict on CMS
 - **LAST DAY TO SUBMIT**

Recall: The For-Loop

```
# Create local var x
```

```
x = seqn[0]
```

```
print(x)
```

```
x = seqn[1]
```

```
print(x)
```

```
...
```

```
x = seqn[len(seqn)-1]
```

```
print(x)
```

Not valid
Python

```
# Write as a for-loop
```

```
for x in seqn:
```

```
    print(x)
```

Key Concepts

- **iterable:** seqn
- **loop variable:** x
- **body:** print(x)

Important Concept in CS: Doing Things Repeatedly

1. Process each item in a sequence

- Compute aggregate statistics for a sequence of numbers, such as the mean, median, standard deviation
- Send everyone in a Facebook group an appointment time

```
for x in sequence:  
    process x
```

2. Perform n trials or get n samples.

- A4: draw a triangle six times to make a snowflake
- Run a protein-folding simulation

```
for x in range(n):  
    do next thing
```

3. Do something an unknown number of times

- CUAUV team, vehicle keeps moving until reached its goal

????



Beyond Sequences: The while-loop

while *<condition>*:

statement 1

...

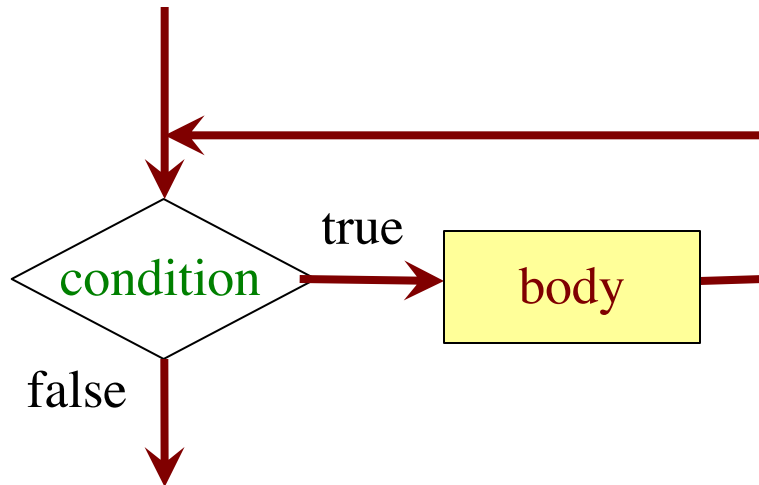
statement n

**loop
condition**

**loop
body**

Vs For-Loop

- Broader notion of loop
 - You define “more to do”
 - Not limited sequences
- Must manage loop var
 - You create it before loop
 - You update it inside loop
 - For-loop automated it
- Trickier to get right



while Versus for

For-Loop

```
def sum_squares(n):  
    """Rets: sum of squares  
    Prec: n is int > 0"""  
    total = 0  
    for x in range(n):  
        total = total + x*x
```

Must remember
to increment

While-Loop

```
def sum_squares(n):  
    """Rets: sum of squares  
    Prec: n is int > 0"""  
    total = 0  
    x = 0  
    while x < n:  
        total = total + x*x  
        x = x+1
```

The Problem with While-Loops

- Infinite loops are possible
 - Forget to update a loop variable
 - Incorrectly write the boolean expression
- Will hang your program
 - Must type control-C to abort/quit
- But detecting problems is not easy
 - Sometimes your code is just slow
 - Scientific computations can take hours
- **Solution:** Traces

Tracing While-Loops

```
print('Before while')
```

```
total = 0
```

```
x = 0
```

```
while x < n:
```

```
    print('Start loop '+str(x))
```

```
    total = total + x*x
```

```
    x = x + 1
```

```
    print('End loop ')
```

```
print('After while')
```

Important

Important

Output:

Before while

Start loop 0

End loop

Start loop 1

End loop

Start loop 2

End loop

After while

How to Design While-Loops

- Many of the same rules from for-loops
 - Often have an **accumulator variable**
 - Loop body adds to this accumulator
- Differences are loop variable and iterable
 - Typically **do not have iterable**
- Breaks up into three **design patterns**
 1. Replacement to range()
 2. Explicit goal condition
 3. Boolean tracking variable

Replacing the Range Iterable

range(a,b)

```
i = a
while i < b:
    process integer i
    i = i + 1
```

```
# store in count # of '/'s in String s
count = 0
i = 0
while i < len(s):
    if s[i] == '/':
        count = count + 1
    i = i + 1
# count is # of '/'s in s[0..s.length()-1]
```

range(c,d+1)

```
i = c
while i <= d:
    process integer i
    i = i + 1
```

```
# Store in double var. v the sum
# 1/1 + 1/2 + ...+ 1/n
v = 0; # call this 1/0 for today
i = 1
while i <= n:
    v = v + 1.0 / i
    i = i + 1
# v = 1/1 + 1/2 + ...+ 1/n
```

Using the Goal as a Condition

```
def prompt(prompt,valid):
```

```
    """Returns: the choice from a given prompt.
```

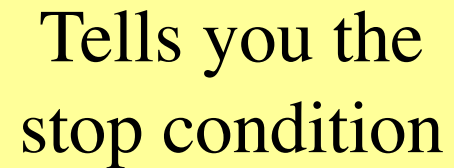
```
    This function asks the user a question, and waits for a response. It checks if the response is valid against a list of acceptable answers.
```

```
    If it is not valid, it asks the question again. Otherwise, it returns the player's answer.
```

```
    Precondition: prompt is a string
```

```
    Precondition: valid is a tuple of strings"""
```

```
    pass # Stub to be implemented
```



Tells you the stop condition

Using the Goal as a Condition

```
def prompt(prompt,valid):
```

```
    """Returns: the choice from a given prompt.
```

```
    Preconditions: prompt is a string, valid is a tuple of strings"""
```

```
    response = input(prompt)
```

```
    # Continue to ask while the response is not valid.
```

```
    while not (response in valid):
```

```
        print('Invalid response. Answer must be one of ')+str(valid)
```

```
        response = input(prompt)
```

```
    return response
```

Using a Boolean Variable

```
def roll_past(goal):
```

```
    """Returns: The score from rolling a die until passing goal.
```

```
    This function starts with a score of 0, and rolls a die, adding the
    result to the score. Once the score passes goal, it stops and
    returns the result as the final score.
```

```
    If the function ever rolls a 1, it stops and the score is 0.
```

```
    Preconditions: goal is an int > 0"""
```

```
    pass # Stub to be implemented
```

Condition is
too complicated

**Introduce a boolean variable.
Use it to track condition.**

Using a Boolean Variable

```
def roll_past(goal):
```

```
    """Returns: The score from rolling a die until passing goal."""
```

```
    loop = True # Keep looping until this is false
```

```
    score = 0
```

```
    while loop:
```

```
        roll = random.randint(1,6)
```

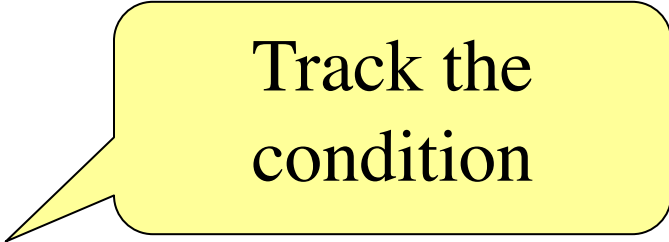
```
        if roll == 1:
```

```
            | score = 0; loop = False
```

```
        else:
```

```
            | score = score + roll; loop = score < goal
```

```
    return score
```



Track the
condition

Advantages of while vs for

```
# table of squares to N
seq = []
n = floor(sqrt(N)) + 1
for k in range(n):
    seq.append(k*k)
```

```
# table of squares to N
seq = []
k = 0
while k*k < N:
    seq.append(k*k)
    k = k+1
```

A for-loop requires that you know where to stop the loop **ahead of time**

A while loop can use complex expressions to check if the loop is done

Advantages of while vs for

Fibonacci numbers:

$$F_0 = 1$$

$$F_1 = 1$$

$$F_n = F_{n-1} + F_{n-2}$$

Table of n Fibonacci nums

```
fib = [1, 1]
```

```
for k in range(2,n):
```

```
    fib.append(fib[-1] + fib[-2])
```

Sometimes you do not use
the loop variable at all

Table of n Fibonacci nums

```
fib = [1, 1]
```

```
while len(fib) < n:
```

```
    fib.append(fib[-1] + fib[-2])
```

Do not need to have a loop
variable if you don't need one

Difficulties with while

Be careful when you **modify** the loop variable

```
def rem3(lst):  
    """Remove all 3's from lst"""  
    i = 0  
    while i < len(lst):  
        # no 3's in lst[0..i-1]  
        if lst[i] == 3:  
            del lst[i]  
            i = i+1
```

```
>>> a = [3, 3, 2]  
>>> rem3(a)  
>>> a
```

A: [2]
B: [3]
C: [3,2]
D: []
E: something else

Difficulties with while

Be careful when you **modify** the loop variable

```
def rem3(lst):  
    """Remove all 3's from lst"""  
    i = 0  
    while i < len(lst):  
        # no 3's in lst[0..i-1]  
        if lst[i] == 3:  
            del lst[i]  
            i = i+1
```

```
>>> a = [3, 3, 2]  
>>> foo(a)  
>>> a
```

A: [2]
B: [3]
C: [3,2] **Correct**
D: []
E: something else

Difficulties with while

Be careful when you **modify** the loop variable

```
def rem3(lst):  
    """Remove all 3's from lst"""  
    i = 0  
    while i < len(lst):  
        # no 3's in lst[0..i-1]  
        if lst[i] == 3:  
            del lst[i]  
        else:  
            i = i+1
```

Stopping
point keeps
changing

```
def rem3(lst):  
    """Remove all 3's from lst"""  
    while 3 in lst:  
        lst.remove(3)
```

The stopping condition is not
a numerical counter this time.
Simplifies code a lot.

Application: Convergence

- How to implement this function?

```
def sqrt(c):
```

```
    """Returns the square root of c"""
```

- Consider the polynomial $f(x) = x^2 - c$
 - Value `sqrt(c)` is a *root* of this polynomial
- Suggests a use for **Newton's Method**
 - **Start with a guess** at the answer
 - Use calculus formula to improve guess

Example: Sqrt(2)

- Actual answer: 1.414235624
- $x_{n+1} = x_n/2 + c/2x_n$
- $x_0 = 1$ # Rough guess of sqrt(2)
- $x_1 = 0.5 + 1 = 1.5$
- $x_2 = 0.75 + 2/3 = 1.41666$
- $x_3 = 0.7083 + 2/2.833 = 1.41425$

When Do We Stop?

- We don't know the $\text{sqrt}(c)$
 - This was thing we wanted to compute!
 - So we cannot tell how far off we are
 - But we do know $\text{sqrt}(c)^2 = c$
- So square approximation and compare
 - `while` $x*x$ is not close enough to c
 - `while` $\text{abs}(x*x - c) > \text{threshold}$

When Do We Stop?

- We don't know the $\text{sqrt}(c)$
 - This was thing we wanted to compute!
 - So we cannot tell how far off we are
 - But we do know $\text{sqrt}(c)^2 = c$
- So square approximation and compare

**While-loop computes until
the answer **converges****

The Final Result

```
def sqrt(c,err=1e-6):
```

```
    """Returns: sqrt of c with given margin of error.
```

```
    Preconditions: c and err are numbers > 0"""
```

```
    x = c/2.0
```

```
    while abs(x*x-c) > err:
```

```
        # Get  $x_{n+1}$  from  $x_n$ 
```

```
        x = x/2.0+c/(2.0*x)
```

```
    return x
```


Using while-loops Instead of for-loops

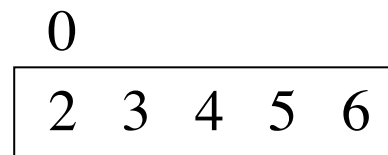
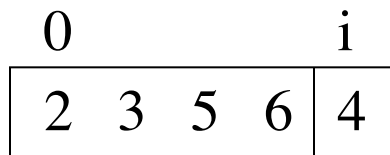
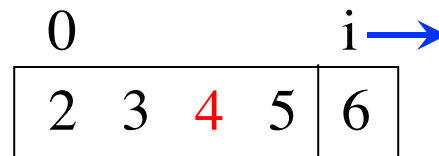
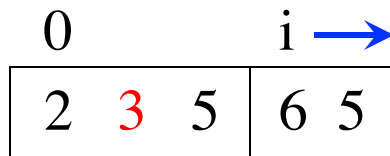
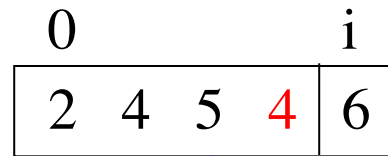
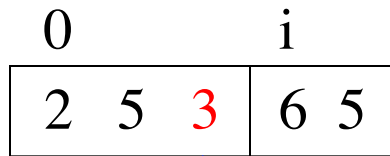
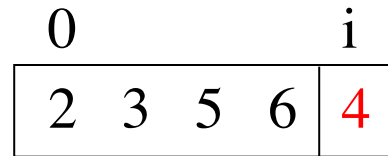
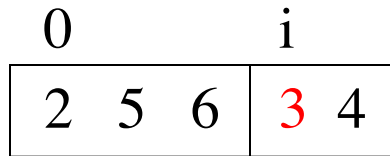
Advantages

- Better for **modifying data**
 - More natural than range
 - Works better with deletion
- Better for **convergent tasks**
 - Loop until calculation done
 - Exact steps are unknown
- Easier to **stop early**
 - Just set loop var to False

Disadvantages

- Performance is **slower**
 - Python optimizes for-loops
 - Cannot optimize while
- **Infinite loops** more likely
 - Easy to forget loop vars
 - Or get stop condition wrong
- **Debugging** is harder
 - Will see why in later lectures

Our Goal From Here: Sorting



Will see how to
do this with
while-loops

Optional Exercise

The Game of Pig: A Random Game

- Play progresses clockwise
- On your turn, throw the die:
 - If roll 1: lose turn, score zero
 - Anything else: add it to score
 - Can also roll again (and lose)
 - If stop, score is “banked”
- First person to 100 wins



The Game of Pig: A Random Game

- Play progresses clockwise
- On your turn, throw the die:
 - If roll 1: lose turn, score 0
 - Anyt
 - Can also roll again (and lose)
 - If stop, score is “banked”
- First person to 100 wins

Easy to write without classes



Designing an AI for Opponent is Easy

# Throws	Survial	Expected Gain	Expected Value
1	83%	3.33	3.33
2	69%	2.78	6.11
3	58%	2.32	8.43
4	48%	1.92	10.35
5	40%	1.61	11.96
6	33%	1.34	13.30
7	28%	1.12	14.42
8	23%	.93	15.35
9	19%	.77	16.12
10	16%	.65	16.77
...
50	0.01%	0.0004	19.998

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9	19%		16.12
10	16%		16.77
...
50	0.01%	0.0004	19.998

Strategy:
Bank at 20

The Primary Function

```
def play(target):  
    """Plays a single game of Pig to target score.  
  
    Precondition: target is an int > 0"""  
    # Initialize the scores  
    # while no one has reached the target  
        # Play a round for the player  
        # If the player did not reach the target  
            # Play a round for the opponent  
    # Display the results
```


The Player Round

```
def player_turn():
```

```
    """ Runs a single turn for the player. """
```

```
    # while the player has not stopped
```

```
        # Roll the die
```

```
        # If is a 1
```

```
            # Set score to 0 and stop the turn
```

```
        # else
```

```
            # Add the to the score
```

```
            # Ask the player whether to continue
```

```
    # Return the score
```



Prompt helper

The Opponent Round

```
def roll_past(goal):
```

```
    """Returns: The score from rolling a die until passing goal."""
```

```
    loop = True # Keep looping until this is false
```

```
    score = 0
```

```
    while loop:
```

```
        roll = random.randint(1,6)
```

```
        if roll == 1:
```

```
            | score = 0; loop = False
```

```
        else:
```

```
            | score = score + roll; loop = score < goal
```

```
    return score
```

Look familiar?