

Conditionals

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Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Conditionals

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Lecture topics

- Making choices
- if-then-else statements
- Reasoning about if-then-else

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Making choices

- Sometimes we need to *make a choice*
- Based on some *condition*, we do *something* rather than *something else*

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Making choices

- If *the sun is shining*
- Then *take a walk*
- Otherwise *go to work*

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Making choices

- If *the engine is too warm and the RPM's are high enough*
- Then *reduce the RPM*
- Otherwise *do nothing*

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Making choices

- Of course conditions like this can be combined
- This means that we can *cascade* decisions
- This is the building block of *intelligent decisions* in our programs

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Making choices

- If *the engine is too warm*
- Then
 - If *the RPM's are high enough*
 - Then *reduce the RPM*
 - Otherwise *light up the temperature lamp*
- Otherwise *do nothing*

Making decisions in Python

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Using if's

if-then-else

- Python offers built-in facilities for decision-making
- `if-then-else` statement
- We can make decisions about which block of code is executed

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Using if's

if-then-else

- The general form is `if CONDITION: THEN-BLOCK else ELSE-BLOCK` (if_{CTE})
- If the condition is true, then we jump to the beginning of THEN-BLOCK, otherwise we jump to the beginning of ELSE-BLOCK

$$\begin{cases} (PC, S) \xrightarrow{if_{CTE}} (firstLine(T), S) & \text{when } (PC, S) \xrightarrow{C} TRUE \\ (PC, S) \xrightarrow{if_{CTE}} (firstLine(E), S) & \text{when } (PC, S) \xrightarrow{C} FALSE \end{cases}$$

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Using if's

if-then-else

- Python is *indentation*-based
- White-spaces go at the beginning of some lines
- A more indented line is *within* a less indented line above

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if-then-else

- Indentation specifies where the then-block and the else-block begin and end
- The general form of an if-then-else is thus:
 - if COND:
 - newline
 - **indentation**
 - code of then
 - **de-indentation**
 - else:
 - newline
 - **indentation**
 - code of then
 - **de-indentation**

A correct example

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Using if's

```
if temp > 350.0:
    if throttle > 2500:
        throttle = throttle - 1500
    else:
        warning = True
else:
    print("everything is OK")
```

An incorrect example

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Using if's

```
if temp > 350.0:
if throttle > 2500:
throttle = throttle - 1500
else:
warning = True
else:
print("everything is OK")
```

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Using if's

if-then-else

- if-then-else statements eventually terminate
- after the then (or else) block is finished, we jump to the first line right after the whole if-then-else

After an if-then-else

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Using if's

```
if temp > 350.0:
    if throttle > 2500:
        throttle = throttle - 1500
    else:
        warning = True
else:
    print("everything is OK")
print(throttle, temp, warning)
```

After an if-then-else?

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Using if's

Without indentation, this:

```
if temp > 350.0:
if throttle > 2500:
throttle = throttle - 1500
else:
warning = True
else:
print("everything is OK")
print(throttle, temp, warning)
```

would be indistinguishable from both:

```
if temp > 350.0:
    if throttle > 2500:
        throttle = throttle - 1500
    else:
        warning = True
else:
    print("everything is OK")
    print(throttle, temp, warning)
```

```
if temp > 350.0:
    if throttle > 2500:
        throttle = throttle - 1500
    else:
        warning = True
else:
    print("everything is OK")
    print(throttle, temp, warning)
```


Reasoning about if-then-else

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Using if's

if-then-else

- if-then-else effectively forks the code
- Until run-time, we are not really sure what path the code will take

Example if's

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Using if's

```
x = 0
y = 0
z = 0
op = "none"
input = sys.stdin.readline()
if input == "*\n":
    x = int(sys.stdin.readline())
    y = int(sys.stdin.readline())
    op = "*"
else:
    if input == "+\n":
        x = int(sys.stdin.readline())
        y = int(sys.stdin.readline())
        op = "+"
    else:
        x = int(sys.stdin.readline())
        y = 2
        op = "*"
```

```
if op == "+":
    z = x + y
else:
    if op == "*":
        z = x * y
    else:
        raise
print(str(x) + "_" + op + "_" +
      str(y) + "_is_" + str(z))
```

Example if's

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Using if's

Which path will be taken?

```
x = 0
y = 0
z = 0
op = "none"
input = sys.stdin.readline()
if input == "*\n":
    x = int(sys.stdin.readline())
    y = int(sys.stdin.readline())
    op = "*"
else:
    if input == "+\n":
        x = int(sys.stdin.readline())
        y = int(sys.stdin.readline())
        op = "+"
    else:
        x = int(sys.stdin.readline())
        y = 2
        op = "*"
```

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Which path will be taken?

```
x = 0
y = 0
z = 0
op = "none"
input = sys.stdin.readline()
if input == "*\n":
    x = int(sys.stdin.readline())
    y = int(sys.stdin.readline())
    op = "*"
else:
    if input == "+\n":
        x = int(sys.stdin.readline())
        y = int(sys.stdin.readline())
        op = "+"
    else:
        x = int(sys.stdin.readline())
        y = 2
        op = "*"
```

We do not know!

Example if's

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Using if's

What values will x, y, op, input have?

```
x = 0
y = 0
z = 0
op = "none"
input = sys.stdin.readline()
if input == "*\n":
    x = int(sys.stdin.readline())
    y = int(sys.stdin.readline())
    op = "*"
else:
    if input == "+\n":
        x = int(sys.stdin.readline())
        y = int(sys.stdin.readline())
        op = "+"
    else:
        x = int(sys.stdin.readline())
        y = 2
        op = "*"
```

Example if's

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Using if's

What values will x, y, op, input have?

```
x = 0
y = 0
z = 0
op = "none"
input = sys.stdin.readline()
if input == "*\n":
    x = int(sys.stdin.readline())
    y = int(sys.stdin.readline())
    op = "*"
else:
    if input == "+\n":
        x = int(sys.stdin.readline())
        y = int(sys.stdin.readline())
        op = "+"
    else:
        x = int(sys.stdin.readline())
        y = 2
        op = "*"
```

We do not know!

Reasoning about if-then-else

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Using if's

if-then-else

- The paths are influenced by the value of the input variable
 - One path for "*"\\n"
 - Another for "+"\\n"
 - Another for all other possible values
- We analyze our code based on all possible outcomes

Example if's

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Using if's

x	y	z	op	input
0	0	0	"none"	"*\n"

```
if input == "*\n":  
    x = int(sys.stdin.readline())  
    y = int(sys.stdin.readline())  
    op = "*"  
else:  
    ...
```


Example if's

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Using if's

x	y	z	op	input
0	0	0	"none"	"*\n"

```
if input == "*\n":  
    x = int(sys.stdin.readline())  
    y = int(sys.stdin.readline())  
    op = "*"  
else:  
    ...
```

x	y	z	op	input
in2	in3	0	"*"	"*\n"

Example if's

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Using if's

x	y	z	op	input
0	0	0	"none"	"+\n"

```
if input == " *\n":
    ...
else:
    if input == "+\n":
        x = int(sys.stdin.readline())
        y = int(sys.stdin.readline())
        op = "+"
    else:
        ...
```

Example if's

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Using if's

x	y	z	op	input
0	0	0	"none"	"+\n"

```
if input == "+"\n":  
    ...  
else:  
    if input == "+"\n":  
        x = int(sys.stdin.readline())  
        y = int(sys.stdin.readline())  
        op = "+"  
    else:  
        ...
```

x	y	z	op	input
in2	in3	0	"+"	"+"\n"

Example if's

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Using if's

x	y	z	op	input
0	0	0	"none"	anything else

```
if input == "*\n":  
    ...  
else:  
    if input == "+\n":  
        ...  
    else:  
        x = int(sys.stdin.readline())  
        y = 2  
        op = "*"
```

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Using if's

x	y	z	op	input
0	0	0	"none"	anything else

```
if input == "*\n":  
    ...  
else:  
    if input == "+\n":  
        ...  
    else:  
        x = int(sys.stdin.readline())  
        y = 2  
        op = "*"
```

x	y	z	op	input
in2	2	0	"*"	"anything else"

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Using if's

We can now merge the various possible outcomes (ignoring input as we do not use it anymore):

x	y	z	op	input
in2	in3	0	"*"	"*\n"
in2	in3	0	"+"	"+\n"
in2	2	0	"*"	"anything else"

Example if's

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Using if's

We can now merge the various possible outcomes (ignoring input as we do not use it anymore):

x	y	z	op	input
in2	in3	0	"*"	"*\n"
in2	in3	0	"+"	"+\n"
in2	2	0	"*"	"anything else"

x	y	z	op
in2	in3 \vee 2	0	"*" \vee "+"

Example if's

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Using if's

x	y	z	op
in2	in3 \vee 2	0	"*" \vee "+"

```
if op == "+":  
    z = x + y  
else:  
    if op == "*":  
        z = x * y  
    else:  
        raise
```


Example if's

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Using if's

x	y	z	op
in2	in3 \vee 2	0	"*" \vee "+"

```
if op == "+":
    z = x + y
else:
    if op == "*":
        z = x * y
    else:
        raise
```

x	y	z	op
in2	in3 \vee 2	in2+in3 \vee in2 \times in3 \vee in2 \times 2	"*" \vee "+"

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Using if's

Exponential explosion of potential control-paths

- $in2 + in3 \vee in2 \times in3 \vee in2 \times 2$ is a long formula
- It is simply saying that there are three possible outcomes:
 - One outcome is $in2 + in3$
 - One outcome is $in2 \times in3$
 - One outcome is $in2 \times 2$

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Using if's

Exponential explosion of potential control-paths

- The more nested conditionals, the more possible resulting execution paths
- But *how many*?

Nested if's

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Using if's

How many if's?

How many execution paths?

```
if C1:  
    A1  
else:  
    B1
```

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Using if's

How many if's?

How many execution paths?

```
if C1:  
    A1  
else:  
    B1
```

1 if's

2 execution paths

Nested if's

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Using if's

```
if C1:
    if C11:
        A11
    else:
        B11
else:
    if C12:
        A12
    else:
        B12
```

Nested if's

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Using if's

```
if C1:
    if C11:
        A11
    else:
        B11
else:
    if C12:
        A12
    else:
        B12
```

2 if's

4 execution paths

Nested if's

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Using if's

```
if C1:
    if C11:
        if C111:
            A111
        else:
            B111
    else:
        if C112:
            A112
        else:
            B112
else:
    if C12:
        if C121:
            A121
        else:
            B121
    else:
        if C122:
            A122
        else:
            B122
```


Nested if's

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Using if's

```
if C1:
    if C11:
        if C111:
            A111
        else:
            B111
    else:
        if C112:
            A112
        else:
            B112
else:
    if C12:
        if C121:
            A121
        else:
            B121
    else:
        if C122:
            A122
        else:
            B122
```

3 if's

8 execution paths

Reasoning about if-then-else

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Using if's

Exponential explosion of potential control-paths

- In general, for n if's
- 2^n possible execution paths

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Using if's

Exponential explosion of potential control-paths

- Each path can alter the state in a different way
- After an `if` with 8 possible paths
 - We have 8 possible resulting states
 - Variables can be one of possible 8 different values

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Using if's

Exponential explosion of potential control-paths

- The more nested the `if`
- The more complex its conditions
- *The harder it is to reason about it!*

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Using if's

Rules of thumb

- Logical, short condition
- Good: `(temp > 350 & throttle > 2500)`
- Bad: `(temp > 350 & throttle > 2500 & op == "+")`

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Using if's

Rules of thumb

- Few levels of nesting
- Good: between one and three
- Bad: beyond three

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Using if's

Rules of thumb

- Semantically connected `then` and `else`
- Good: both `then` and `else` perform similar operations on the same variables
- Bad: `then` and `else` perform unrelated operations or on different variables

A disastrous example

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Using if's

```
if (temp > 350 & throttle > 2500) | op == "+":  
    if op == "+":  
        z = x + y  
    else:  
        z = x * y  
        throttle = throttle - 1000  
else:  
    if op == "*":  
        z = x * y
```

What went wrong?

A disastrous example

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Using if's

```
if (temp > 350 & throttle > 2500) | op == "+":  
    if op == "+":  
        z = x + y  
    else:  
        z = x * y  
        throttle = throttle - 1000  
else:  
    if op == "*":  
        z = x * y
```

What went wrong?

- The condition is very hard to reason about
- The condition involves unrelated quantities
- The various then's and else's are partially unrelated
- There is repetition

Bringing order

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Using if's

```
if temp > 350 & throttle > 2500:
    throttle = throttle - 1000

if op == "+":
    z = x + y
else:
    z = x * y
```

What went right?

Bringing order

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Using if's

```
if temp > 350 & throttle > 2500:
    throttle = throttle - 1000

if op == "+":
    z = x + y
else:
    z = x * y
```

What went right?

- The conditions are simple to reason about
- The conditions are all tight (no unrelated variables)
- The various then's and else's are all strongly related
- Separate if's for separate tasks
- There is no repetition

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Using if's

The value of reasoning

- **Always keep in mind:**
- You have the power to make your own life a living Hell...

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The value of reasoning

- **Always keep in mind:**
- You have the power to make your own life a living Hell...
- ...unless you reason first and then structure code logically

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Using `if`'s

The best of luck, and thanks for the
attention!