CE 311K: Control flow - Branching and Iterations

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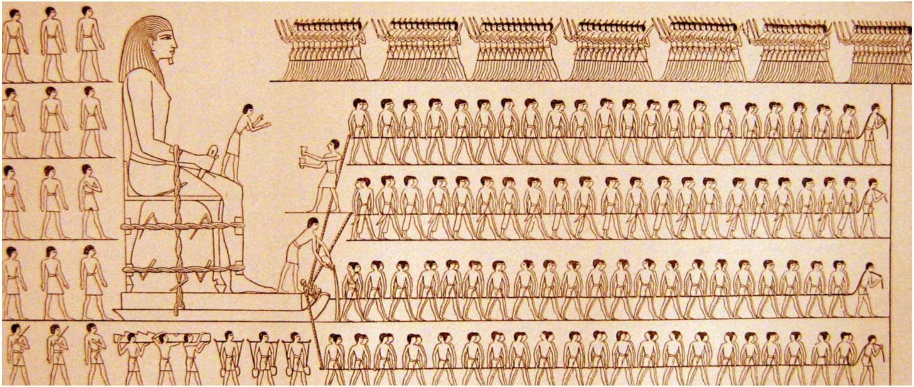
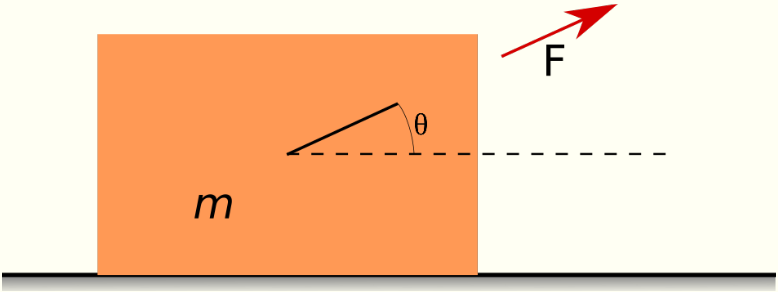
1. Numerical solution of a sliding block
2. Bisection method

What is the optimal angle to pull the statue?



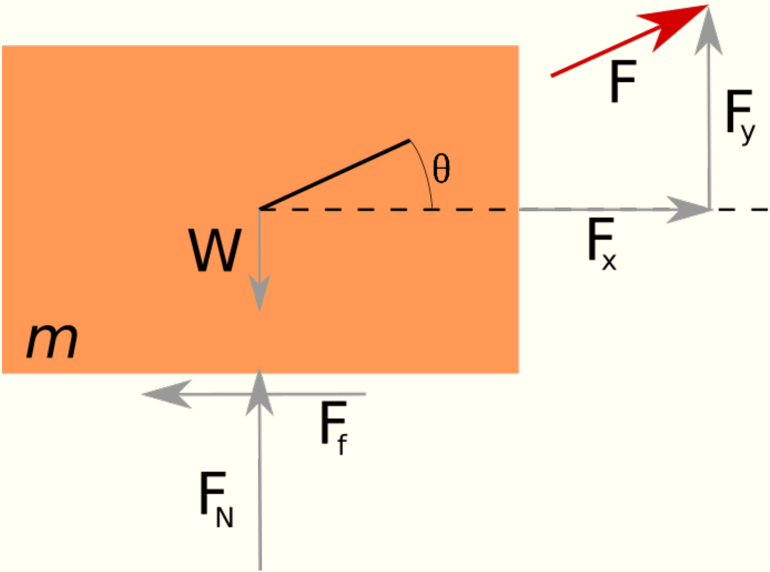
A wall painting from the tomb of Djehutihotep (credit: martinhumanities.com)

Numerical solution of a sliding block: Approximation



What is the optimal angle to pull the block applying the least amount of force?

Numerical solution of a sliding block: Forces



Numerical solution of a sliding block: Forces

$$F_x = F\cos\theta \quad \& \quad F_y = F\sin\theta$$

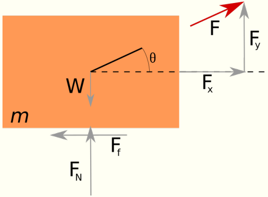
$$F_f = \mu \cdot F_N = \mu \cdot W - \mu F_y = \mu mg - \mu F\sin\theta$$

Vertical forces $\sum F_{vert} \uparrow$: $F_y + F_N - W = 0$

$$F_N = mg - F\sin\theta$$

Horizontal forces $\sum F_{hor} \rightarrow$: $F_x - F_f = 0$

$$F\cos\theta - \mu mg + \mu F\sin\theta = 0$$



$$\boxed{F = \frac{\mu \cdot mg}{(\cos\theta + \mu\sin\theta)}}$$

Numerical solution of a sliding block: Compute force

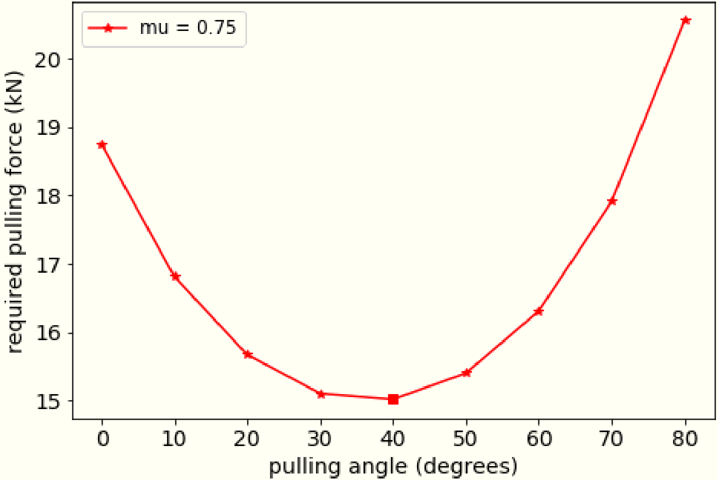
- Given $W = 25kN(2500\,\text{kg})$, $\theta = 45^o$ and $\mu = 0.75$ (35^o):

$$F = \frac{0.75 \times 25}{\cos(45) + 0.75\sin(45)} = 15.15\,\text{kN}.$$

- Given $W = 25kN(2500\,\text{kg})$ and $\mu = 0.75$, what's the optimum θ?

Numerical solution of a sliding block: Optimal theta?

Given $W = 25\,\text{kN}(2500\,\text{kg})$ and $\mu = 0.75$, what's the optimum θ?



Lists

- A list is a sequence of data. (mutable)
- An 'array' in most other languages is a similar concept, but Python lists are more general than most arrays as they can hold a mixture of types.
- A list is constructed using square brackets:

```
>>> a = [0, 10, 20, 30, 40, 50, 60, 70, 80]
>>> print(a)
[0, 10, 20, 30, 40, 50, 60, 70, 80]
>>> type(a)
<class 'list'>
>>> len(a)
10
>>> a.append(90)
>>> print(a)
[0, 10, 20, 30, 40, 50, 60, 70, 80, 90]
```

Iterating through a list: for loops

Looping over each item in a list (or more generally a sequence) is called 'iterating'. We iterate over the members of the lab group using the syntax:

```
for each item in list do
        print(item)

for item in list:
        print(item)
```

Indentation matters in python!

Iterating through a list: for loops

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```
for each item in list do
        print(item)

for item in list:
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```

⚠ Indentation matters in python!

Variables defined inside a for loop is not accessible outside.

np.arange()

We need a new library called ‘numpy‘, we are going to import the new library. `import numpy as np` The `np.arange()` returns a sequence of numbers:

```
range(stop)
```

stop: Number of integers (whole numbers) to generate, starting from zero. eg. np.arange(3) yields a sequence of [0, 1, 2].

```
np.arange([start], stop[, step])
```

- *start*: Starting number of the sequence.
- *stop*: Generate numbers up to, but not including this number.
- *step*: Difference between each number in the sequence.

Note that:

- All parameters can be positive or negative.
- range() (and Python in general) is 0-index based, meaning list indexes start at 0, not 1

np.arange()

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`range(stop)`

stop: Number of integers (whole numbers) to generate, starting from zero. eg. np.arange(3) yields a sequence of [0, 1, 2].

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- *start*: Starting number of the sequence.
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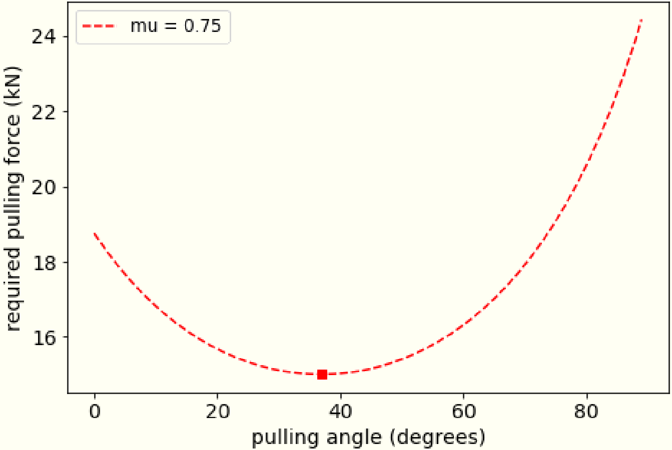
Numerical solution of a sliding block: Optimal theta?

Given $W = 25\,\text{kN}(2500\,\text{kg})$ and $\mu = 0.75$, what's the optimum θ?



? Identifying optimum requires conditional statements

Comparison on int, float and strings

`i` and `j` are variable names and comparisons below evaluate to a Boolean

- `i > j`
- `i >= j`
- `i < j`
- `i <=j`
- `i == j`: equality test, `True` if `i` is the same as `j`
- `i != j`: in equality test, `True` if `i` is not the same as `j`

Logic operators on bools

`a` and `b` are variable names with Boolean values

- `not a`: `True` if `a` is `False`
  `False` if `a` is `True`
- `a and b`: `True` if both are `True`.
- `a or b`: `True` if either or both are `True`.

A	B	A and B	A or B
True	True	True	True
True	False	False	True
False	True	False	True
False	False	False	False

Designing a smart window: if condition

- An electric window opener, attached to a rain sensor and a temperature gauge, might be controlled by the following program:
- If raining: close window
- If too hot (80F): open window
- If too cold (66F): close window
- Otherwise: do nothing and leave window as it is

Designing a smart window: if condition

```
# If raining, close the window
if raining:
        close_window()

# If the temperature is over 80 F, open window
elif temperature > 80: # else if
        open_window()

# If the temperature is below 66 F, close window
elif temperature < 66:
        close_window()

# Otherwise, do nothing and leave window as it is
else:
        continue
```

Designing a smart window: if condition

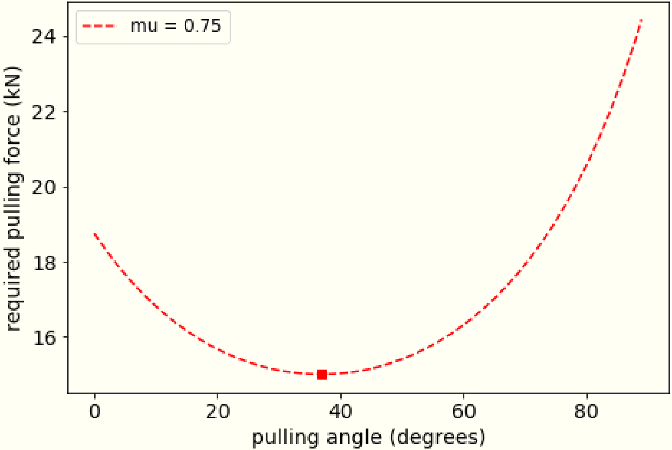
```
# If raining, close the window
if raining:
        close_window()

# If the temperature is over 80 F, open window
elif temperature > 80: # else if
        open_window()

# If the temperature is below 66 F, close window
elif temperature < 66:
        close_window()

# Otherwise, do nothing and leave window as it is
else:
        continue
```

`<condition>` has a value `True` or `False`

evaluate `expressions` in that block if `<condition>` is True

Numerical solution of a sliding block: Optimal theta?

Given $W = 25\,\text{kN}(2500\,\text{kg})$ and $\mu = 0.75$, what's the optimum θ?



Identify optimum with an if conditional statement

1. Numerical solution of a sliding block
2. Bisection method

Calculate the optimum angle to pull for a given force

- Given $F = 17.5\,\text{kN}(1750\,\text{kg})$, $W = 25\,\text{kN}$ and $\mu = 0.75$, what's θ?

$$Try\ \theta = 60^o:\ \ F = \frac{0.75 \times 25}{\cos(60) + 0.75\sin(60)} = 16.31\,\text{kN}.$$

$$Try\ \theta = 70^o:\ \ F = \frac{0.75 \times 25}{\cos(70) + 0.75\sin(70)} = 17.91\,\text{kN}.$$

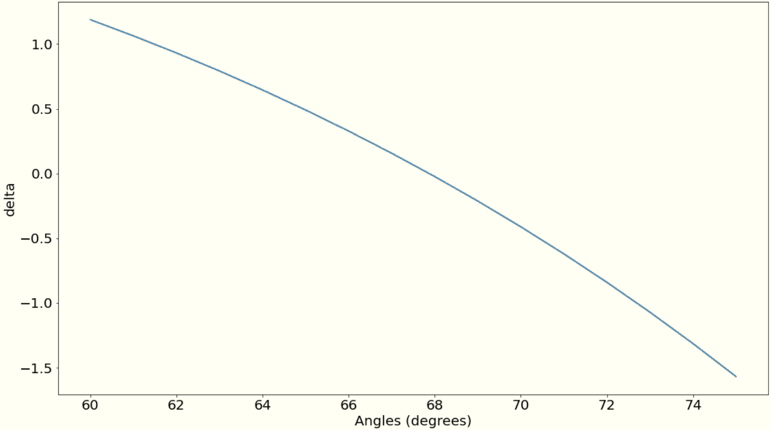
$$Try\ \theta = 65^o:\ \ F = \frac{0.75 \times 25}{\cos(65) + 0.75\sin(65)} = 17.00\,\text{kN}.$$

$$Try\ \theta = 67.5^o:\ \ F = \frac{0.75 \times 25}{\cos(67.5) + 0.75\sin(67.5)} = 17.43\,\text{kN}.$$

This is **bisection method!**

Calculate the optimum angle to pull for a given force

- Given $F = 17.5\,\text{kN}(1750\,\text{kg})$, $W = 25\,\text{kN}$ and $\mu = 0.75$, what's θ?



What are the characteristics of a numerical solution?

- A numerical recipe is *a sequence of simple steps*
- *Flow of control* as each step is executed.
- Yields an *approximate* numerical answer (a finite number) for the problem
- These solutions can be very accurate
- Most answers are determined in an iterative approach (numerical method: mathematical / computer-aided technique) until a desired minimum/acceptable accuracy is obtained
- Typically, a finite set of iterations (steps) are used in the numerical method to obtain a solution. A means of determining *when to stop*.

Numerical solution of a sliding block: Friction angles