

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
`if-then-else`

Using `if`'s

Conditionals

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Hogeschool Rotterdam
Rotterdam, Netherlands

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
`if-then-else`

Using `if`'s

Introduction

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Lecture topics

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
`if-then-else`

Using `if`'s

Making choices

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Making choices

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Making choices

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Making choices

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
`if-then-else`

Using `if`'s

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

Conditionals

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Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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*

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
`if-then-else`

Using `if`'s

Making decisions in Python

Making decisions in Python

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
`if-then-else`

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

Making decisions in Python

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

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

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

Making decisions in Python

Conditionals

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Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

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

Making decisions in Python

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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 else
 - **de-indentation**

A correct example

Conditionals

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Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

```
1  if temp > 350.0:
2      if throttle > 2500:
3          throttle = throttle - 1500
4      else:
5          warning = True
6  else:
7      print("everything is OK")
```

An incorrect example

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

```
1  if temp > 350.0:  
2  if throttle > 2500:  
3  throttle = throttle - 1500  
4  else:  
5  warning = True  
6  else:  
7  print("everything is OK")
```


Making decisions in Python

Conditionals

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Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

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

Conditionals

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Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

```
1 if temp > 350.0:
2     if throttle > 2500:
3         throttle = throttle - 1500
4     else:
5         warning = True
6 else:
7     print("everything is OK")
8 print(throttle, temp, warning)
```

After an if-then-else?

Conditionals

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Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Without indentation, this:

```
1 if temp > 350.0:
2   if throttle > 2500:
3     throttle = throttle - 1500
4   else:
5     warning = True
6   else:
7     print("everything is OK")
8   print(throttle, temp, warning)
```

would be indistinguishable from both:

<pre>1 if temp > 350.0: 2 if throttle > 2500: 3 throttle = throttle - 1500 4 else: 5 warning = True 6 else: 7 print("everything is OK") 8 print(throttle, temp, warning)</pre>	<pre>1 if temp > 350.0: 2 if throttle > 2500: 3 throttle = throttle - 1500 4 else: 5 warning = True 6 else: 7 print("everything is OK") 8 print(throttle, temp, warning)</pre>
--	--

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
`if-then-else`

Using `if`'s

Reasoning about `if-then-else`

Reasoning about if-then-else

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

<pre> 1 x = 0 2 y = 0 3 z = 0 4 op = "none" 5 input = sys.stdin.readline() 6 if input == "*\n": 7 x = int(sys.stdin.readline()) 8 y = int(sys.stdin.readline()) 9 op = "*" 10 else: 11 if input == "+\n": 12 x = int(sys.stdin.readline()) 13 y = int(sys.stdin.readline()) 14 op = "+" 15 else: 16 x = int(sys.stdin.readline()) 17 y = 2 18 op = "*" </pre>	<pre> 1 if op == "+": 2 z = x + y 3 else: 4 if op == "*": 5 z = x * y 6 else: 7 raise 8 print(str(x) + "_" + op + "_" + 9 str(y) + "_is_" + str(z)) </pre>	

Example if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Which path will be taken?

```
1 x = 0
2 y = 0
3 z = 0
4 op = "none"
5 input = sys.stdin.readline()
6 if input == "*\n":
7     x = int(sys.stdin.readline())
8     y = int(sys.stdin.readline())
9     op = "*"
10 else:
11     if input == "+\n":
12         x = int(sys.stdin.readline())
13         y = int(sys.stdin.readline())
14         op = "+"
15     else:
16         x = int(sys.stdin.readline())
17         y = 2
18         op = "*"
```

Example if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Which path will be taken?

```
1 x = 0
2 y = 0
3 z = 0
4 op = "none"
5 input = sys.stdin.readline()
6 if input == "*\n":
7     x = int(sys.stdin.readline())
8     y = int(sys.stdin.readline())
9     op = "*"
10 else:
11     if input == "+\n":
12         x = int(sys.stdin.readline())
13         y = int(sys.stdin.readline())
14         op = "+"
15     else:
16         x = int(sys.stdin.readline())
17         y = 2
18         op = "*"
```

We do not know!

Example if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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

```
1 x = 0
2 y = 0
3 z = 0
4 op = "none"
5 input = sys.stdin.readline()
6 if input == "*\n":
7     x = int(sys.stdin.readline())
8     y = int(sys.stdin.readline())
9     op = "*"
10 else:
11     if input == "+\n":
12         x = int(sys.stdin.readline())
13         y = int(sys.stdin.readline())
14         op = "+"
15     else:
16         x = int(sys.stdin.readline())
17         y = 2
18         op = "*"
```

Example if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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

```
1 x = 0
2 y = 0
3 z = 0
4 op = "none"
5 input = sys.stdin.readline()
6 if input == "*\\n":
7     x = int(sys.stdin.readline())
8     y = int(sys.stdin.readline())
9     op = "*"
10 else:
11     if input == "+\\n":
12         x = int(sys.stdin.readline())
13         y = int(sys.stdin.readline())
14         op = "+"
15     else:
16         x = int(sys.stdin.readline())
17         y = 2
18         op = "*"
```

We do not know!

Reasoning about if-then-else

Conditionals

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Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
`if-then-else`

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

Conditionals

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Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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

```
1 if input == "*\n":
2     x = int(sys.stdin.readline())
3     y = int(sys.stdin.readline())
4     op = "*"
5 else:
6     ...
```

Example if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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

```
1 if input == "*\n":
2     x = int(sys.stdin.readline())
3     y = int(sys.stdin.readline())
4     op = "*"
5 else:
6     ...
```

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

Example if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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

```
1  if input == "+"\n":
2      ...
3  else:
4      if input == "+"\n":
5          x = int(sys.stdin.readline())
6          y = int(sys.stdin.readline())
7          op = "+"
8      else:
9          ...
```

Example if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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

```

1  if input == "+"\n":
2      ...
3  else:
4      if input == "+"\n":
5          x = int(sys.stdin.readline())
6          y = int(sys.stdin.readline())
7          op = "+"
8      else:
9          ...

```

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

Example if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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

```
1  if input == "*\n":
2      ...
3  else:
4      if input == "+\n":
5          ...
6      else:
7          x = int(sys.stdin.readline())
8          y = 2
9          op = "*"

```


Example if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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

```
1 if input == "*\n":
2     ...
3 else:
4     if input == "+\n":
5         ...
6     else:
7         x = int(sys.stdin.readline())
8         y = 2
9         op = "*"

```

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

Example if's

Conditionals

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Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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

```
1 if op == "+":  
2     z = x + y  
3 else:  
4     if op == "*":  
5         z = x * y  
6     else:  
7         raise
```

Example if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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

```

1  if op == "+":
2      z = x + y
3  else:
4      if op == "*":
5          z = x * y
6      else:
7          raise

```

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

Conditionals

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Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

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 $in2 \times 2$

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Exponential explosion of potential control-paths

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

Sequential if's

Conditionals

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Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

How many if's?

How many execution paths?

```
1  if C1:  
2      A1  
3  else:  
4      B1
```


Sequential if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

How many if's?

How many execution paths?

```
1 if C1:  
2     A1  
3 else:  
4     B1
```

1 if

2 execution paths

Sequential if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

```
1  if C1:
2      A1
3  else:
4      B1
5
6  if C2:
7      A2
8  else:
9      B2
```

Sequential if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

```
1  if C1:
2      A1
3  else:
4      B1
5
6  if C2:
7      A2
8  else:
9      B2
```

2 if's
4 execution paths

Sequential if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

```
1  if C1:
2      A1
3  else:
4      B1
5
6  if C2:
7      A2
8  else:
9      B2
10
11 if C3:
12     A3
13 else:
14     B3
```

Sequential if's

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

```
1  if C1:
2      A1
3  else:
4      B1
5
6  if C2:
7      A2
8  else:
9      B2
10
11 if C3:
12     A3
13 else:
14     B3
```

3 if's

8 execution paths

Conditionals

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Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Exponential explosion of potential control-paths

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

Reasoning about if-then-else

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Exponential explosion of potential control-paths

- The more if's
- The more complex its conditions
- *The harder it is to reason about your program!*

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
`if-then-else`

Using `if`'s

Using `if`'s

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Rules of thumb

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

Rules of thumb

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making choices

Making decisions in Python

Reasoning about if-then-else

Using if's

```
1  if (temp > 350 & throttle > 2500) | op == "+":  
2      if op == "+":  
3          z = x + y  
4      else:  
5          z = x * y  
6          throttle = throttle - 1000  
7  else:  
8      if op == "*":  
9          z = x * y
```

What went wrong?

A disastrous example

Conditionals

The INFDEV
Team @ HR

Introduction

Making choices

Making decisions in Python

Reasoning about if-then-else

Using if's

```
1  if (temp > 350 & throttle > 2500) | op == "+":  
2      if op == "+":  
3          z = x + y  
4      else:  
5          z = x * y  
6          throttle = throttle - 1000  
7  else:  
8      if op == "*":  
9          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

Conditionals

The INFDEV
Team @ HR

Introduction

Making choices

Making decisions in Python

Reasoning about if-then-else

Using if's

```
1  if temp > 350 & throttle > 2500:
2      throttle = throttle - 1000
3
4  if op == "+":
5      z = x + y
6  else:
7      z = x * y
```

What went right?

Bringing order

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

```
1  if temp > 350 & throttle > 2500:
2      throttle = throttle - 1000
3
4  if op == "+":
5      z = x + y
6  else:
7      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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

The value of reasoning

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
if-then-else

Using if's

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

Conditionals

The INFDEV
Team @ HR

Introduction

Making
choices

Making
decisions in
Python

Reasoning
about
`if-then-else`

Using `if`'s

The best of luck, and thanks for the
attention!