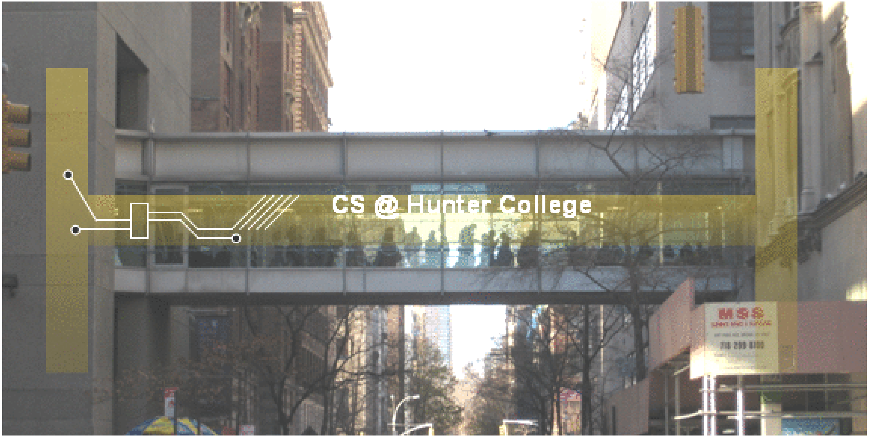
CSci 127: Introduction to Computer Science



hunter.cuny.edu/csci

Frequently Asked Questions

From email and tutoring.

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  - *All previous final exams (and answer keys) on the website.*
  - *UTAs in drop-in tutoring happy to review concepts and old exam questions.*
  - *There will be opportunity for practice during our last meeting on 13 December.*

Handle Exam Anxiety – courtesy Dr. St. John

- Print out the past exams and do as much as possible in 1 hour.
- Then grade yourselves, figure out which problems are similar to past problems, keeping all the exams youve done in a 3-hole notebook, 1 problem per page, organized by problem number, reinforces the similarity.
- Make a list of what does not make sense and asking the instructor.
- Attempting to do the exam in half the time means that in the real exam, you will have plenty of time.

Today's Topics

- Design Patterns: Searching
- Python Recap
- Machine Language
- Machine Language: Jumps & Loops
- Binary & Hex Arithmetic
- Final Exam: Format

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Predict what the code will do:

```python
def search(nums, locate):
    found = False
    i = 0
    while not found and i < len(nums):
        print(nums[i])
        if locate == nums[i]:
            found = True
        else:
            i = i+1

    return(found)
```

Predict what the code will do: II

```
nums= [1,4,10,6,5,42,9,8,12]
target = 6
if search(nums, target):
    print(target, ’is in the list.’)
else:
    print(target, ’is not in the list.’)
```

Simplified but a little tricky

```python
def search(nums, locate):
    i = 0
    while i < len(nums) and locate!=nums[i]:
        print(nums[i])
        i = i+1

    return (i < len(nums))
    #If locate is in the list,
    #then for some i < len(nums), we have
    #locate == nums[i].
    #If i >= len(nums), this implies that all
    #items are searched, no match is found.
```

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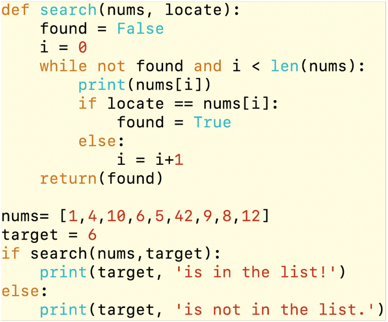
Design Pattern: Linear Search



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- Example of **linear search**.

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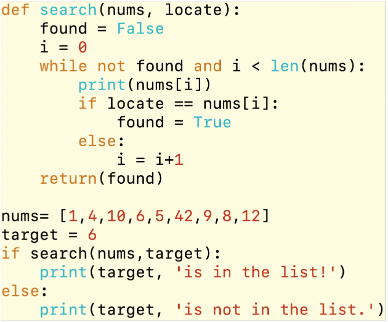

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- Start at the beginning of the list.

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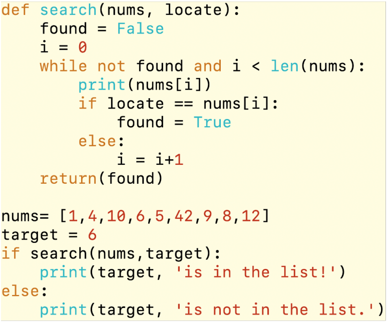

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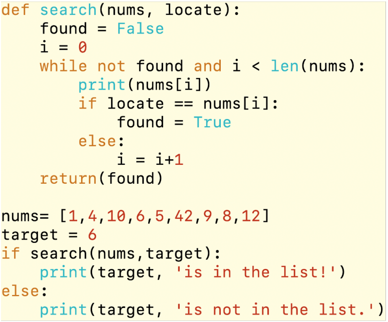
- Start at the beginning of the list.
- Look at each item, one-by-one.

Design Pattern: Linear Search



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- Example of **linear search**.
- Start at the beginning of the list.
- Look at each item, one-by-one.
- Stop when found, or the end of lis reached.

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- **Python Recap**
- Machine Language
- Machine Language: Jumps & Loops
- Binary & Hex Arithmetic

Python & Circuits Review: 10 Weeks in 10 Minutes

A whirlwind tour of the semester, so far...

Week 1: print(), loops, comments, & turtles

```python
#Texts following # are comments.
#Comments are read by human beings, not computer.
#Name: Thomas Hunter
#Date: September 1, 2017
#This program prints: Hello, World!

print("Hello, World!")
```

Week 1: print(), loops, comments, & turtles

```python
import turtle

taylor = turtle.Turtle()
taylor.color("purple")
taylor.shape("turtle")

n = 6
for i in range(n):
    taylor.forward(100)
    taylor.stamp()
    taylor.left(360/n)
```

Week 2: variables, data types, more on loops & range()

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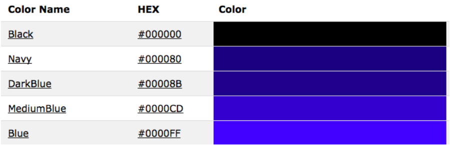
  - **list**: a sequence of items
    e.g. `[3, 1, 4, 5, 9]` or `['violet','purple','indigo']`
  - **class variables**: for complex objects, like turtles.
- More on loops & ranges:

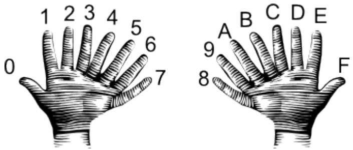
Examples on loop and ranges

```
for num in [2,4,6,8,10]:
    print(num)

sum = 0
for x in range(0,12,2):
    print(x)
    sum += x

print(sum)

for c in 'ABCD':
    print(c)
```

Week 3: colors, hex, slices, numpy & images



Color Name	HEX	Color
Black	#000000	⬛
Navy	#000080	🟦
DarkBlue	#00008B	🟦
MediumBlue	#0000CD	🟦
Blue	#0000FF	🟦



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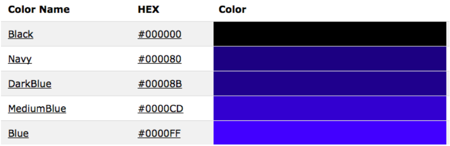

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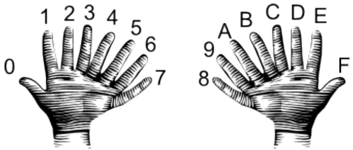

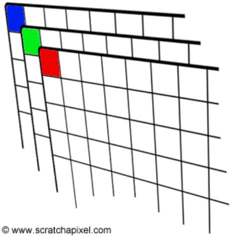

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Two Dimensional Array Slicing

```python
import numpy as np

numRows = 6
numCols = 6
a = np.zeros((numRows, numCols))
#create a table with 6 rows and 6 columns,
#each element is initialized to be zero.
#Do not forget parentheses around
#numRows, numCols.
```

Two Dimensional Array Slicing: II

```
for i in range(numRows):
    for j in range(numCols):
        a[i, j] = i*10 + j
#range(numRows) returns [0, 1, 2, 3, 4, 5],
#where outer loop variable i chooses from.
#When i is 0, run
#    for j in range(numCols):
#        a[i, j] = i*10 + j
#When i is 1, run
#    for j in range(numCols):
#        a[i, j] = i*10 + j
#The last round of i is 5.
```

Two Dimensional Array Slicing: III

```python
for i in range(numRows):
    for j in range(numCols):
        print("%3i"%(a[i, j]), end="")
        #"%3i"%(a[i, j]) prints a[i, j] --
        #element of a at ith row and
        #jth column -- as an 3-digit int.
        #"%3i" is a place holder and is filled by a[i, j].
        #If a[i, j] does not have 3 digits,
        #pad space(s) to the left.
        #end="" print w/o a new line.

    print() #print a new line after each row
```

Two Dimensional Array Slicing: III

```
print(a[0, 3:5])
```

row \ col	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

Two Dimensional Array Slicing: III

```
print(a[0, 3:5])
```

col row	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
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col row	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

print

```
[3. 4.]
```

Two Dimensional Array Slicing: IV

```python
print(a[4:, 4:])
```

col row	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
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Two Dimensional Array Slicing: IV

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col row	0	1	2	3	4	5
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col row	0	1	2	3	4	5
0	0	1	2	3	4	5
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3	30	31	32	33	34	35
4	40	41	42	43	44	45
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Print out

```
[[44. 45.]
 [54. 55.]]
```

Two Dimensional Array Slicing: V

```python
print(a[:, 2])
```

col row	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

Two Dimensional Array Slicing: V

```
print(a[:, 2])
```

col row	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
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col row	0	1	2	3	4	5
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3	30	31	32	33	34	35
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Print out

```
[ 2. 12. 22. 32. 42. 52.]
```

Two Dimensional Array Slicing: VI

```python
print(a[2::2, ::2])
```

	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

Two Dimensional Array Slicing: VI

```python
print(a[2::2, ::2])
```

	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
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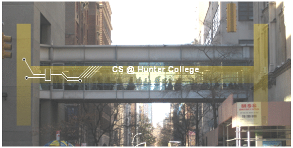
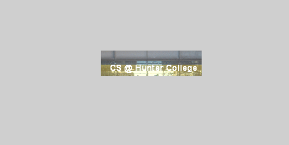
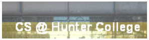
print

```
[[20. 22. 24.]
 [40. 42. 44.]]
```

Week 4: design problem (cropping images) & decisions







Week 4: design problem (cropping images) & decisions

- First: specify inputs/outputs. *Input file name, output file name, upper, lower, left, right ("bounding box")*

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- First: specify inputs/outputs. *Input file name, output file name, upper, lower, left, right ("bounding box")*
- Next: write pseudocode.
  1. Import numpy and pyplot.
  2. Ask user for file names and dimensions for cropping.
  3. Save input file to an array.
  4. Copy the cropped portion to a new array.
  5. Save the new array to the output file.

Week 4: design problem (cropping images) & decisions

- First: specify inputs/outputs. *Input file name, output file name, upper, lower, left, right ("bounding box")*
- Next: write pseudocode.
  1. Import numpy and pyplot.
  2. Ask user for file names and dimensions for cropping.
  3. Save input file to an array.
  4. Copy the cropped portion to a new array.
  5. Save the new array to the output file.
- Next: translate to Python.

Grayed surrounding area of an image

```python
#Leave middle 1/5 height * 1/2 width unchanged,
#gray the rest area of the image
import matplotlib.pyplot as plt
import numpy as np

fileName = input("Enter a file name: ")
img = plt.imread(fileName)

height = img.shape[0]
width = img.shape[1]
```

Grayed surrounding area of an image: II

```
#make the top 2/5 area gray
img[:height*2//5, :] = [0.5, 0.5, 0.5, 1]
#[0.5, 0.5, 0.5, 1] means
#red 0.5, green 0.5, blue 0.5 and opacity 1

#make the bottom 1/4 area gray
img[-height*2//5:, :] = [0.5, 0.5, 0.5, 1]
#img[-height*2//5:, :] same as
#img[height*3//5:, :]
##height*2//5 from BOTTOM sams as
#height*3//5 from TOP
#img[height*3//5:, :] = [0.5, 0.5, 0.5, 1]
```

Grayed surrounding area of an image: III

```
#make the left 1/4 area gray
img[:, :width//4] = [0.5, 0.5, 0.5, 1]

#make the right 1/4 area gray
img[:, width*3//4:] = [0.5, 0.5, 0.5, 1]
#img[:, width*3//4: ] same as
#img[:, -width//4: ]
#width*3//4 from LEFT same as
#width//4 from RIGHT
#img[:, -width//4:] = [0.5, 0.5, 0.5, 1]

plt.imshow(img)
plt.show()
```

Highlight part of image

```python
#Leave middle 1/5 height * 1/2 width
#section unchanged,
#dim the rest area of the image
#It is like to highlight the middle part.

import matplotlib.pyplot as plt
import numpy as np

fileName = "csBridge.png"
#fileName = input("Enter a file name: ")
img = plt.imread(fileName)
```

Highlight part of image: II

```
height = img.shape[0]
width = img.shape[1]

#make the top 1/4 area gray
#img[:height*2//5, :] = [0.5, 0.5, 0.5, 1]
#[0.5, 0.5, 0.5, 1] means
#red 0.5, green 0.5, blue 0.5 and opacity 1
#unlike user created stripe images,
#some images have four channels.

#dim the top 1/4 area
img[:height*2//5, :, 3] = 0.5
```

Highlight part of image: III

```
#dim the bottom 1/4 area
img[-height*2//5:, :, 3] = 0.5
#img[-height*2//5:, :, 3] same as img[height*3//5:, :, 3]
#height*2//5 from BOTTOM same as height*3//5 from TOP

#dim the left 1/4 area
img[:, :width//4, 3] = 0.5
```

Highlight part of image: IV

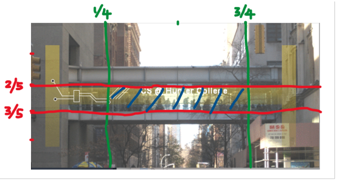
```
#dim the right 1/4 area
img[:, width*3//4:, 3] = 0.5
#img[:, width*3//4:, 3] same as
#img[:, -width//4:, 3]
#width*3//4 from LEFT same as
#width//4 from RIGHT

plt.imshow(img)
plt.show()
```

Crop image

```python
#crop middle 1/5 * height * 1/2 * width area
import matplotlib.pyplot as plt
import numpy as np

fileName = "csBridge.png"
#fileName = input("Enter a file name: ")
img = plt.imread(fileName)

height = img.shape[0]
width = img.shape[1]
```

Crop image: II

```
img2 = img[height*2//5 : height*3//5, width
    *1//4 : width*3//4] #// cannot be replaced
     by /, indices need to be int.

plt.imshow(img2)
plt.show()

plt.imsave('cropped_image.png', img2)
```



Week 4: design problem (cropping images) & decisions

```python
yearBorn = int(input("Enter year born: "))
if yearBorn < 1946:
   print("Greatest Generation")
elif yearBorn <= 1964:
     print("Baby Boomer")
elif yearBorn <= 1984:
     print("Generation X")
elif yearBorn <= 2004:
     print("Millennial")
else:
     print("TBD")
```

Week 4: design problem (cropping images) & decisions: II

```
x = int(input("Enter number: "))

if x % 2 == 0:
    print("Even number")
else:
    print("Odd number")
```

Week 5: logical operators, truth tables & logical circuits

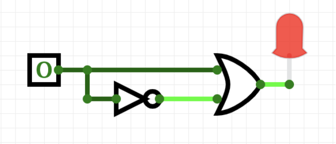
```
origin = "Indian Ocean"
winds = 100
if winds >= 74:
    print("Major storms, called a ", end="")
    if origin == "Indian Ocean" or origin == "South Pacific":
        print("cyclone.")
    elif origin == "North Pacific":
        print("typhoon.")
    else:
        print("hurricane.")
```

Week 5: logical operators, truth tables & logical circuits: II

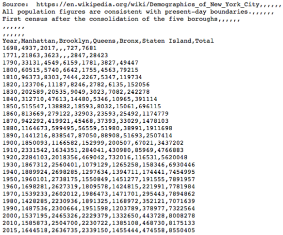
```python
visibility = 0.2
winds = 40
conditions = "blowing snow"
if (winds > 35) and (visibility < 0.25) and
    (conditions == "blowing snow" or
      conditions == "heavy snow"):
    print("Blizzard!")
```

Week 5: logical operators, truth tables & logical circuits: III

in1		in2	*returns:*
False	and	False	False
False	and	True	False
True	and	False	False
True	and	True	True



Week 6: structured data, pandas, & more design



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1870,942292,419921,45468,37393,33029,1478103
1880,1164673,599495,56559,51980,38991,1911698
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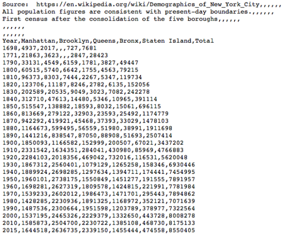
2010,1585873,2504700,2230722,1385108,468730,8175133
2015,1644518,2636735,2339150,1455444,474558,8550405
```

`nycHistPop.csv`

In Lab 6

Week 6: structured data, pandas, & more design

```
import matplotlib.pyplot as plt
import pandas as pd
```



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```

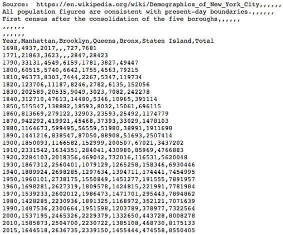
`nycHistPop.csv`

In Lab 6

Week 6: structured data, pandas, & more design

```
import matplotlib.pyplot as plt
import pandas as pd

pop = pd.read_csv('nycHistPop.csv',skiprows=5)
```



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nycHistPop.csv

In Lab 6

Week 6: structured data, pandas, & more design

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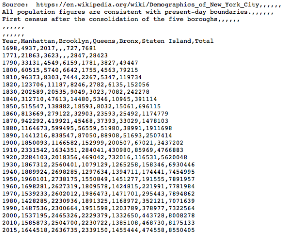
import pandas as pd

pop = pd.read_csv('nycHistPop.csv',skiprows=5)

pop.plot(x="Year")
plt.show()
```



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nycHistPop.csv

In Lab 6

Week 6: structured data, pandas, & more design

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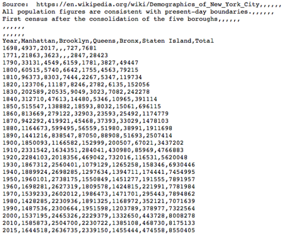

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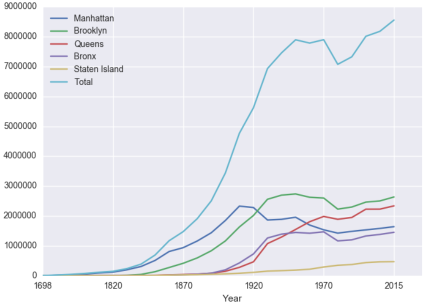
`nycHistPop.csv`

In Lab 6



Week 7: functions

```
#Name:  your name here
#Date:  October 2017
#This program, uses functions,
#     says hello to the world!

def main():
     print("Hello, World!")

if __name__ == "__main__":
     main()
```

- Functions are a way to break code into pieces, that can be easily reused.

Week 7: functions

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- Many languages require that all code must be organized with functions.

Week 7: functions

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- The opening function is often called `main()`

Week 7: functions

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- Functions are a way to break code into pieces, that can be easily reused.
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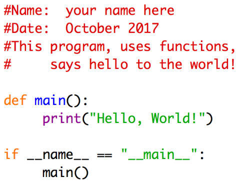
- The opening function is often called `main()`
- You **call** or **invoke** a function by typing its name, followed by any inputs, surrounded by parenthesis:

Week 7: functions



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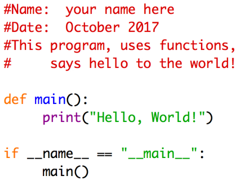
Week 7: functions



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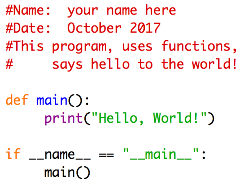
- Can write, or **define** your own functions,

Week 7: functions



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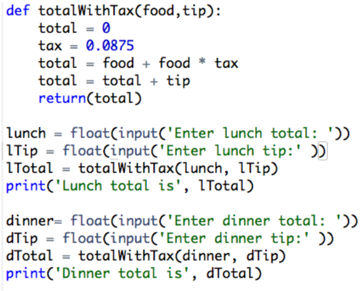
- The opening function is often called `main()`
- You **call** or **invoke** a function by typing its name, followed by any inputs, surrounded by parenthesis: Example: `print("Hello", "World")`
- Can write, or **define** your own functions, which are stored, until invoked or called.

Week 8: function parameters, github

- Functions can have **input parameters**.

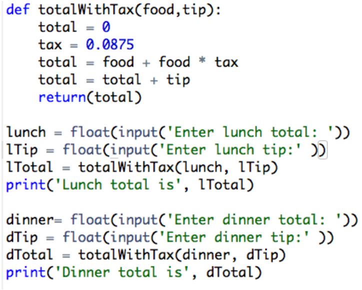


```
def totalWithTax(food,tip):
    total = 0
    tax = 0.0875
    total = food + food * tax
    total = total + tip
    return(total)

lunch = float(input('Enter lunch total: '))
lTip = float(input('Enter lunch tip:' ))
lTotal = totalWithTax(lunch, lTip)
print('Lunch total is', lTotal)

dinner= float(input('Enter dinner total: '))
dTip = float(input('Enter dinner tip:' ))
dTotal = totalWithTax(dinner, dTip)
print('Dinner total is', dTotal)
```

Week 8: function parameters, github



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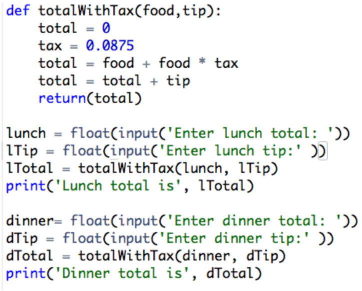
- Functions can have **input parameters**.
- Surrounded by parenthesis, both in the function definition, and in the function call (invocation).

Week 8: function parameters, github



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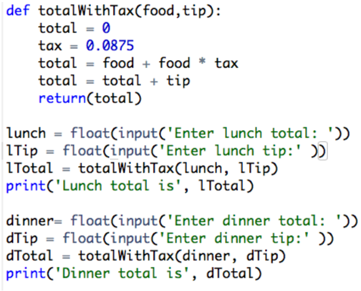
- The “placeholders” in the function definition: **formal parameters**.

Week 8: function parameters, github



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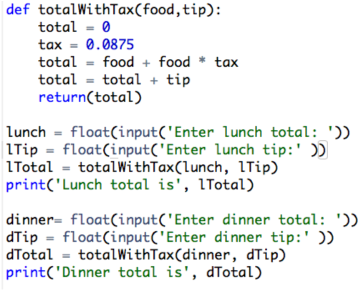
- Functions can have **input parameters**.
- Surrounded by parenthesis, both in the function definition, and in the function call (invocation).
- The “placeholders” in the function definition: **formal parameters**.
- The ones in the function call: **actual parameters**

Week 8: function parameters, github



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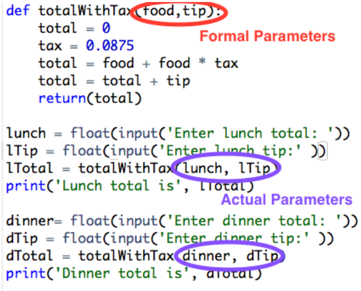
    return(total)

lunch = float(input('Enter lunch total: '))
lTip = float(input('Enter lunch tip:' ))
lTotal = totalWithTax(lunch, lTip)
print('Lunch total is', lTotal)

dinner= float(input('Enter dinner total: '))
dTip = float(input('Enter dinner tip:' ))
dTotal = totalWithTax(dinner, dTip)
print('Dinner total is', dTotal)
```

- Functions can have **input parameters**.
- Surrounded by parenthesis, both in the function definition, and in the function call (invocation).
- The “placeholders” in the function definition: **formal parameters**.
- The ones in the function call: **actual parameters**
- Functions can also **return values** to where it was called.

Week 8: function parameters, github



```
def totalWithTax(food,tip):
    total = 0
    tax = 0.0875
    total = food + food * tax
    total = total + tip
    return(total)

lunch = float(input('Enter lunch total: '))
lTip = float(input('Enter lunch tip:' ))
lTotal = totalWithTax(lunch, lTip)
print('Lunch total is', lTotal)

dinner= float(input('Enter dinner total: '))
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- Functions can have **input parameters**.
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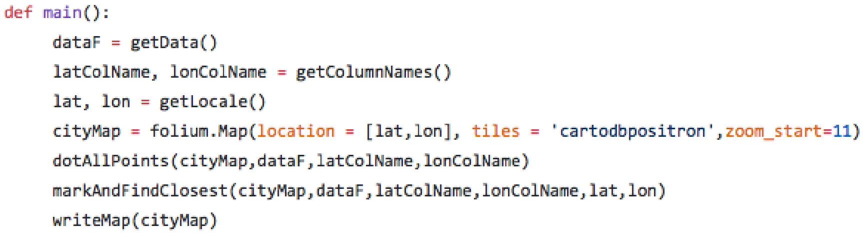
- The “placeholders” in the function definition: **formal parameters**.
- The ones in the function call: **actual parameters**.
- Functions can also **return values** to where it was called.

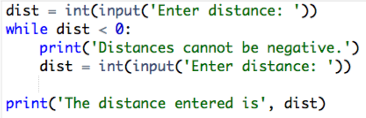
Week 9: top-down design, folium, loops, and random()

+
−
EEHAWKEN
Hudson River
Hell Gate
East River
BROADWAY



```
def main():
    dataF = getData()
    latColName, lonColName = getColumnNames()
    lat, lon = getLocale()
    cityMap = folium.Map(location = [lat,lon], tiles = 'cartodbpositron',zoom_start=11)
    dotAllPoints(cityMap,dataF,latColName,lonColName)
    markAndFindClosest(cityMap,dataF,latColName,lonColName,lat,lon)
    writeMap(cityMap)
```

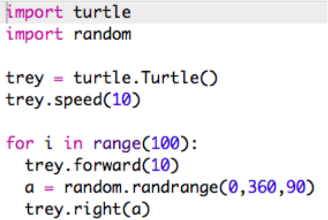
Week 10: more on loops, max design pattern, random()



```
dist = int(input('Enter distance: '))
while dist < 0:
    print('Distances cannot be negative.')
    dist = int(input('Enter distance: '))

print('The distance entered is', dist)
```

- Indefinite (while) loops allow you to repeat a block of code as long as a condition holds.

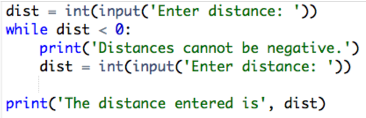


```
import turtle
import random

trey = turtle.Turtle()
trey.speed(10)

for i in range(100):
  trey.forward(10)
  a = random.randrange(0,360,90)
  trey.right(a)
```

Week 10: more on loops, max design pattern, random()



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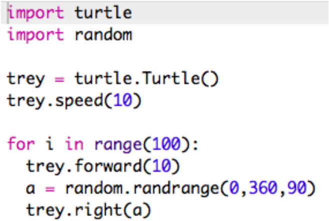
- Indefinite (while) loops allow you to repeat a block of code as long as a condition holds.
- Very useful for checking user input for correctness.



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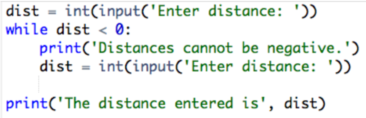
Week 10: more on loops, max design pattern, random()



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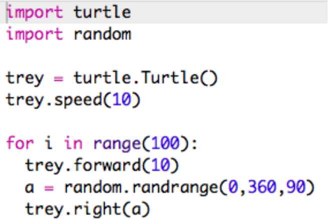

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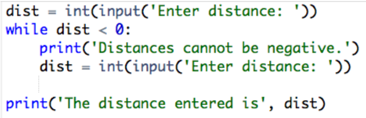
- Indefinite (while) loops allow you to repeat a block of code as long as a condition holds.
- Very useful for checking user input for correctness.
- Python's built-in random package has useful methods for generating random whole numbers and real numbers.

Week 10: more on loops, max design pattern, random()



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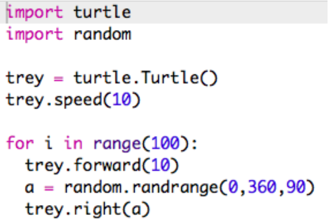

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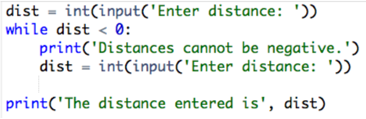

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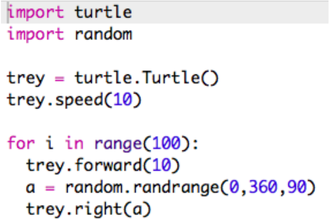

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- Very useful for checking user input for correctness.
- Python's built-in random package has useful methods for generating random whole numbers and real numbers.
- To use, must include: `import random`.
- The max design pattern provides a template for finding maximum value from a list.

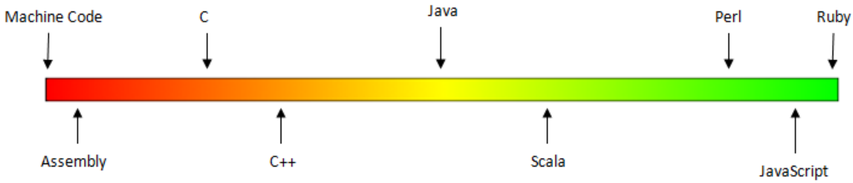
Python & Circuits Review: 10 Weeks in 10 Minutes

- Input/Output (I/O): `input()` and `print()`; pandas for CSV files
- Types:
  - Primitive: int, float, bool, string;
  - Container: lists (but not dictionaries/hashes or tuples)
- Objects: turtles (used but did not design our own)
- Loops: definite & indefinite
- Conditionals: if-elif-else
- Logical Expressions & Circuits
- Functions: parameters & returns
- Packages:
  - Built-in: turtle, math, random
  - Popular: numpy, matplotlib, pandas, folium

Today's Topics

- Design Patterns: Searching
- Python Recap
- **Machine Language**
- Machine Language: Jumps & Loops
- Binary & Hex Arithmetic

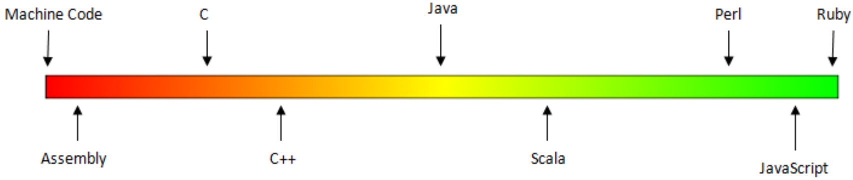
Low-Level vs. High-Level Languages



(codeCommit)

- Can view programming languages on a continuum.

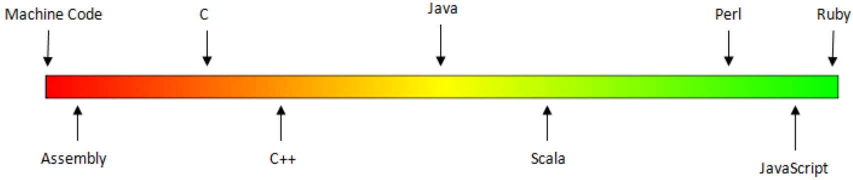
Low-Level vs. High-Level Languages



(codeCommit)

- Can view programming languages on a continuum.
- Those that directly access machine instructions & memory and have little abstraction are **low-level languages**

Low-Level vs. High-Level Languages



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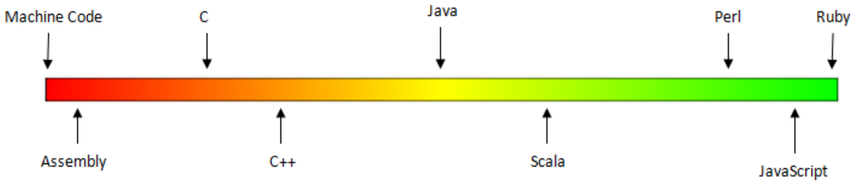
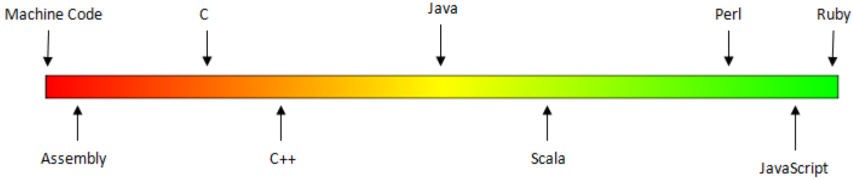


(codeCommit)

- Can view programming languages on a continuum.
- Those that directly access machine instructions & memory and have little abstraction are **low-level languages** (e.g. machine language, assembly language).
- Those that have strong abstraction (allow programming paradigms independent of the machine details, such as complex variables, functions and looping that do not translate directly into machine code) are called **high-level languages**.

Low-Level vs. High-Level Languages



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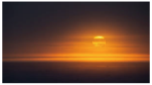
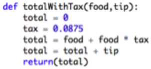
- Those that have strong abstraction (allow programming paradigms independent of the machine details, such as complex variables, functions and looping that do not translate directly into machine code) are called **high-level languages**.
- Some languages, like C, are in between– allowing both low level access and high level data structures.

Processing

Dies ist ein Blindtext. An ihm lässt sich vieles über die Schrift ablesen, in der er gesetzt ist. Auf den ersten Blick wird der Grauwert der Schriftfläche sichtbar. Dann kann man prüfen, wie gut die Schrift zu lesen ist und wie sie auf den Leser wirkt. Dies ist ein Blindtext. An ihm lässt sich





```
def totalWithTax(food,tip):
    total = 0
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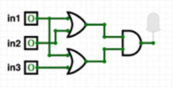
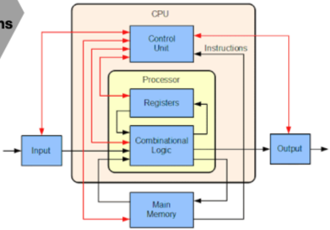
    total = food + food * tax
    total = total + tip
    return(total)
```

Data & Instructions

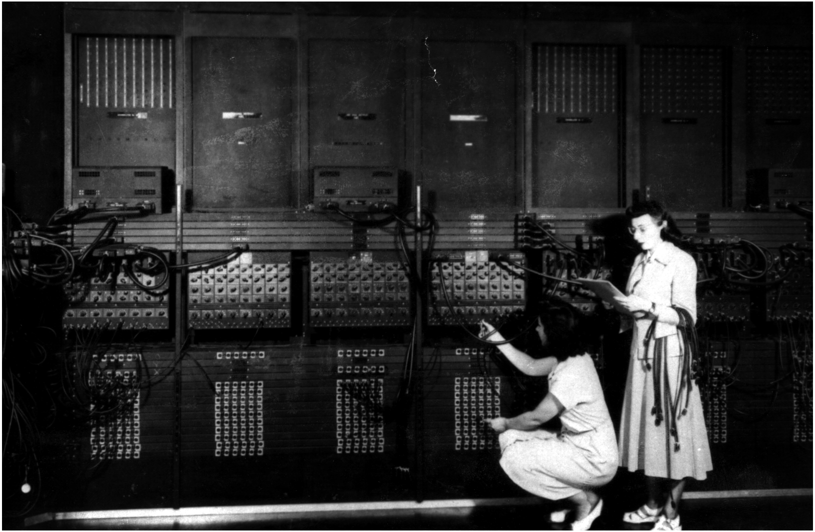
Data & Instructions



Circuits (switches)
On/Off 1/0 Logic
Billions of switches/bits

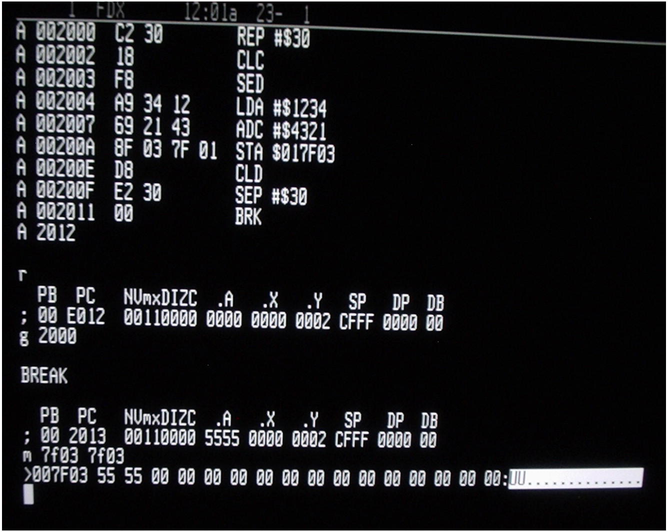


Machine Language



(Ruth Gordon & Ester Gerston programming the ENIAC, UPenn)

Machine Language



```
      I  FDX        12:01a  23-  1
A 002000  C2 30          REP #$30
A 002002  18             CLC
A 002003  F8             SED
A 002004  A9 34 12       LDA #$1234
A 002007  69 21 43       ADC #$4321
A 00200A  8F 03 7F 01    STA $017F03
A 00200E  D8             CLD
A 00200F  E2 30          SEP #$30
A 002011  00             BRK
A 2012

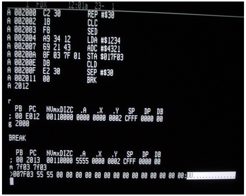

r
  PB  PC   NVmxDIZC  .A   .X   .Y   SP   DP  DB
; 00 E012  00110000 0000 0000 0002 CFFF 0000 00
g 2000

BREAK

  PB  PC   NVmxDIZC  .A   .X   .Y   SP   DP  DB
; 00 2013  00110000 5555 0000 0002 CFFF 0000 00
m 7f03 7f03
>007F03 55 55 00 00 00 00 00 00 00 00 00 00 00 00 00 00:UU..............
```

(wiki)

Machine Language



```
      1  FDX       12:01a  23-  1
A 002000  C2 30          REP #$30
A 002002  18             CLC
A 002003  F8             SED
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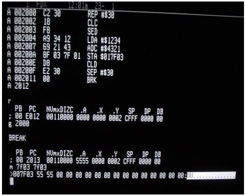
```

(wiki)

- We will be writing programs in a simplified machine language, WeMIPS.

Machine Language



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BREAK

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(wiki)

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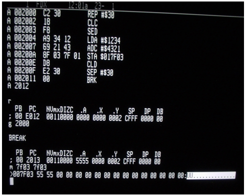
Machine Language



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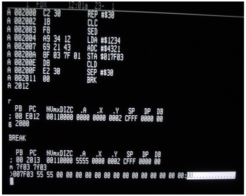
(wiki)

- We will be writing programs in a simplified machine language, WeMIPS.
- It is based on a reduced instruction set computer (RISC) design, originally developed by the MIPS Computer Systems.
- Due to its small set of commands, processors can be designed to run those commands very efficiently.

Machine Language



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(wiki)

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- It is based on a reduced instruction set computer (RISC) design, originally developed by the MIPS Computer Systems.
- Due to its small set of commands, processors can be designed to run those commands very efficiently.
- More in future architecture classes....

“Hello World!” in Simplified Machine Language

```
# Store ’Hello world!’ at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # 72 is ASCII code of ’H’
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
```

“Hello World!” in Simplified Machine Language: II

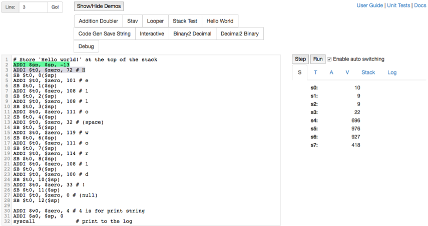
```
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
```

"Hello World!" in Simplified Machine Language: II

```
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
 syscall             # print to the log
```

WeMIPS



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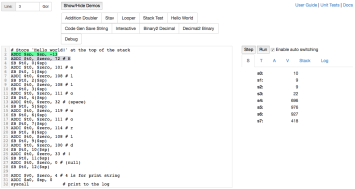
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall             # print to the log
```

```
s0:    10
s1:     9
s2:     9
s3:    22
s4:   696
s5:   976
s6:   927
s7:   418
```

(Demo with `WeMIPS`)

MIPS Commands



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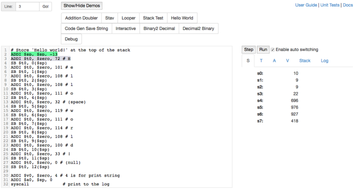
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall              # print to the log
```

s0:	10
s1:	9
s2:	9
s3:	22
s4:	696
s5:	976
s6:	927
s7:	418

- **Registers:** locations for storing information that can be quickly accessed.

MIPS Commands



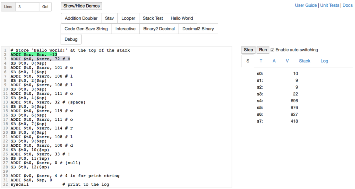
```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall            # print to the log
```

s0:	10
s1:	9
s2:	9
s3:	22
s4:	696
s5:	976
s6:	927
s7:	418

- **Registers:** locations for storing information that can be quickly accessed. Names start with '$': `$s0`, `$s1`, `$t0`, `$t1`,...

MIPS Commands



Line: 3

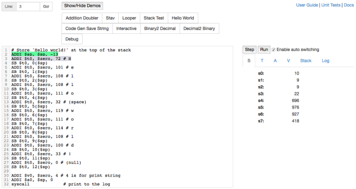
```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall             # print to the log
```

s0:	10
s1:	9
s2:	9
s3:	22
s4:	696
s5:	976
s6:	927
s7:	418

- **Registers:** locations for storing information that can be quickly accessed. Names start with '$': $s0, $s1, $t0, $t1,...
- **R Instructions:** Commands that use data in the registers:

MIPS Commands



Line: 3 Go!

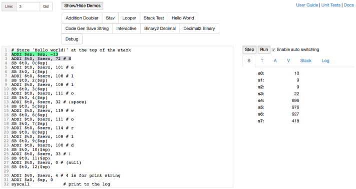
```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall             # print to the log
```

```
s0:   10
s1:    9
s2:    9
s3:   22
s4:  696
s5:  976
s6:  927
s7:  418
```

- **Registers:** locations for storing information that can be quickly accessed. Names start with '$': `$s0`, `$s1`, `$t0`, `$t1`,...
- **R Instructions:** Commands that use data in the registers:
  `add $s1, $s2, $s3`

MIPS Commands



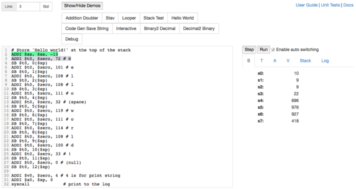
```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall             # print to the log
```

s0:	10
s1:	9
s2:	9
s3:	22
s4:	696
s5:	976
s6:	927
s7:	418

- **Registers:** locations for storing information that can be quickly accessed. Names start with '$': `$s0`, `$s1`, `$t0`, `$t1`,...
- **R Instructions:** Commands that use data in the registers: `add $s1, $s2, $s3` (Basic form: `OP rd, rs, rt`)
- **I Instructions:** instructions that also use intermediate values.

MIPS Commands



Line: 3 Go!
Show/Hide Demos
User Guide | Unit Tests | Docs
Addition Doubler | Stav | Looper | Stack Test | Hello World
Code Gen Save String | Interactive | Binary2 Decimal | Decimal2 Binary
Debug
Step | Run | ☑ Enable auto switching
S T A V Stack Log

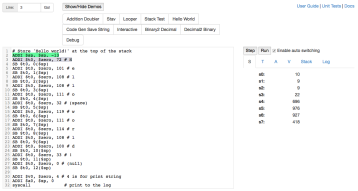
```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall             # print to the log
```

s0:	10
s1:	9
s2:	9
s3:	22
s4:	696
s5:	976
s6:	927
s7:	418

- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': `$s0`, `$s1`, `$t0`, `$t1`,...
- **R Instructions:** Commands that use data in the registers:
  `add $s1, $s2, $s3`   (Basic form: `OP rd, rs, rt`)
- **I Instructions:** instructions that also use intermediate values.
  `addi $s1, $s2, 100`

MIPS Commands



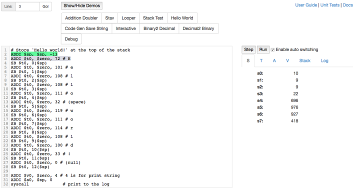
```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall             # print to the log
```

s0:	10
s1:	9
s2:	9
s3:	22
s4:	696
s5:	976
s6:	927
s7:	418

- **Registers:** locations for storing information that can be quickly accessed. Names start with '$': `$s0`, `$s1`, `$t0`, `$t1`,...
- **R Instructions:** Commands that use data in the registers: `add $s1, $s2, $s3` (Basic form: `OP rd, rs, rt`)
- **I Instructions:** instructions that also use intermediate values. `addi $s1, $s2, 100` (Basic form: `OP rd, rs, imm`)
- **J Instructions:** instructions that jump to another memory location.

MIPS Commands



```
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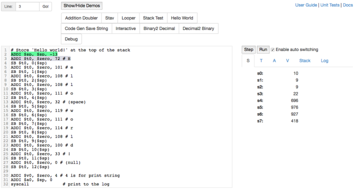
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall             # print to the log
```

s0:	10
s1:	9
s2:	9
s3:	22
s4:	696
s5:	976
s6:	927
s7:	418

- **Registers:** locations for storing information that can be quickly accessed. Names start with '$': `$s0`, `$s1`, `$t0`, `$t1`,...
- **R Instructions:** Commands that use data in the registers:
  `add $s1, $s2, $s3` (Basic form: `OP rd, rs, rt`)
- **I Instructions:** instructions that also use intermediate values.
  `addi $s1, $s2, 100` (Basic form: `OP rd, rs, imm`)
- **J Instructions:** instructions that jump to another memory location.
  `j done`

MIPS Commands



```
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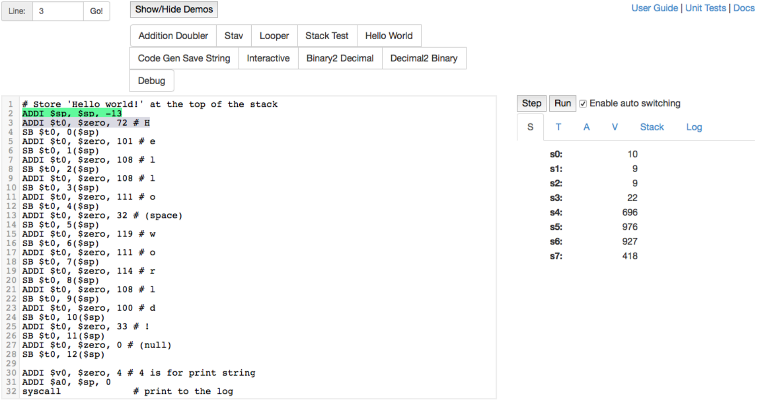
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall            # print to the log
```

s0:	10
s1:	9
s2:	9
s3:	22
s4:	696
s5:	976
s6:	927
s7:	418

- **Registers:** locations for storing information that can be quickly accessed. Names start with '$': `$s0`, `$s1`, `$t0`, `$t1`,...
- **R Instructions:** Commands that use data in the registers:
  `add $s1, $s2, $s3` (Basic form: `OP rd, rs, rt`)
- **I Instructions:** instructions that also use intermediate values.
  `addi $s1, $s2, 100` (Basic form: `OP rd, rs, imm`)
- **J Instructions:** instructions that jump to another memory location.
  `j done` (Basic form: `OP label`)

Challenge:



```
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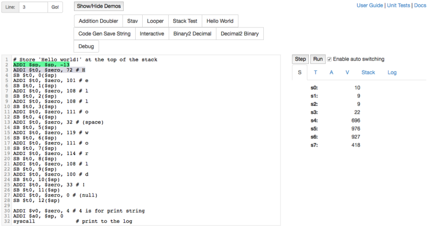
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall            # print to the log
```

s0:	10
s1:	9
s2:	9
s3:	22
s4:	696
s5:	976
s6:	927
s7:	418

Write a program that prints out the alphabet: `a b c d ... x y z`

WeMIPS



```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
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SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall             # print to the log
```

```
s0:    10
s1:     9
s2:     9
s3:    22
s4:   696
s5:   976
s6:   927
s7:   418
```

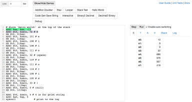
(Demo with `WeMIPS`)

Today's Topics

- Design Patterns: Searching
- Python Recap
- Machine Language
- **Machine Language: Jumps & Loops**
- Binary & Hex Arithmetic

Loops & Jumps in Machine Language

- Instead of built-in looping structures like `for` and `while`, you create your own loops by "jumping" to the location in the program.



```
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ADDI $t0, $zero, 72 # H
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ADDI $t0, $zero, 101 # e
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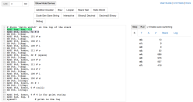
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall          # print to the log
```

```
s0:   10
s1:    8
s2:    9
s3:   22
s4:  686
s5:  976
s6:  927
s7:  418
```

Loops & Jumps in Machine Language

- Instead of built-in looping structures like `for` and `while`, you create your own loops by "jumping" to the location in the program.
- Can indicate locations by writing **labels** at the beginning of a line.



```
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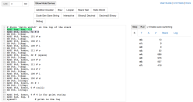
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall              # print to the log
```

s0:	10
s1:	9
s2:	9
s3:	22
s4:	686
s5:	976
s6:	927
s7:	418

Loops & Jumps in Machine Language



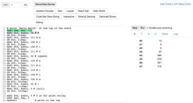
```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall            # print to the log
```

```
s0:    10
s1:     8
s2:     9
s3:    22
s4:   686
s5:   976
s6:   927
s7:   418
```

- Instead of built-in looping structures like `for` and `while`, you create your own loops by "jumping" to the location in the program.
- Can indicate locations by writing **labels** at the beginning of a line.
- Then give a command to jump to that location.

Loops & Jumps in Machine Language



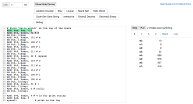
```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall            # print to the log
```

```
s0:    10
s1:     9
s2:     9
s3:    22
s4:   686
s5:   976
s6:   927
s7:   418
```

- Instead of built-in looping structures like `for` and `while`, you create your own loops by "jumping" to the location in the program.
- Can indicate locations by writing **labels** at the beginning of a line.
- Then give a command to jump to that location.
- Different kinds of jumps:

Loops & Jumps in Machine Language



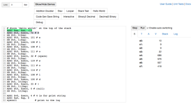
```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall            # print to the log
```

s0:	10
s1:	9
s2:	9
s3:	22
s4:	686
s5:	976
s6:	927
s7:	418

- Instead of built-in looping structures like `for` and `while`, you create your own loops by "jumping" to the location in the program.
- Can indicate locations by writing **labels** at the beginning of a line.
- Then give a command to jump to that location.
- Different kinds of jumps:
  - **Unconditional:** `j Done` will jump to the address with label `Done`.

Loops & Jumps in Machine Language



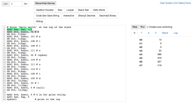
```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall            # print to the log
```

```
s0:   10
s1:    9
s2:    9
s3:   22
s4:  696
s5:  976
s6:  927
s7:  418
```

- Instead of built-in looping structures like `for` and `while`, you create your own loops by "jumping" to the location in the program.
- Can indicate locations by writing **labels** at the beginning of a line.
- Then give a command to jump to that location.
- Different kinds of jumps:
  - **Unconditional:** `j Done` will jump to the address with label `Done`.
  - **Branch if Equal:** `beq $s0 $s1 DoAgain` will jump to the address with label `DoAgain` if the registers $s0 and $s1 contain the same value.

Loops & Jumps in Machine Language



```
# Store 'Hello world!' at the top of the stack
ADDI $sp, $sp, -13
ADDI $t0, $zero, 72 # H
SB $t0, 0($sp)
ADDI $t0, $zero, 101 # e
SB $t0, 1($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 2($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 3($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 4($sp)
ADDI $t0, $zero, 32 # (space)
SB $t0, 5($sp)
ADDI $t0, $zero, 119 # w
SB $t0, 6($sp)
ADDI $t0, $zero, 111 # o
SB $t0, 7($sp)
ADDI $t0, $zero, 114 # r
SB $t0, 8($sp)
ADDI $t0, $zero, 108 # l
SB $t0, 9($sp)
ADDI $t0, $zero, 100 # d
SB $t0, 10($sp)
ADDI $t0, $zero, 33 # !
SB $t0, 11($sp)
ADDI $t0, $zero, 0 # (null)
SB $t0, 12($sp)

ADDI $v0, $zero, 4 # 4 is for print string
ADDI $a0, $sp, 0
syscall            # print to the log
```

```
s0:   10
s1:    8
s2:    9
s3:   22
s4:  686
s5:  976
s6:  927
s7:  418
```

- Instead of built-in looping structures like `for` and `while`, you create your own loops by "jumping" to the location in the program.
- Can indicate locations by writing **labels** at the beginning of a line.
- Then give a command to jump to that location.
- Different kinds of jumps:
  - **Unconditional:** `j Done` will jump to the address with label `Done`.
  - **Branch if Equal:** `beq $s0 $s1 DoAgain` will jump to the address with label `DoAgain` if the registers $s0 and $s1 contain the same value.
  - See reading for more variations.

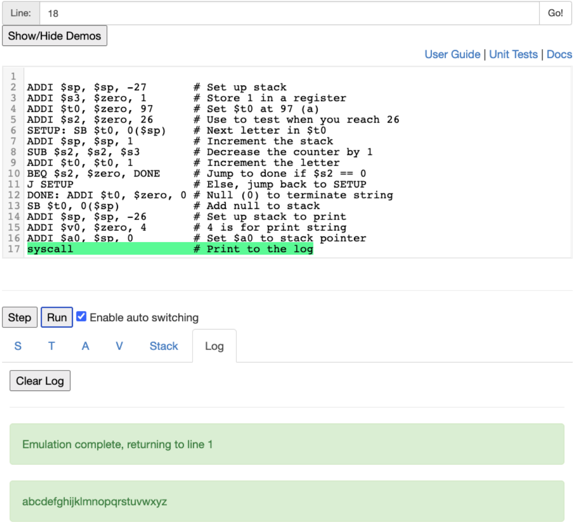
Print alphabet table in Simplified Machine Language: II

```
ADDI $sp, $sp, -27 #setup stack, 26 letters + 1 null
ADDI $t0, $zero, 97 #save ASCII of 'a' to $t0
ADDI $s2, $zero, 26 #set $s2 to be 26, track whether 26 is reached or not
SETUP:SB $t0, 0($sp) #save contents of $t0 to stack
ADDI $sp, $sp, 1 #increment the stack
ADDI $s2, $s2, -1 #subtract 1 from $s2
ADDI $t0, $t0, 1 #increment the letter
BEQ $s2, $zero, DONE
J SETUP
```

Print alphabet table in Simplified Machine Language: II

```
DONE:ADDI $t0, $zero, 0 #set null
SB $t0, 0($sp)
ADDI $sp, $sp, -26
ADDI $v0, $zero, 4 #$v0 is 4 means to print
ADDI $a0, $sp, 0 #set $a0 to stack pointer
 syscall
```

Jump Demo



```

ADDI $sp, $sp, -27        # Set up stack
ADDI $s3, $zero, 1        # Store 1 in a register
ADDI $t0, $zero, 97       # Set $t0 at 97 (a)
ADDI $s2, $zero, 26       # Use to test when you reach 26
SETUP: SB $t0, 0($sp)     # Next letter in $t0
ADDI $sp, $sp, 1          # Increment the stack
SUB $s2, $s2, $s3         # Decrease the counter by 1
ADDI $t0, $t0, 1          # Increment the letter
BEQ $s2, $zero, DONE      # Jump to done if $s2 == 0
J SETUP                   # Else, jump back to SETUP
DONE: ADDI $t0, $zero, 0 # Null (0) to terminate string
SB $t0, 0($sp)            # Add null to stack
ADDI $sp, $sp, -26        # Set up stack to print
ADDI $v0, $zero, 4        # 4 is for print string
ADDI $a0, $sp, 0          # Set $a0 to stack pointer
syscall                   # Print to the log
```

```
Emulation complete, returning to line 1
```

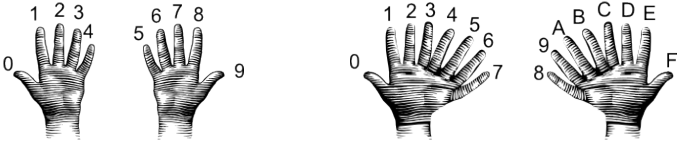
```
abcdefghijklmnopqrstuvwxyz
```

(Demo with WeMIPS)

Today's Topics

- Design Patterns: Searching
- Python Recap
- Machine Language
- Machine Language: Jumps & Loops
- **Binary & Hex Arithmetic**

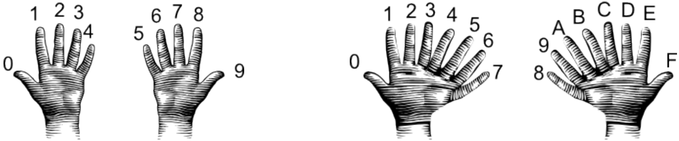
Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.

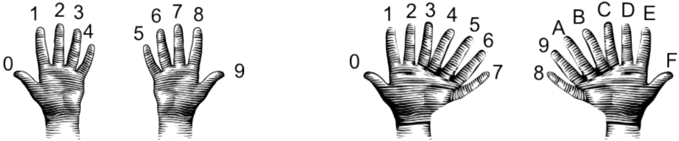
Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
  - Convert second digit to decimal and add to total.

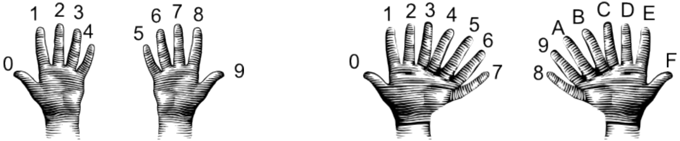
Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
  - Convert second digit to decimal and add to total.
  - Example: what is 2A as a decimal number?

Hexadecimal to Decimal: Converting Between Bases



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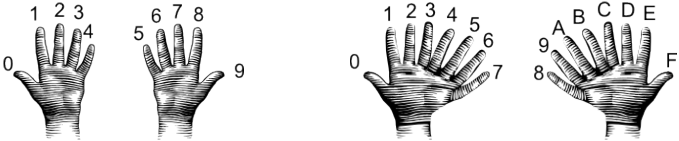
- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
  - Convert second digit to decimal and add to total.
  - Example: what is 2A as a decimal number?

    `2 in decimal is 2.`

Hexadecimal to Decimal: Converting Between Bases



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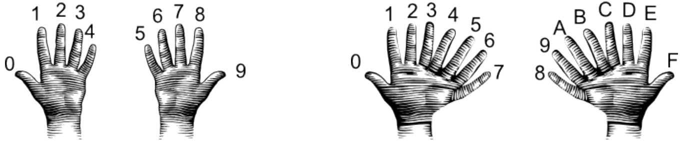
- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
  - Convert second digit to decimal and add to total.
  - Example: what is 2A as a decimal number?

    `2 in decimal is 2. 2*16 is 32.`

Hexadecimal to Decimal: Converting Between Bases

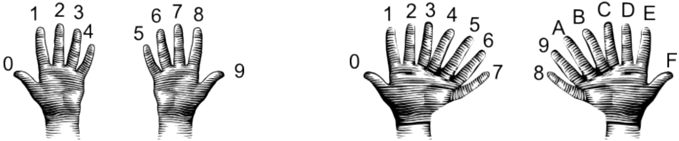


(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
  - Convert second digit to decimal and add to total.
  - Example: what is 2A as a decimal number?

```
2 in decimal is 2. 2*16 is 32.
A in decimal digits is 10.
```

Hexadecimal to Decimal: Converting Between Bases

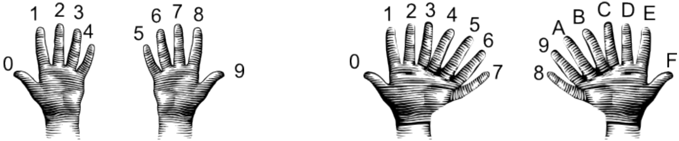


(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
  - Convert second digit to decimal and add to total.
  - Example: what is 2A as a decimal number?

    ```
    2 in decimal is 2. 2*16 is 32.
    A in decimal digits is 10.
    32 + 10 is 42.
    ```

Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
  - Convert second digit to decimal and add to total.
  - Example: what is 2A as a decimal number?

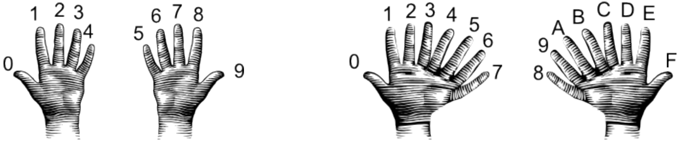
    `2 in decimal is 2. 2*16 is 32.`

    `A in decimal digits is 10.`

    `32 + 10 is 42.`

    Answer is 42.
  - Example: what is 99 as a decimal number?

Hexadecimal to Decimal: Converting Between Bases



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- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
  - Convert second digit to decimal and add to total.
  - Example: what is 2A as a decimal number?

    `2 in decimal is 2. 2*16 is 32.`

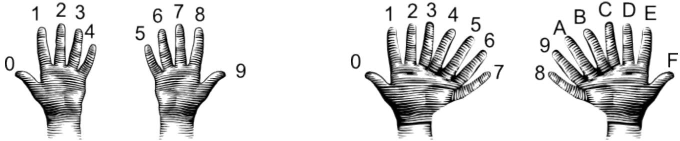
    `A in decimal digits is 10.`

    `32 + 10 is 42.`

    Answer is 42.
  - Example: what is 99 as a decimal number?

    `9 in decimal is 9.`

Hexadecimal to Decimal: Converting Between Bases



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- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
  - Convert second digit to decimal and add to total.
  - Example: what is 2A as a decimal number?

    `2 in decimal is 2. 2*16 is 32.`

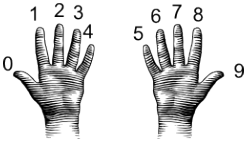
    `A in decimal digits is 10.`

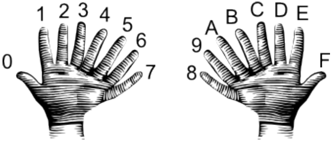
    `32 + 10 is 42.`

    Answer is 42.
  - Example: what is 99 as a decimal number?

    `9 in decimal is 9. 9*16 is 144.`

Hexadecimal to Decimal: Converting Between Bases





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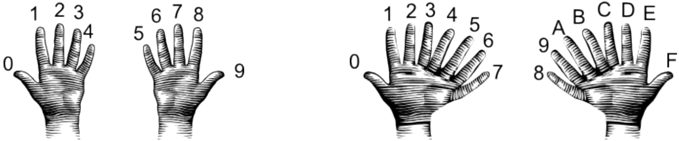
- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
  - Convert second digit to decimal and add to total.
  - Example: what is 2A as a decimal number?

    ```
    2 in decimal is 2. 2*16 is 32.
    A in decimal digits is 10.
    32 + 10 is 42.
    ```

    Answer is 42.
  - Example: what is 99 as a decimal number?

    ```
    9 in decimal is 9. 9*16 is 144.
    9 in decimal digits is 9
    ```

Hexadecimal to Decimal: Converting Between Bases



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- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
  - Convert second digit to decimal and add to total.
  - Example: what is 2A as a decimal number?

    `2 in decimal is 2. 2*16 is 32.`

    `A in decimal digits is 10.`

    `32 + 10 is 42.`

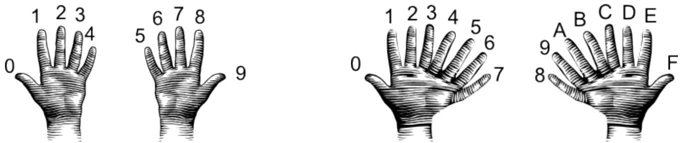
    Answer is 42.
  - Example: what is 99 as a decimal number?

    `9 in decimal is 9. 9*16 is 144.`

    `9 in decimal digits is 9`

    `144 + 9 is 153.`

Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):
  - Convert first digit to decimal and multiple by 16.
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  - Example: what is 2A as a decimal number?

    `2 in decimal is 2. 2*16 is 32.`

    `A in decimal digits is 10.`

    `32 + 10 is 42.`

    Answer is 42.
  - Example: what is 99 as a decimal number?

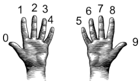
    `9 in decimal is 9. 9*16 is 144.`

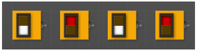
    `9 in decimal digits is 9`

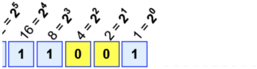
    `144 + 9 is 153.`

    Answer is 153.

Decimal to Binary: Converting Between Bases



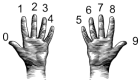


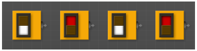


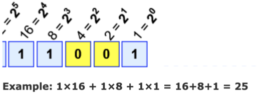
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

- From decimal to binary:
  - Divide by 128 ($= 2^7$). Quotient is the first digit.

Decimal to Binary: Converting Between Bases







Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

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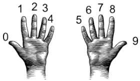

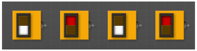

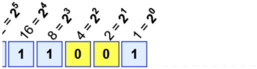

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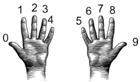

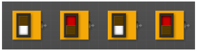

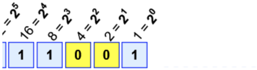

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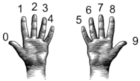

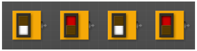

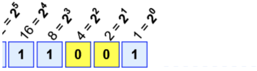

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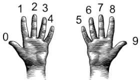

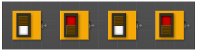

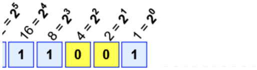

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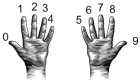

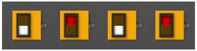

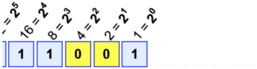

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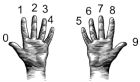

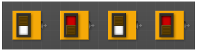

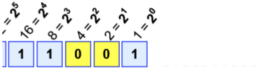

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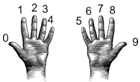

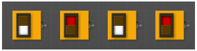

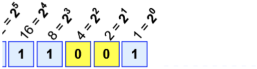

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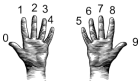

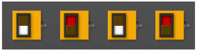

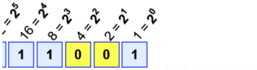

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130/128 is 1 rem 2.
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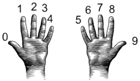

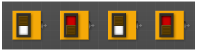

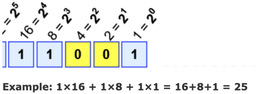

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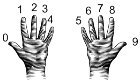

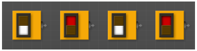

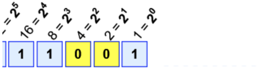

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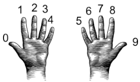

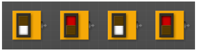

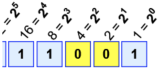

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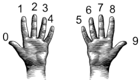

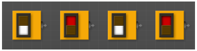

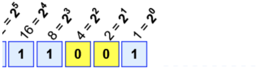

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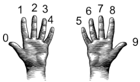

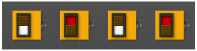

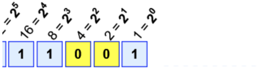

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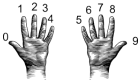

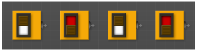

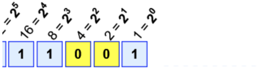

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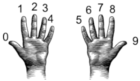

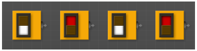

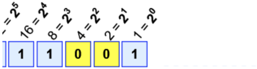

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130/128 is 1 rem 2. First digit is 1:    1...
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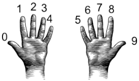
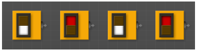
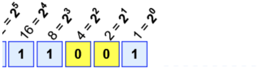
Decimal to Binary: Converting Between Bases







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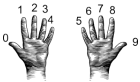

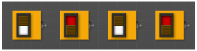

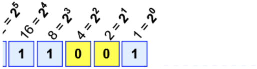

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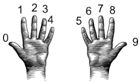

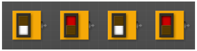

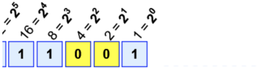

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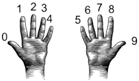

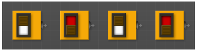

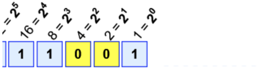

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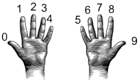

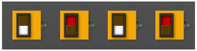

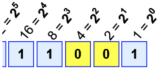

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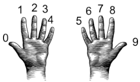

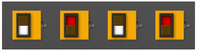

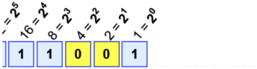

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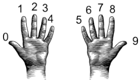

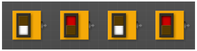

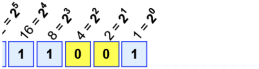

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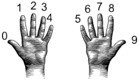

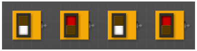

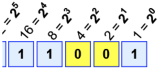

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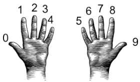

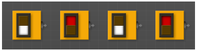

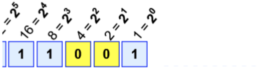

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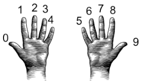

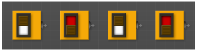

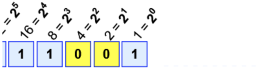

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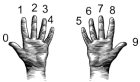

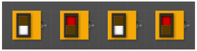

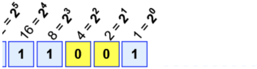

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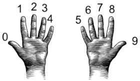

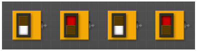

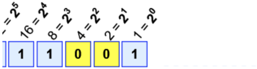

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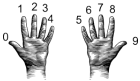
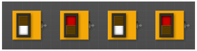
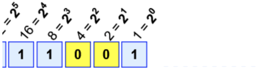




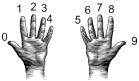


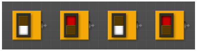
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

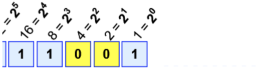
- From decimal to binary:
  - Divide by 128 ($= 2^7$). Quotient is the first digit.
  - Divide remainder by 64 ($= 2^6$). Quotient is the next digit.
  - Divide remainder by 32 ($= 2^5$). Quotient is the next digit.
  - Divide remainder by 16 ($= 2^4$). Quotient is the next digit.
  - Divide remainder by 8 ($= 2^3$). Quotient is the next digit.
  - Divide remainder by 4 ($= 2^2$). Quotient is the next digit.
  - Divide remainder by 2 ($= 2^1$). Quotient is the next digit.
  - The last remainder is the last digit.
  - Example: what is 130 in binary notation?

```
130/128 is 1 rem 2. First digit is 1:    1...
2/64 is 0 rem 2. Next digit is 0:        10...
2/32 is 0 rem 2. Next digit is 0:        100...
2/16 is 0 rem 2. Next digit is 0:        1000...
2/8 is 0 rem 2. Next digit is 0:         10000...
2/4 is 0 remainder 2. Next digit is 0:   100000...
2/2 is 1 rem 0. Next digit is 1:         1000001...
Adding the last remainder:               10000010
```

Decimal to Binary: Converting Between Bases







Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

- From decimal to binary:
  - Divide by 128 ($= 2^7$). Quotient is the first digit.
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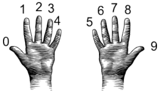
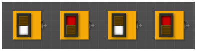
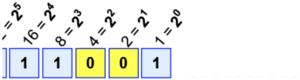
  - The last remainder is the last digit.
  - Example: what is 130 in binary notation?

```
130/128 is 1 rem 2. First digit is 1:     1...
2/64 is 0 rem 2. Next digit is 0:         10...
2/32 is 0 rem 2. Next digit is 0:         100...
2/16 is 0 rem 2. Next digit is 0:         1000...
2/8 is 0 rem 2. Next digit is 0:          10000...
2/4 is 0 remainder 2. Next digit is 0:    100000...
2/2 is 1 rem 0. Next digit is 1:          1000001...
Adding the last remainder:                10000010
```

Decimal to Binary: Converting Between Bases



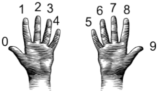


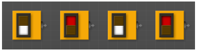


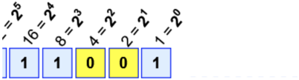
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

- Example: what is 99 in binary notation?

Decimal to Binary: Converting Between Bases





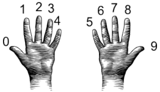


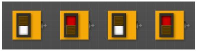
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

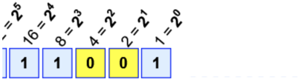
- Example: what is 99 in binary notation?

```
99/128 is 0 rem 99.
```

Decimal to Binary: Converting Between Bases





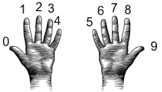


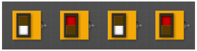
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

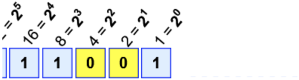
- Example: what is 99 in binary notation?

```
99/128 is 0 rem 99. First digit is 0:
```

Decimal to Binary: Converting Between Bases





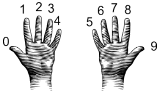


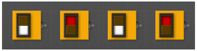
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

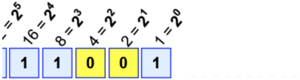
- Example: what is 99 in binary notation?

```
99/128 is 0 rem 99. First digit is 0:    0...
99/64 is 1 rem 35.
```

Decimal to Binary: Converting Between Bases







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- Example: what is 99 in binary notation?

```
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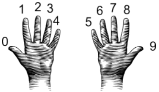
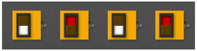
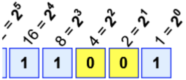
```

Decimal to Binary: Converting Between Bases







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- Example: what is 99 in binary notation?

```
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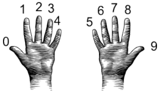
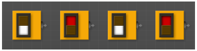
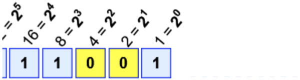
```

Decimal to Binary: Converting Between Bases







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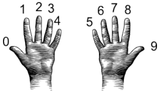
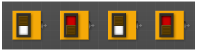
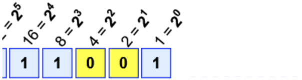
- Example: what is 99 in binary notation?

```
99/128 is 0 rem 99. First digit is 0:    0...
99/64 is 1 rem 35. Next digit is 1:      01...
35/32 is 1 rem 3.
```

Decimal to Binary: Converting Between Bases







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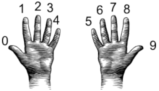
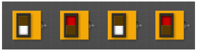
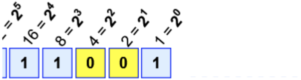
```

Decimal to Binary: Converting Between Bases





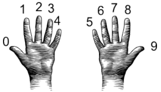


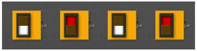
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

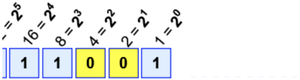
- Example: what is 99 in binary notation?

```
99/128 is 0 rem 99. First digit is 0:    0...
99/64 is 1 rem 35. Next digit is 1:      01...
35/32 is 1 rem 3. Next digit is 1:       011...
```

Decimal to Binary: Converting Between Bases







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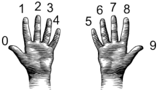
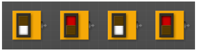
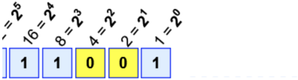
  35/32 is 1 rem 3. Next digit is 1: 011...

  3/16 is 0 rem 3.

Decimal to Binary: Converting Between Bases







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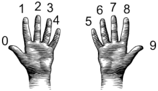

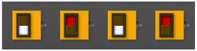

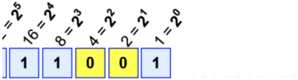

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```
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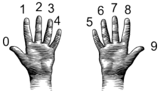
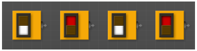
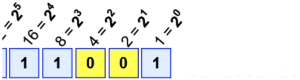
```

Decimal to Binary: Converting Between Bases







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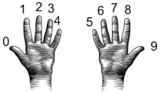
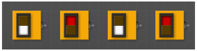
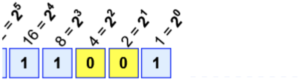
```

Decimal to Binary: Converting Between Bases







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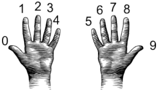
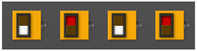
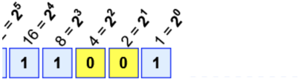
```

Decimal to Binary: Converting Between Bases







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```
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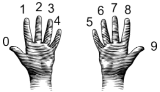
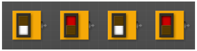
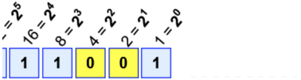
35/32 is 1 rem 3. Next digit is 1:       011...
3/16 is 0 rem 3. Next digit is 0:        0110...
3/8 is 0 rem 3. Next digit is 0:         01100...
```

Decimal to Binary: Converting Between Bases







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```
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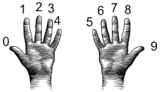
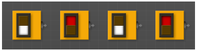
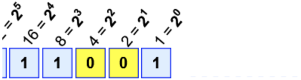
35/32 is 1 rem 3. Next digit is 1:       011...
3/16 is 0 rem 3. Next digit is 0:        0110...
3/8 is 0 rem 3. Next digit is 0:         01100...
3/4 is 0 remainder 3.
```

Decimal to Binary: Converting Between Bases





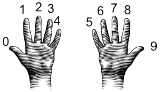


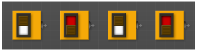
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

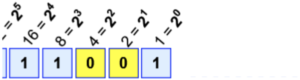
- Example: what is 99 in binary notation?

```
99/128 is 0 rem 99. First digit is 0:     0...
99/64 is 1 rem 35. Next digit is 1:       01...
35/32 is 1 rem 3. Next digit is 1:        011...
3/16 is 0 rem 3. Next digit is 0:         0110...
3/8 is 0 rem 3. Next digit is 0:          01100...
3/4 is 0 remainder 3. Next digit is 0:
```

Decimal to Binary: Converting Between Bases







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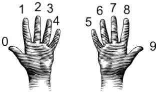

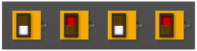

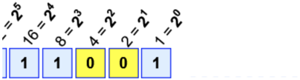

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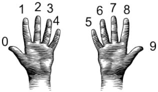
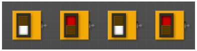
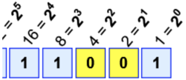
Decimal to Binary: Converting Between Bases







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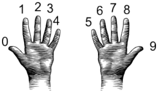
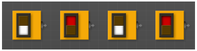
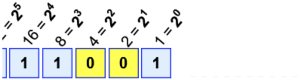
Decimal to Binary: Converting Between Bases







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3/8 is 0 rem 3. Next digit is 0:           01100...
3/4 is 0 remainder 3. Next digit is 0:     011000...
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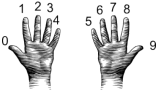
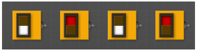
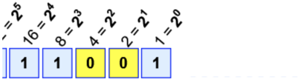
```

Decimal to Binary: Converting Between Bases







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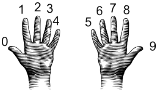
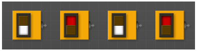
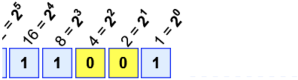
3/4 is 0 remainder 3. Next digit is 0:     011000...
3/2 is 1 rem 1. Next digit is 1:           0110001...
Adding the last remainder:                 01100011
```

Decimal to Binary: Converting Between Bases







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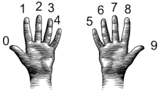
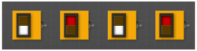
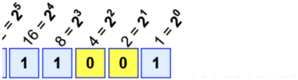
3/4 is 0 remainder 3. Next digit is 0:    011000...
3/2 is 1 rem 1. Next digit is 1:          0110001...
Adding the last remainder:                01100011
```

Answer is 1100011.

Binary to Decimal: Converting Between Bases







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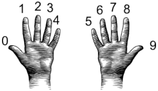
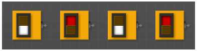
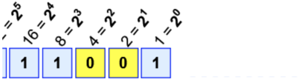
- From binary to decimal:
  - Set sum = last digit.

Binary to Decimal: Converting Between Bases







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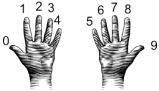

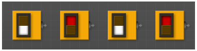

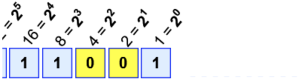

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- From binary to decimal:
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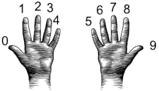
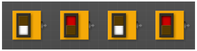
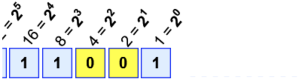
Binary to Decimal: Converting Between Bases







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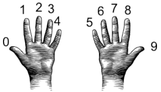
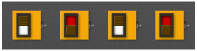
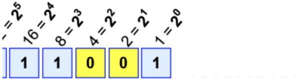
Binary to Decimal: Converting Between Bases







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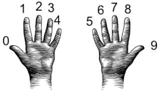

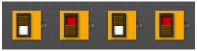

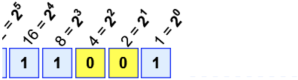

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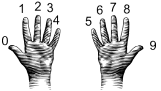
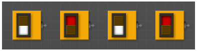
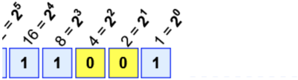
  - Multiply next digit by $8 = 2^3$. Add to sum.
  - Multiply next digit by $16 = 2^4$. Add to sum.
  - Multiply next digit by $32 = 2^5$. Add to sum.

Binary to Decimal: Converting Between Bases







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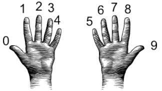
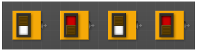
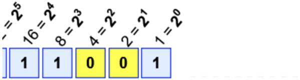
  - Multiply next digit by $16 = 2^4$. Add to sum.
  - Multiply next digit by $32 = 2^5$. Add to sum.
  - Multiply next digit by $64 = 2^6$. Add to sum.

Binary to Decimal: Converting Between Bases







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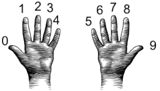
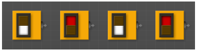
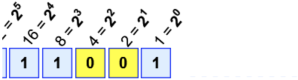
  - Multiply next digit by $8 = 2^3$. Add to sum.
  - Multiply next digit by $16 = 2^4$. Add to sum.
  - Multiply next digit by $32 = 2^5$. Add to sum.
  - Multiply next digit by $64 = 2^6$. Add to sum.
  - Multiply next digit by $128 = 2^7$. Add to sum.

Binary to Decimal: Converting Between Bases







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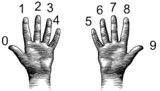
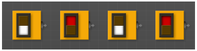
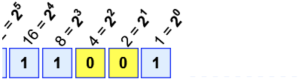
  - Multiply next digit by $8 = 2^3$. Add to sum.
  - Multiply next digit by $16 = 2^4$. Add to sum.
  - Multiply next digit by $32 = 2^5$. Add to sum.
  - Multiply next digit by $64 = 2^6$. Add to sum.
  - Multiply next digit by $128 = 2^7$. Add to sum.
  - Sum is the decimal number.

Binary to Decimal: Converting Between Bases







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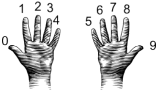
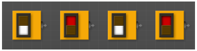
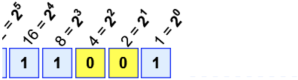
  - Multiply next digit by $8 = 2^3$. Add to sum.
  - Multiply next digit by $16 = 2^4$. Add to sum.
  - Multiply next digit by $32 = 2^5$. Add to sum.
  - Multiply next digit by $64 = 2^6$. Add to sum.
  - Multiply next digit by $128 = 2^7$. Add to sum.
  - Sum is the decimal number.
  - Example: What is 111101 in decimal?

```
Sum starts with:
```

Binary to Decimal: Converting Between Bases





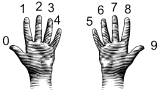


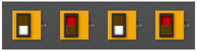
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

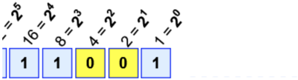
- From binary to decimal:
  - Set sum = last digit.
  - Multiply next digit by $2 = 2^1$. Add to sum.
  - Multiply next digit by $4 = 2^2$. Add to sum.
  - Multiply next digit by $8 = 2^3$. Add to sum.
  - Multiply next digit by $16 = 2^4$. Add to sum.
  - Multiply next digit by $32 = 2^5$. Add to sum.
  - Multiply next digit by $64 = 2^6$. Add to sum.
  - Multiply next digit by $128 = 2^7$. Add to sum.
  - Sum is the decimal number.
  - Example: What is 111101 in decimal?

```
Sum starts with:            1
0*2 = 0.  Add 0 to sum:
```

Binary to Decimal: Converting Between Bases







Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

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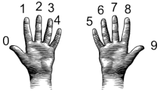
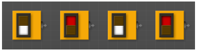
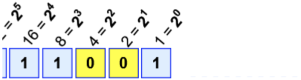
  - Multiply next digit by $64 = 2^6$. Add to sum.
  - Multiply next digit by $128 = 2^7$. Add to sum.
  - Sum is the decimal number.
  - Example: What is 111101 in decimal?

```
Sum starts with:            1
0*2 = 0.   Add 0 to sum:    1
```

Binary to Decimal: Converting Between Bases







Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

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  - Set sum $=$ last digit.
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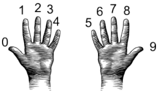
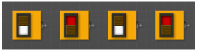
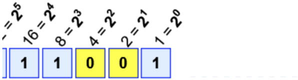
  - Multiply next digit by $8 = 2^3$. Add to sum.
  - Multiply next digit by $16 = 2^4$. Add to sum.
  - Multiply next digit by $32 = 2^5$. Add to sum.
  - Multiply next digit by $64 = 2^6$. Add to sum.
  - Multiply next digit by $128 = 2^7$. Add to sum.
  - Sum is the decimal number.
  - Example: What is 111101 in decimal?

```
Sum starts with:          1
0*2 = 0.  Add 0 to sum:   1
1*4 = 4.  Add 4 to sum:
```

Binary to Decimal: Converting Between Bases







Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

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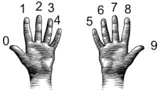
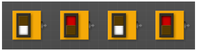
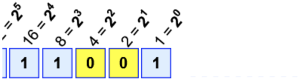
  - Multiply next digit by $16 = 2^4$. Add to sum.
  - Multiply next digit by $32 = 2^5$. Add to sum.
  - Multiply next digit by $64 = 2^6$. Add to sum.
  - Multiply next digit by $128 = 2^7$. Add to sum.
  - Sum is the decimal number.
  - Example: What is 111101 in decimal?

```
Sum starts with:             1
0*2 = 0.   Add 0 to sum:     1
1*4 = 4.   Add 4 to sum:     5
```

Binary to Decimal: Converting Between Bases







Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

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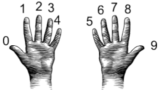
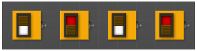
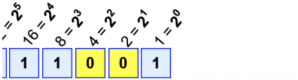
  - Multiply next digit by $32 = 2^5$. Add to sum.
  - Multiply next digit by $64 = 2^6$. Add to sum.
  - Multiply next digit by $128 = 2^7$. Add to sum.
  - Sum is the decimal number.
  - Example: What is 111101 in decimal?

```
Sum starts with:             1
0*2 = 0.  Add 0 to sum:      1
1*4 = 4.  Add 4 to sum:      5
1*8 = 8.  Add 8 to sum:
```

Binary to Decimal: Converting Between Bases







Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

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  - Multiply next digit by $16 = 2^4$. Add to sum.
  - Multiply next digit by $32 = 2^5$. Add to sum.
  - Multiply next digit by $64 = 2^6$. Add to sum.
  - Multiply next digit by $128 = 2^7$. Add to sum.
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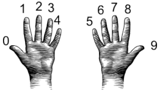
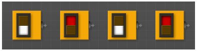
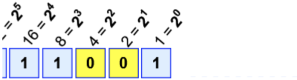
  - Example: What is 111101 in decimal?

```
Sum starts with:          1
0*2 = 0.  Add 0 to sum:   1
1*4 = 4.  Add 4 to sum:   5
1*8 = 8.  Add 8 to sum:   13
```

Binary to Decimal: Converting Between Bases







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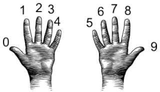
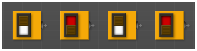
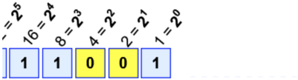
  - Multiply next digit by $64 = 2^6$. Add to sum.
  - Multiply next digit by $128 = 2^7$. Add to sum.
  - Sum is the decimal number.
  - Example: What is 111101 in decimal?

```
Sum starts with:            1
0*2 = 0.  Add 0 to sum:     1
1*4 = 4.  Add 4 to sum:     5
1*8 = 8.  Add 8 to sum:     13
1*16 = 16.  Add 16 to sum:
```

Binary to Decimal: Converting Between Bases







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```
Sum starts with:            1
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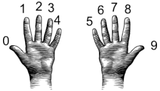
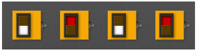
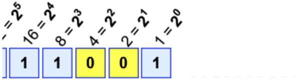
1*4 = 4.  Add 4 to sum:     5
1*8 = 8.  Add 8 to sum:     13
1*16 = 16.  Add 16 to sum:  29
```

Binary to Decimal: Converting Between Bases







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```
Sum starts with:            1
0*2 = 0.   Add 0 to sum:    1
1*4 = 4.   Add 4 to sum:    5
1*8 = 8.   Add 8 to sum:    13
1*16 = 16.  Add 16 to sum:  29
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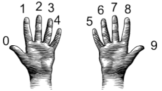
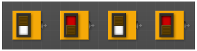
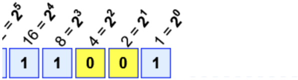
```

Binary to Decimal: Converting Between Bases







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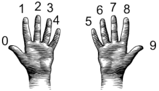
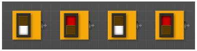
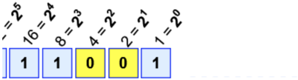
```
Sum starts with:            1
0*2 = 0.  Add 0 to sum:     1
1*4 = 4.  Add 4 to sum:     5
1*8 = 8.  Add 8 to sum:     13
1*16 = 16.  Add 16 to sum:  29
1*32 = 32.  Add 32 to sum:  61
```

Binary to Decimal: Converting Between Bases







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  - Multiply next digit by $64 = 2^6$. Add to sum.
  - Multiply next digit by $128 = 2^7$. Add to sum.
  - Sum is the decimal number.
  - Example: What is 111101 in decimal?

```
Sum starts with:            1
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1*4 = 4.   Add 4 to sum:    5
1*8 = 8.   Add 8 to sum:    13
1*16 = 16.  Add 16 to sum:  29
1*32 = 32.  Add 32 to sum:  61
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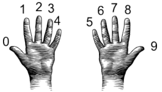
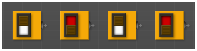
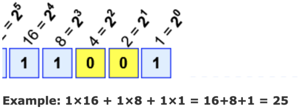
Binary to Decimal: Converting Between Bases





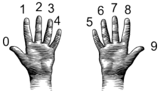


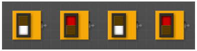
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

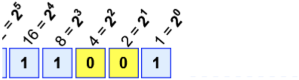
- Example: What is 10100100 in decimal?

  `Sum starts with:`

Binary to Decimal: Converting Between Bases





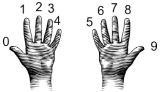


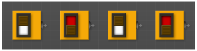
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

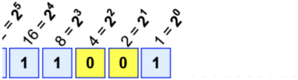
- Example: What is 10100100 in decimal?

```
Sum starts with:              0
0*2 = 0.  Add 0 to sum:
```

Binary to Decimal: Converting Between Bases





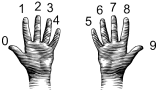


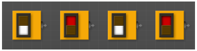
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

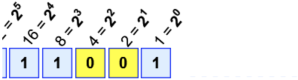
- Example: What is 10100100 in decimal?

```
Sum starts with:            0
0*2 = 0.  Add 0 to sum:     0
```

Binary to Decimal: Converting Between Bases





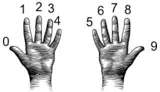


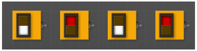
Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

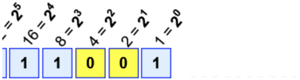
- Example: What is 10100100 in decimal?

```
Sum starts with:                0
0*2 = 0.   Add 0 to sum:        0
1*4 = 4.   Add 4 to sum:
```

Binary to Decimal: Converting Between Bases







Example: 1×16 + 1×8 + 1×1 = 16+8+1 = 25

- Example: What is 10100100 in decimal?

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```

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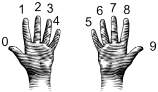

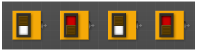

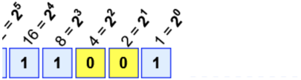

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```

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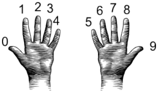

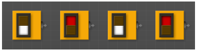

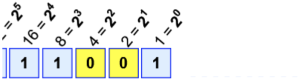

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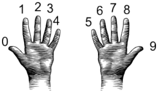

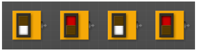

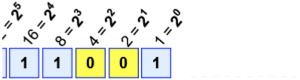

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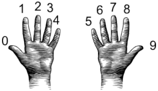
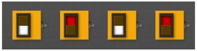
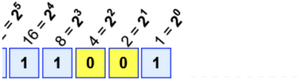
0*8 = 0.  Add 0 to sum:     4
0*16 = 0.  Add 0 to sum:
```

Binary to Decimal: Converting Between Bases







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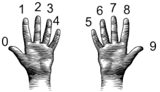
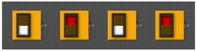
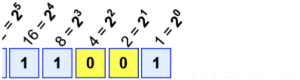
```

Binary to Decimal: Converting Between Bases







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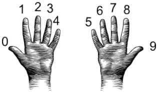
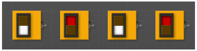
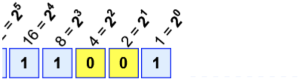
```
Sum starts with:              0
0*2 = 0.   Add 0 to sum:      0
1*4 = 4.   Add 4 to sum:      4
0*8 = 0.   Add 0 to sum:      4
0*16 = 0.   Add 0 to sum:     4
1*32 = 32.   Add 32 to sum:
```

Binary to Decimal: Converting Between Bases







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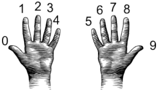
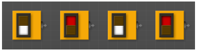
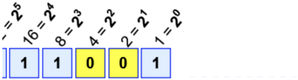
```
Sum starts with:            0
0*2 = 0.   Add 0 to sum:    0
1*4 = 4.   Add 4 to sum:    4
0*8 = 0.   Add 0 to sum:    4
0*16 = 0.   Add 0 to sum:   4
1*32 = 32.   Add 32 to sum: 36
```

Binary to Decimal: Converting Between Bases







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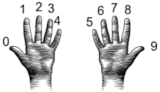
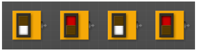
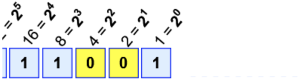
0*8 = 0.   Add 0 to sum:     4
0*16 = 0.   Add 0 to sum:    4
1*32 = 32.   Add 32 to sum:  36
0*64 = 0.   Add 0 to sum:
```

Binary to Decimal: Converting Between Bases







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0*64 = 0.   Add 0 to sum:     36
```

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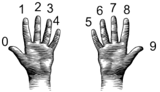

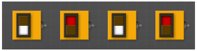

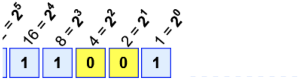

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```
Sum starts with:               0
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1*4 = 4.  Add 4 to sum:        4
0*8 = 0.  Add 0 to sum:        4
0*16 = 0.  Add 0 to sum:       4
1*32 = 32.  Add 32 to sum:     36
0*64 = 0.  Add 0 to sum:       36
1*128 = 0.  Add 128 to sum:
```

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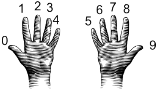

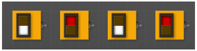

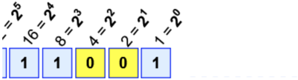

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```
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1*4 = 4.   Add 4 to sum:       4
0*8 = 0.   Add 0 to sum:       4
0*16 = 0.   Add 0 to sum:      4
1*32 = 32.   Add 32 to sum:    36
0*64 = 0.   Add 0 to sum:      36
1*128 = 0.   Add 128 to sum:   164
```

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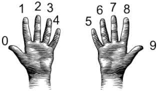

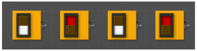

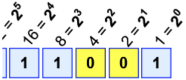

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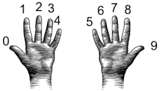
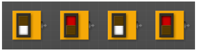
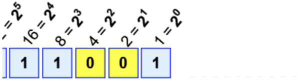
0*16 = 0.   Add 0 to sum:       4
1*32 = 32.   Add 32 to sum:     36
0*64 = 0.   Add 0 to sum:       36
1*128 = 0.   Add 128 to sum:    164
```

The answer is 164.

Design Challenge: Incrementers







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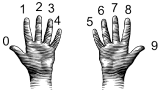
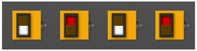
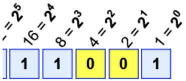
- Simplest arithmetic: add one ("increment") a variable.

Design Challenge: Incrementers







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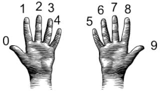

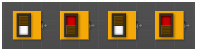

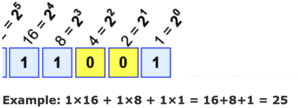

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def addOne(n):
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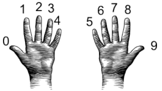
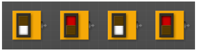
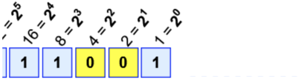
```

Design Challenge: Incrementers







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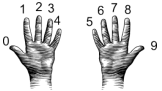
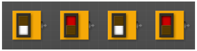
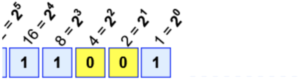
- Challenge: Write an algorithm for incrementing numbers expressed as words.

Design Challenge: Incrementers







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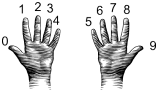
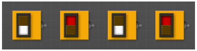
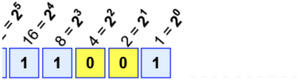
```

- Challenge: Write an algorithm for incrementing numbers expressed as words.
  Example: `"forty one"` → `"forty two"`

Design Challenge: Incrementers







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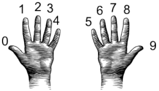
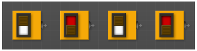
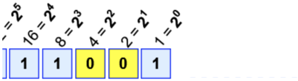
  Example: `"forty one"` → `"forty two"`

  Hint: Convert to numbers, increment, and convert back to strings.

Design Challenge: Incrementers







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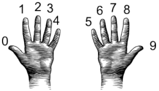
- Example: Increment a decimal number:

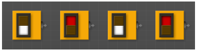
```
def addOne(n):
    m = n+1
    return(m)
```

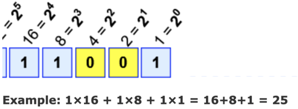
- Challenge: Write an algorithm for incrementing numbers expressed as words.
  Example: "forty one" → "forty two"

  Hint: Convert to numbers, increment, and convert back to strings.
- Challenge: Write an algorithm for incrementing binary numbers.

Design Challenge: Incrementers







- Simplest arithmetic: add one ("increment") a variable.
- Example: Increment a decimal number:

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- Challenge: Write an algorithm for incrementing numbers expressed as words.
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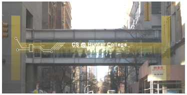
  Example: `"1001"` → `"1010"`

Recap



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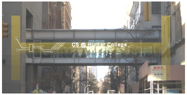

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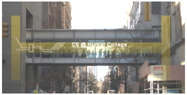

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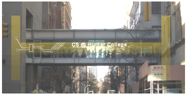

- Searching through data is a common task– built-in functions and standard design patterns for this.
- Programming languages can be classified by the level of abstraction and direct access to data.
- WeMIPS simplified machine language
- Converting between Bases

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- Past exams available on webpage (includes answer keys).

Exam Options

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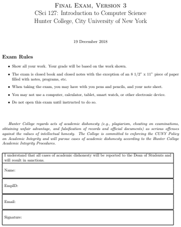

Final Exam, Version 3
CSci 127: Introduction to Computer Science
Hunter College, City University of New York

19 December 2018

Exam Rules

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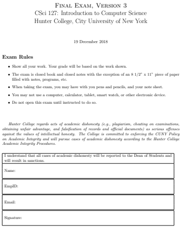

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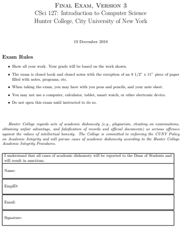

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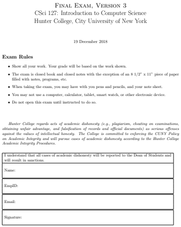

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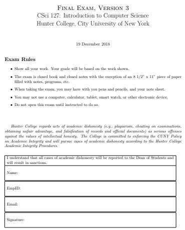

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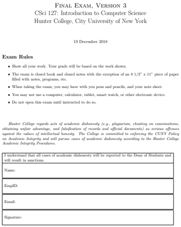

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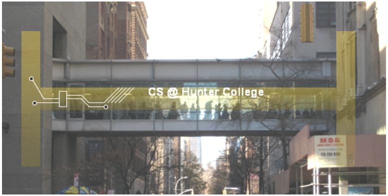
Weekly Reminders!



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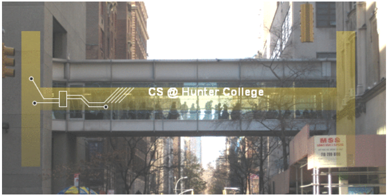

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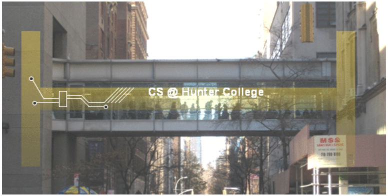

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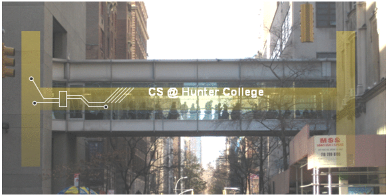

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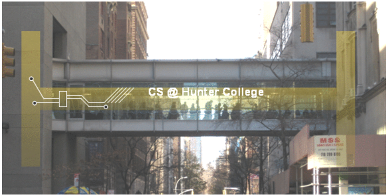

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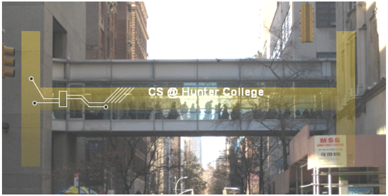

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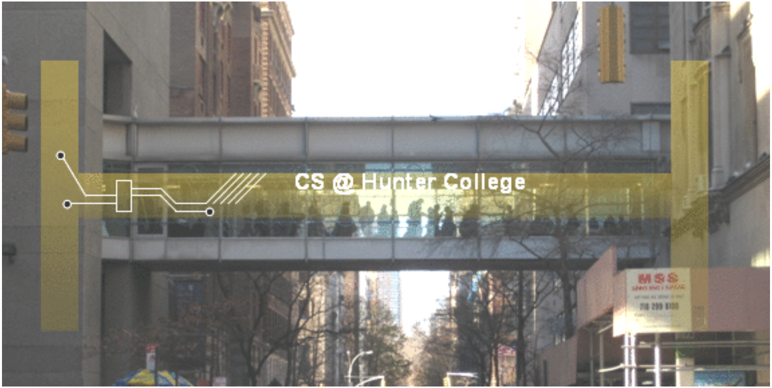
Lecture Slips & Writing Boards



- Hand your lecture slip to a UTA.
- Return writing boards as you leave.