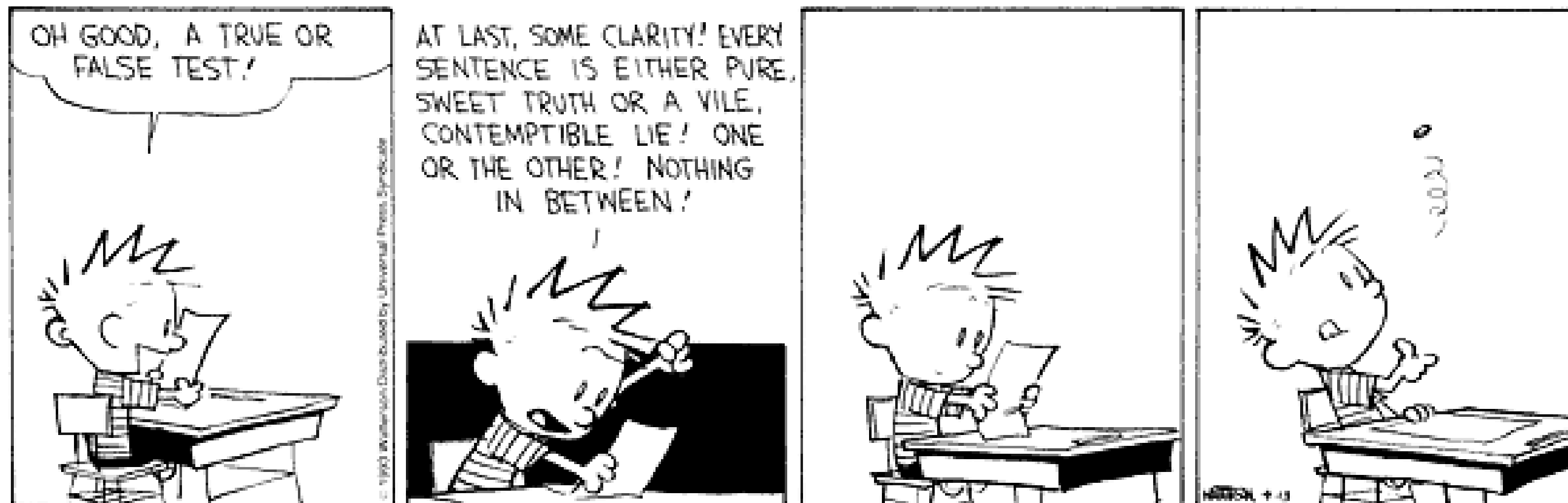
CSc 110, Autumn 2017

Lecture 13: Cumulative Sum and Boolean Logic

Adapted from slides by Marty Stepp and Stuart Reges



Adding many numbers

- How would you find the sum of all integers from 1-1000?

```
# This may require a lot of typing
sum = 1 + 2 + 3 + 4 + ...
print("The sum is", sum)
```

- What if we want the sum from 1 - 1,000,000?
  Or the sum up to any maximum?
  - How can we generalize the above code?

Cumulative sum loop

```
sum = 0
for i in range(1, 1001):
    sum = sum + i

print("The sum is", sum)
```

- **cumulative sum**: A variable that keeps a sum in progress and is updated repeatedly until summing is finished.
  - The `sum` in the above code is an attempt at a cumulative sum.
  - Cumulative sum variables must be declared *outside* the loops that update them, so that they will still exist after the loop.

Cumulative product

- This cumulative idea can be used with other operators:

```
product = 1
for i in range(1, 21):
    product = product * 2

print("2 ^ 20 =", product)
```

  - How would we make the base and exponent adjustable?

`input` and cumulative sum

- We can do a cumulative sum of user input:

```
sum = 0
for i in range(1, 101):
    next = int(input("Type a number: "))
    sum = sum + next

print("The sum is", sum)
```

Cumulative sum question

- Modify the `receipt` program from lecture 2
  - Prompt for how many people, and each person's dinner cost.
  - Use functions to structure the solution.

- Example log of execution:

```
How many people ate? 4
Person #1: How much did your dinner cost? 20.00
Person #2: How much did your dinner cost? 15
Person #3: How much did your dinner cost? 30.0
Person #4: How much did your dinner cost? 10.00

Subtotal: $75.0
Tax: $6.0
Tip: $11.25
Total: $92.25
```

Cumulative sum answer

```
# This program enhances our Receipt program using a cumulative sum.
def main():
    subtotal = meals()
    results(subtotal)

# Prompts for number of people and returns total meal subtotal.
def meals():
    people = float(input("How many people ate? "))
    subtotal = 0.0;              # cumulative sum

    for i in range(1, people + 1):
        person_cost = float(input("Person #" + str(i) +
                                  ": How much did your dinner cost? "))
        subtotal = subtotal + person_cost  # add to sum
    return subtotal
...
```

Cumulative answer, cont'd.

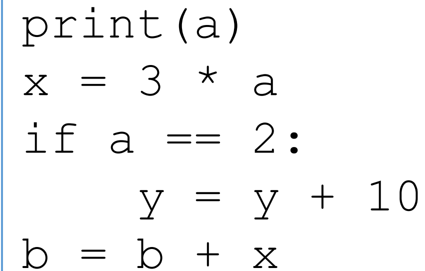
```
# Calculates total owed, assuming 8% tax and 15% tip
def results(subtotal):
    tax = subtotal * .08
    tip = subtotal * .15
    total = subtotal + tax + tip

    print("Subtotal: $" + str(subtotal))
    print("Tax: $" + str(tax))
    print("Tip: $" + str(tip))
    print("Total: $" + str(total))
```

Factoring `if/else` code

- **factoring**: Extracting common/redundant code.
  - Can reduce or eliminate redundancy from `if/else` code.

- Example:

```
if a == 1:
    print(a)
    x = 3
    b = b + x
elif a == 2:
    print(a)
    x = 6
    y = y + 10
    b = b + x
else:          # a == 3
    print(a)
    x = 9
    b = b + x
```



```
print(a)
x = 3 * a
if a == 2:
    y = y + 10
b = b + x
```

Relational expressions

- `if` statements use logical tests.

```
if i <= 10: ...
```

  - These are Boolean expressions.
- Tests use *relational operators*:

Operator	Meaning	Example	Value
`==`	equals	`1 + 1 == 2`	`True`
`!=`	does not equal	`3.2 != 2.5`	`True`
`<`	less than	`10 < 5`	`False`
`>`	greater than	`10 > 5`	`True`
`<=`	less than or equal to	`126 <= 100`	`False`
`>=`	greater than or equal to	`5.0 >= 5.0`	`True`

Logical operators

- Tests can be combined using *logical operators*:

Operator	Description	Example	Result
`and`	and	`(2 == 3) and (-1 < 5)`	`False`
`or`	or	`(2 == 3) or (-1 < 5)`	`True`
`not`	not	`not (2 == 3)`	`True`

- "Truth tables" for each, used with logical values *p* and *q*:

P	q	p and q	p or q
True	True	True	True
True	False	False	True
False	True	False	True
False	False	False	False

p	not p
True	False
False	True

Evaluating logical expressions

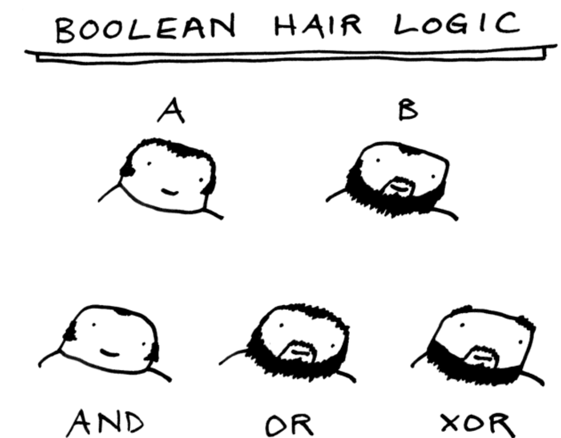
- Relational operators have lower precedence than math; logical operators have lower precedence than relational operators

```
5 * 7 >= 3 + 5 * (7 – 1) and 7 <= 11
5 * 7 >= 3 + 5 * 6 and 7 <= 11
35    >= 3 + 30 and 7 <= 11
35    >= 33 and 7 <= 11
True and True
True
```

Logical questions

- What is the result of each of the following expressions?

```
x = 42
y = 17
z = 25
```



  - `y < x and y <= z`
  - `x % 2 == y % 2 or x % 2 == z % 2`
  - `x <= y + z and x >= y + z`
  - `not(x < y and x < z)`
  - `(x + y) % 2 == 0 or not((z - y) % 2 == 0)`

    - Answers: `True`, `False`, `True`, `True`, `False`

Type bool

- **bool**: A logical type whose values are True and False.
  - A logical ***test*** is actually a Boolean expression.
  - Like other types, it is legal to:
    - create a bool variable
    - pass a bool value as a parameter
    - return a bool value from function
    - call a function that returns a bool and use it as a test

```
minor     = age < 21
is_prof   = "Prof" in name
loves_csc = True

# allow only CS-loving students over 21
if minor or is_prof or not loves_csc:
    print("Can't enter the club!")
```

Returning `bool`

```
def is_prime(n):
    factors = 0;
    for i in range(1, n + 1):
        if (n % i == 0):
            factors += 1

    if factors == 2:
        return True
    else:
        return False
```

- Calls to functions returning `bool` can be used as tests:

```
if is_prime(57):
    ...
```

"Boolean Zen", part 1

- Students new to `boolean` often test if a result is `True`:

```
if is_prime(57) == True:     # bad
    ...
```

- But this is unnecessary and redundant. Preferred:

```
if is_prime(57):             # good
    ...
```

- A similar pattern can be used for a `False` test:

```
if is_prime(57) == False:    # bad
if not is_prime(57):         # good
```

"Boolean Zen", part 2

- Functions that return `bool` often have an `if/else` that returns `True` or `False`:

```
def both_odd(n1, n2):
    if n1 % 2 != 0 and n2 % 2 != 0:
        return True
    else:
        return False
```

  - But the code above is unnecessarily verbose.

Solution w/ `bool` variable

- We could store the result of the logical test.

```
def both_odd(n1, n2):
    test = (n1 % 2 != 0 and n2 % 2 != 0)
    if test:    # test == True
        return True
    else:       # test == False
        return False
```

- Notice: Whatever `test` is, we want to return that.
  - If `test` is `True`, we want to return `True`.
  - If `test` is `False`, we want to return `False`.

Solution w/ "Boolean Zen"

- Observation: The `if/else` is unnecessary.
  - The variable `test` stores a `bool` value;
    its value is exactly what you want to return. So return that!

```
def both_odd(n1, n2):
    test = (n1 % 2 != 0 and n2 % 2 != 0)
    return test
```

- An even shorter version:
  - We don't even need the variable `test`.
    We can just perform the test and return its result in one step.

```
def both_odd(n1, n2):
    return (n1 % 2 != 0 and n2 % 2 != 0)
```

"Boolean Zen" template

- Replace

```
def name(parameters):
    if test:
        return True
    else:
        return False
```

- with

```
def name(parameters):
    return test
```

Improve the `is_prime` function

- How can we fix this code?

```
def is_prime(n):
    factors = 0;
    for i in range(1, n + 1):
        if n % i == 0:
            factors += 1

    if factors != 2:
        return False
    else:
        return True
```

De Morgan's Law

- **De Morgan's Law**: Rules used to negate boolean tests.
  - Useful when you want the opposite of an existing test.

Original Expression	Negated Expression	Alternative
`a and b`	`not a or not b`	`not(a and b)`
`a or b`	`not a and not b`	`not(a or b)`

- Example:

Original Code	Negated Code
`if x == 7 and y > 3:` `    ...`	`if x != 7 or y <= 3:` `    ...`

Boolean practice questions

- Write a function named `is_vowel` that returns whether a `str` is a vowel (a, e, i, o, or u), case-insensitively.
  - `is_vowel("q")` returns `False`
  - `is_vowel("A")` returns `True`
  - `is_vowel("e")` returns `True`

- Change the above function into an `is_non_vowel` that returns whether a `str` is any character except a vowel.
  - `is_non_vowel("q")` returns `True`
  - `is_non_vowel("A")` returns `False`
  - `is_non_vowel("e")` returns `False`

Boolean practice answers

```
# Enlightened version.  I have seen the true way (and false way)
def is_vowel(s):
    return s == 'a' or s == 'A' or s == 'e' or s == 'E' or s =='i' or s == 'I'
           or s == 'o' or s == 'O' or s == 'u' or s =='U'


# Enlightened "Boolean Zen" version
def is_non_vowel(s):
    return not(s == 'a') and not(s == 'A') and not(s == 'e') and not(s == 'E')
           and not(s =='i') and not(s == 'I') and not(s == 'o') and
           not(s == 'O') and not(s == 'u') and not(s =='U')

    # or, return not is_vowel(s)
```

When to return?

- Functions with loops and return values can be tricky.
  - When and where should the function return its result?

- Write a function `seven` that uses `randint` to draw up to ten lotto numbers from 1-30.
  - If any of the numbers is a lucky 7, the function should stop and return `True`. If none of the ten are 7 it should return `False`.
  - The method should print each number as it is drawn.

```
15 29 18 29 11 3 30 17 19 22 (first call)
29 5 29 4 7                  (second call)
```

Flawed solution

```
# Draws 10 lotto numbers; returns True if one is 7.
def seven():
    for i in range(10):
        num = randint(1, 30)
        print(num, " ", end='')

        if num == 7:
            return True
        else:
            return False
```

- The function always returns immediately after the first draw.
- This is wrong if that draw isn't a 7; we need to keep drawing.

Returning at the right time

```
# Draws 10 lotto numbers; returns True if one is 7.
def seven():
    for i in range(1, 11):
        num = randint(1, 30)
        print(str(num) + " ", end='')

        if num == 7:     # found lucky 7; can exit now
            return True

    return False   # if we get here, there was no 7
```

- Returns `True` immediately if 7 is found.
- If 7 isn't found, the loop continues drawing lotto numbers.
- If all ten aren't 7, the loop ends and we return `False`.

if/else, return question

- Write a function count_factors that returns the number of factors of an integer.
  - count_factors(24) returns 8 because 1, 2, 3, 4, 6, 8, 12, and 24 are factors of 24.

- Solution:

```
# Returns how many factors the given number has.
def count_factors(number):
    count = 0
    for i in range(1, number + 1):
        if (number % i == 0):
            count += 1      # i is a factor of number
    return count
```