IT5001 Software Development Fundamentals

8. Sequences Contd.

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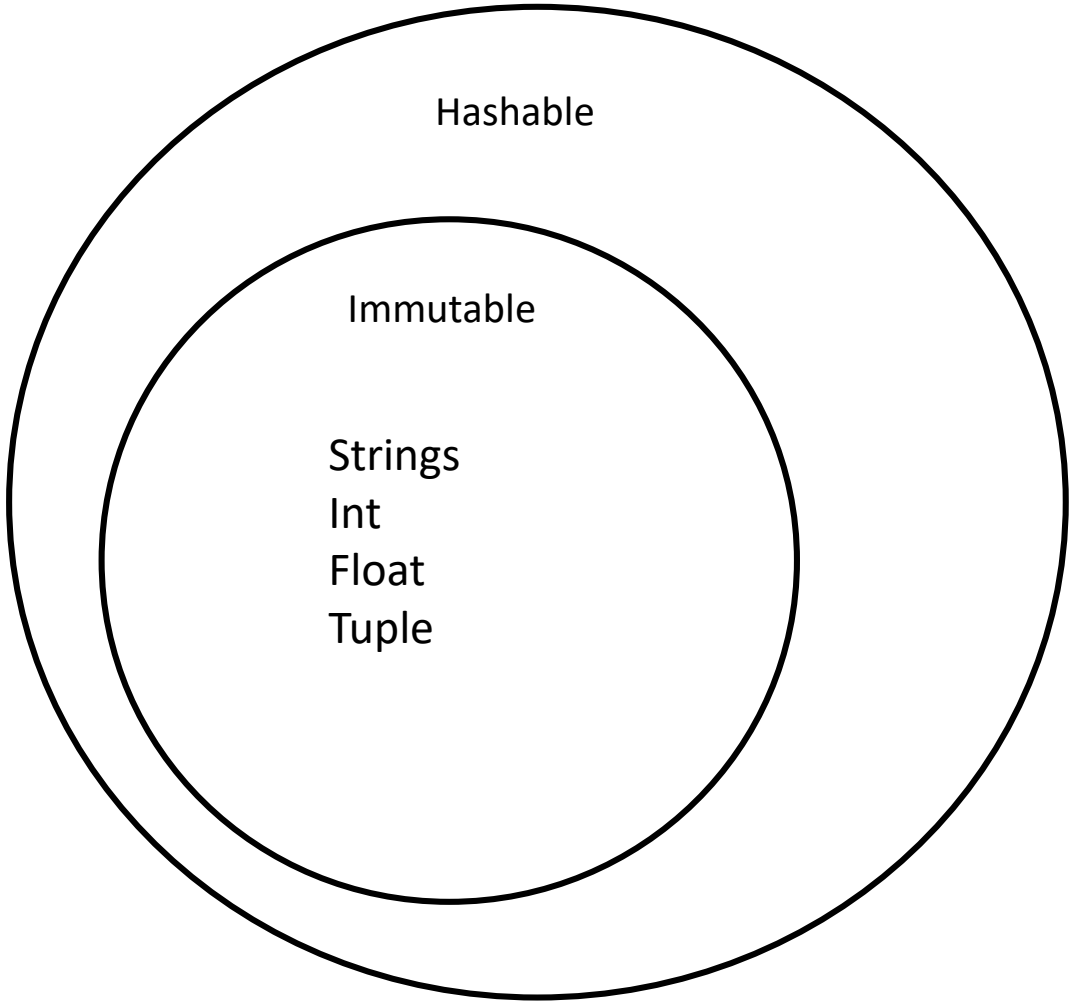
Python: Hashability and Immutability

Data Type	Immutable	Hashable
Integer	Yes	Yes
Float	Yes	Yes
String	Yes	Yes
Tuple	Yes	Yes
List	No	No
Set	No	No
Dictionary	No	No



All immutable objects are Hashable but not vice-versa

Returning Multiple Values

```
def f():
    return 1,2

x = f()
print(x)
print(type(x))
x,y= f()
print(x,y)
print(type(x),type(y))
```

Treated as a tuple

Unpacking of tuple

Output:

```
(1, 2)
<class 'tuple'>
1 2
<class 'int'> <class 'int'>
```

If you don’t know number of arguments

Unknown number of positional arguments

```
def f(*args):
    print(f'Type of input arguments: {type(args)}')
    for i in args:
        print(i)

f(1,2,3,4)
```

Output:

```
Type of input arguments: <class 'tuple'>
1
2
3
4
```

If you don’t know number of arguments

Unknown number of keyword arguments

```
def f(**kwargs):
    print(f'Type of input arguments: {type(kwargs)}')
    for i,j in kwargs.items():
        print(f'{i} = {j}')

f(arg_1 = 1,arg_2 = 2,arg_3 = 3)
```

Output:

```
Type of input arguments: <class 'dict'>
arg_1 = 1
arg_2 = 2
arg_3 = 3
```

Accessing Global Variables

- Can a function access (read) a global variable?
  - Variable is Immutable
    - Yes
  - Variable is Mutable
    - Yes

```
def my_func_1(y):
    return x+y
x = 2
print(x)
print(my_func_1(4))
print(x)

x = [2,3]
print(x)
print(my_func_1([1,4]))
print(x)
```

Output:

```
2
6
2
[2, 3]
[2, 3, 1, 4]
[2, 3]
```

Modifying Global Variables

- Can a function modify a global variable with variable declared global within local function?
  - Yes, for both mutable and immutable variables

```
def my_func_2(y):
    global x
    x = x+y
    return x

x = 2
print(x)
my_func_2(3)
print(x)

x = [2,3]
print(x)
my_func_2([4,5])
print(x)

x = (2,3)
print(x)
my_func_2((4,5))
print(x)
```

Output:

```
2
5
[2, 3]
[2, 3, 4, 5]
(2, 3)
(2, 3, 4, 5)
```

Modifying Global Variables

- Can a function modify a global variable with variable not declared as global within local function?
  - No, for immutable variables
  - Yes, for mutable variables with only the methods that mutate data (append, sort, etc.)

```
def my_func_3(y):
    return x.append(y)

x = [2,3]
print(x)
print(my_func_3([4,5]))
print(x)
```

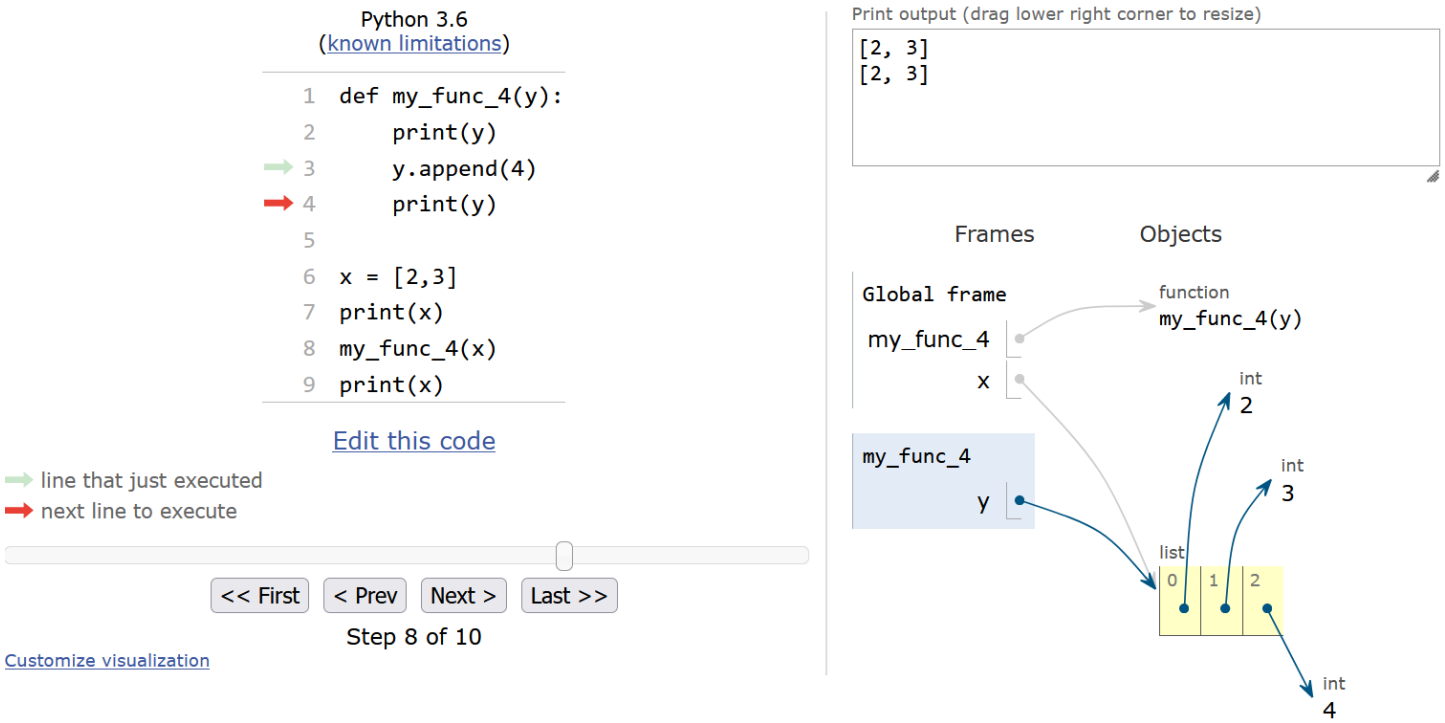
No assignment to variable x

Output:

```
[2, 3]
None
[2, 3, [4, 5]]
```

Scope

- Passing a mutable variable as argument

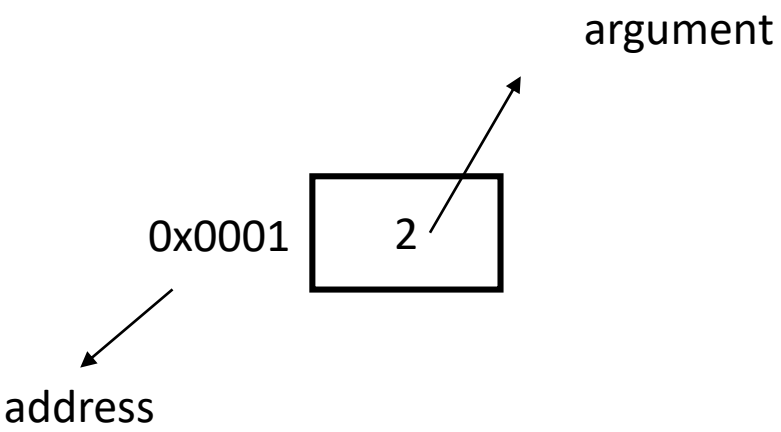


Output:

```
[2, 3]
[2, 3]
[2, 3, 4]
[2, 3, 4]
```

How are arguments passed to functions?

- Pass-by-Value
  - An independent (duplicate) copy of argument is passed as input
  - Not good if the argument size is very large
    - Requires additional memory and execution time



- Pass-by-Reference
  - Address of argument is passed and function access the value from address
  - Efficient for arguments of very large size

How about Python?

- Pass-by-Value or Pass-by-Reference?
  - Neither of them
- Python passes objects by assignment
  - Pass-by-Assignment
- Only exception is with *global* keyword

With global keyword

```
def square_1():
    global x
    x = x**2

x=2
square_1()
```

equivalent to pass-by-reference

Pass-by-Assignment

- Best Practice
  - Pass value by assignment, modify, and reassign

```
def square_2(y):
    return y**2

x = 2
x = square_2(x)
```

```
def modifyTup(t):
    return t + (999,)
```

```
>>> tup = (1,2,3,4,5)
>>> tup = modifyTup(tup)
```

Pass-by-Assignment

- For mutable variables

```
def my_func_1(y):
    return x+y


x = [2,3]
print(x)
print(my_func_1([1,4]))
print(x)
```

Effect is similar to pass-by-value

```
def my_func_3(y):
    return x.append(y)

x = [2,3]
print(x)
print(my_func_3([4,5]))
print(x)
```

Effect is similar to pass-by-reference

Scope: Summary

- Parameter Passing
  - Pass-by-Assignment
- Immutable Variable
  - Can access global variable
  - Cannot modify global variable unless declared global
- Mutable Variable
  - Can access global variable
  - Can modify the variable
    - Need to use global keyword for methods that do not mutate objects
    - No need of global keywords for methods that mutate objects

How are lists resized with *append*?

Ternary operator in C

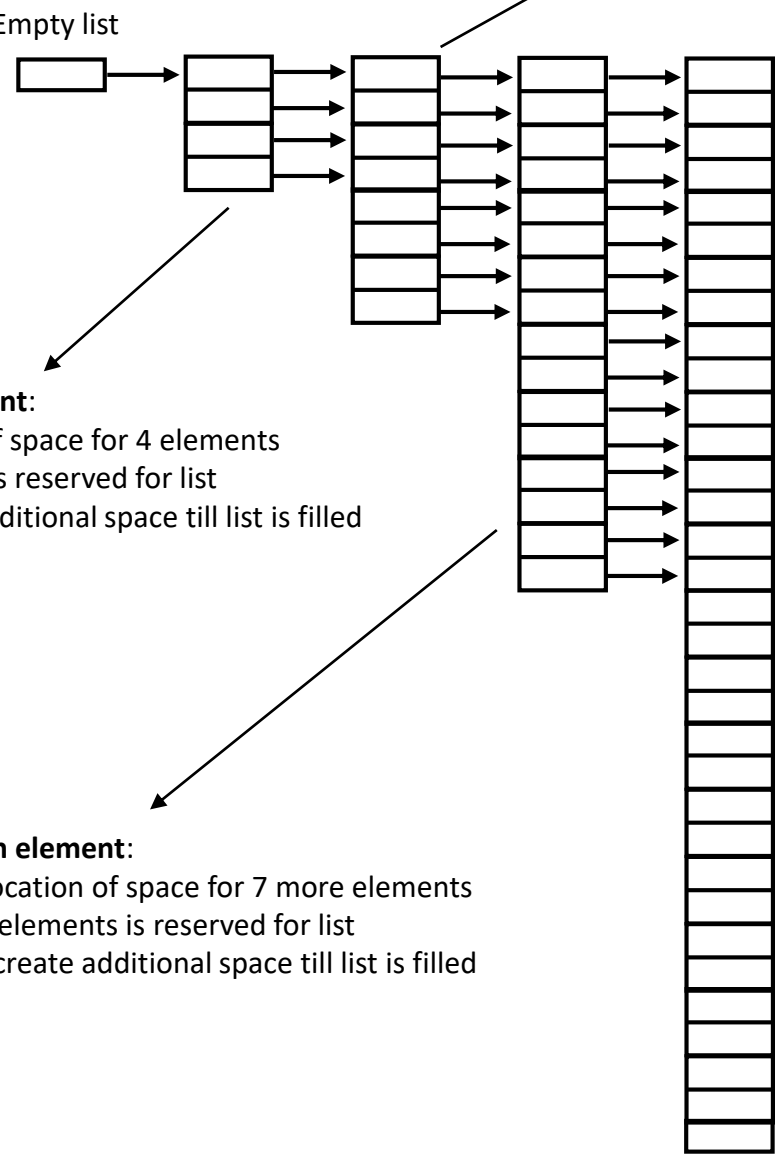
additional_allocated = current_size >>3 + current_size < 9 ? 3 : 6

floored-division by 8

$$\left\lfloor \frac{current\_size}{8} \right\rfloor$$

if current_size < 9:
    3
else:
    6

How are lists resized with *append*?



Appending 5th element:
Leads to allocation of space for 3 more elements
Space of 8 elements is reserved for list
No need to create additional space till list is filled

Appending 1st element:
Leads to allocation of space for 4 elements
Space of 4 elements is reserved for list
No need to create additional space till list is filled

Appending 9th element:
leads to allocation of space for 7 more elements
Space of 16 elements is reserved for list
No need to create additional space till list is filled

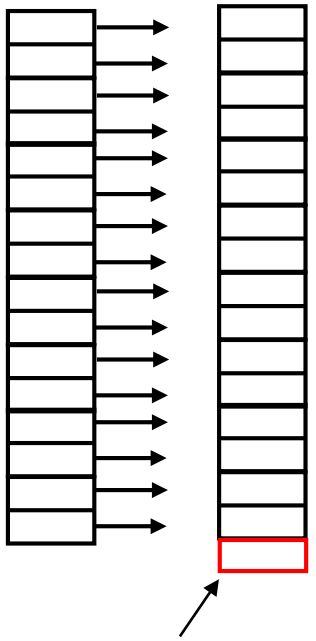
Appending 17th element:
Leads to allocation of space for 8 (= 2+6) more elements
Space of 25 elements is reserved for list
No need to create additional space till list is filled

How are lists resized with *append*?

```
import sys
my_list = []
my_list_length = []
my_list_size = []
limit= 100
for k in range(limit):
    my_list_length.append(len(my_list))
    my_list_size.append(sys.getsizeof(my_list))
    my_list.append(k)
```

How are lists resized with *concatenation*?

- Always create a new list
  - Copies the contents of old list and new list combined

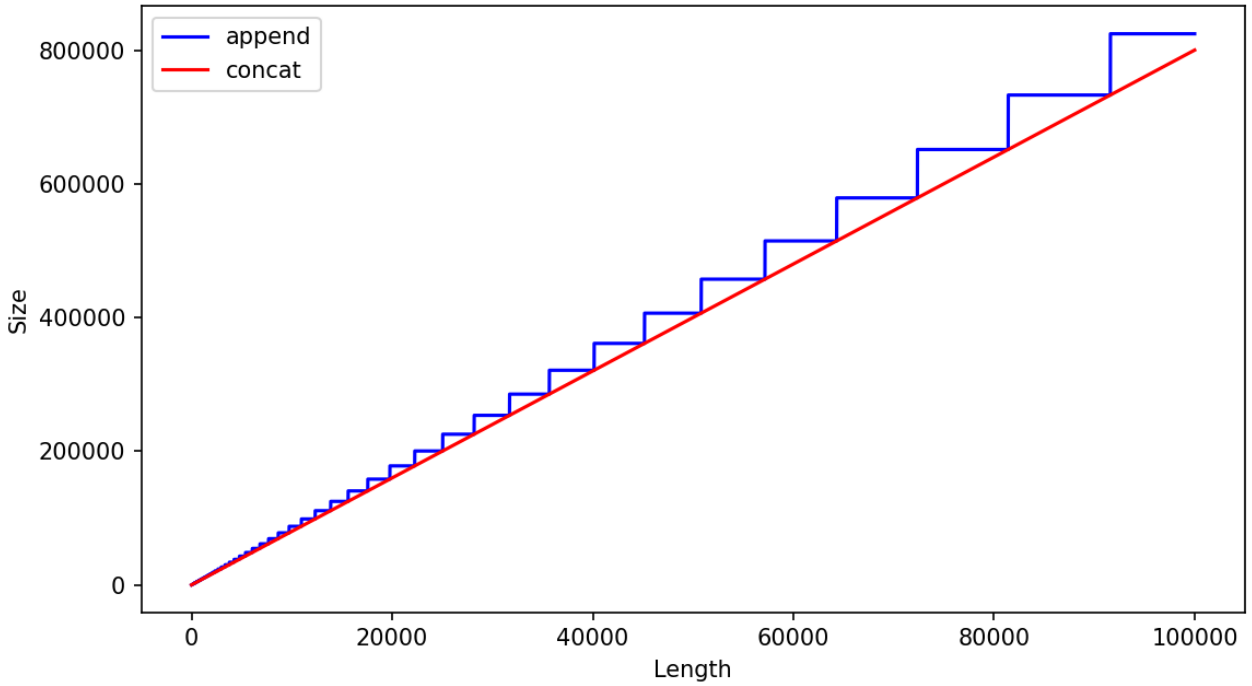


List Append Vs Concatenation

```
from time import time
import sys
my_list_append = []
my_list_append_length = []
my_list_append_size = []

start= 0
end= 10**5

append_start_time = time()
for k in range(start,end):
    my_list_append_length.append(len(my_list_append))
    my_list_append_size.append(sys.getsizeof(my_list_append))
    my_list_append.append(k)
append_end_time = time()

my_list_concat = []
my_list_concat_length = []
my_list_concat_size = []
concat_start_time = time()
for k in range(start,end):
    my_list_concat_length.append(len(my_list_concat))
    my_list_concat_size.append(sys.getsizeof(my_list_concat))
    my_list_concat = my_list_concat + [k]
concat_end_time = time()
```

```
print(f'Append: {round(append_end_time-append_start_time,4)}s')
print(f'Concatenation: {round(concat_end_time - concat_start_time,4)}s')
from matplotlib import pyplot
pyplot.plot(my_list_append_length, my_list_append_size,color = 'b')
pyplot.plot(my_list_concat_length, my_list_concat_size,color='r')
pyplot.xlabel('Length')
pyplot.ylabel('Size')
pyplot.legend(['append','concat'])
pyplot.show()
```

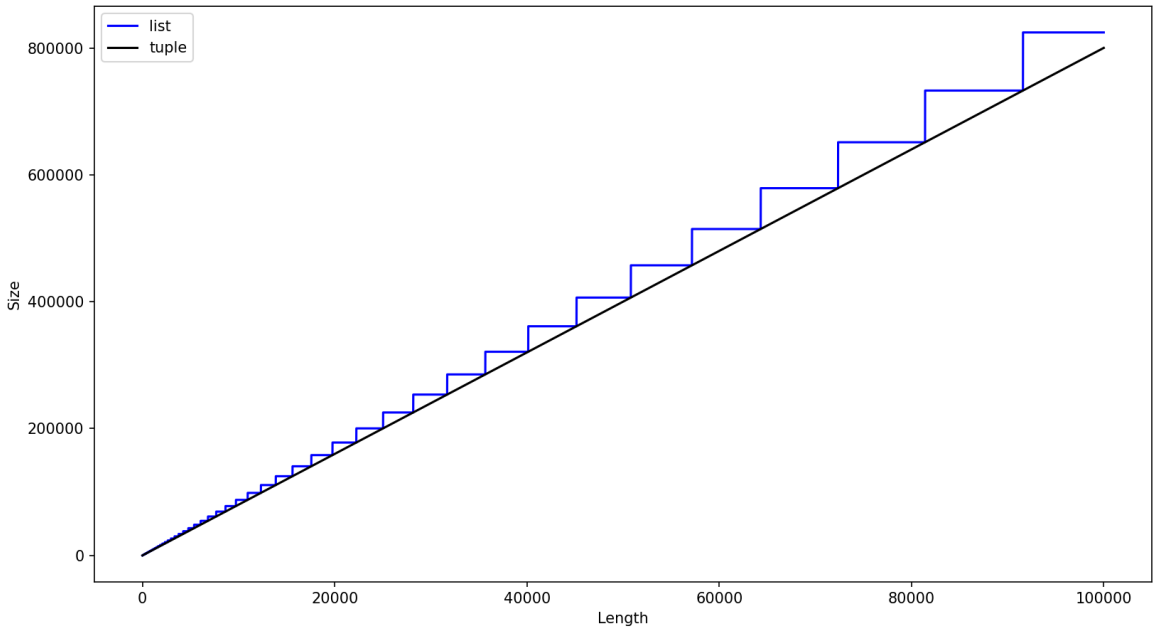
List Append Vs Concatenation




```
Append: 0.0316s
Concatenation: 20.7656s
```

Concatenation is slow as it creates new list for every new concatenation

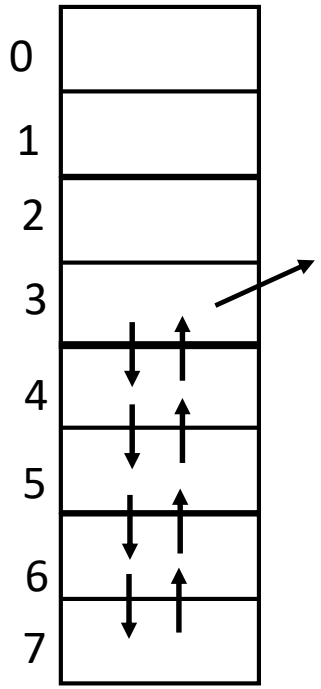
List Append Vs Tuple Concatenation




```
Append: 0.0211s
Concatenation: 20.3768s
```

Modifying tuple is slow as it creates new tuple for every new concatenation

Insertion/Deletion in lists?



Inserting of new element or
Deletion of an element
leads to to relocation of
elements in subsequent indices

List Vs Tuple: Conclusion

Tuple Version


Preserve input

Must return result


Slower

List Version

May or may not preserve input

- May modify input

May or may not need to return result


Faster (append)

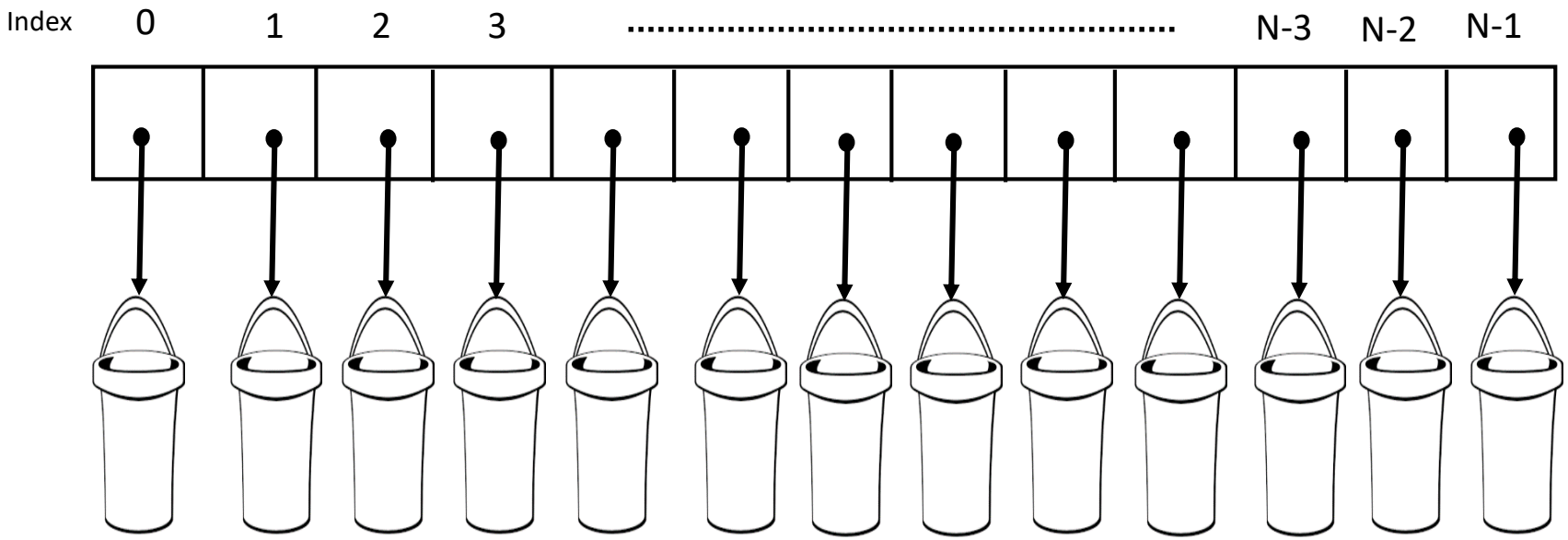

Slower (concatenation)

Miscellaneous

Dictionary – Bucket Array

$$A(h(k)) = v$$

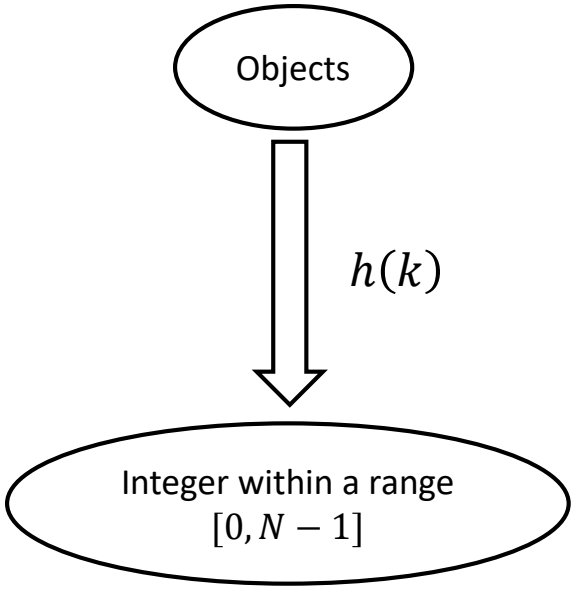
Key (k) is mapped to an index (0 to N-1) and Value (v) is stored in the corresponding bucket

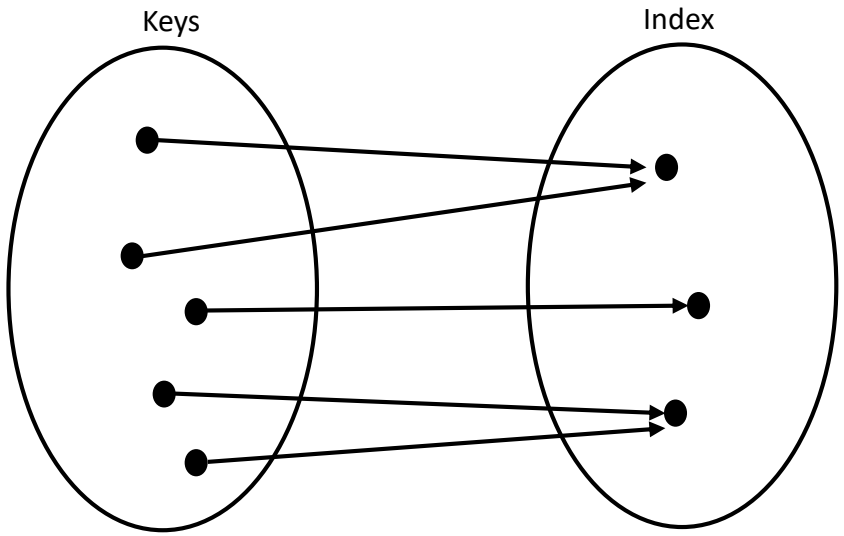


Key to index mapping is done through Hash Function ($h(k)$)

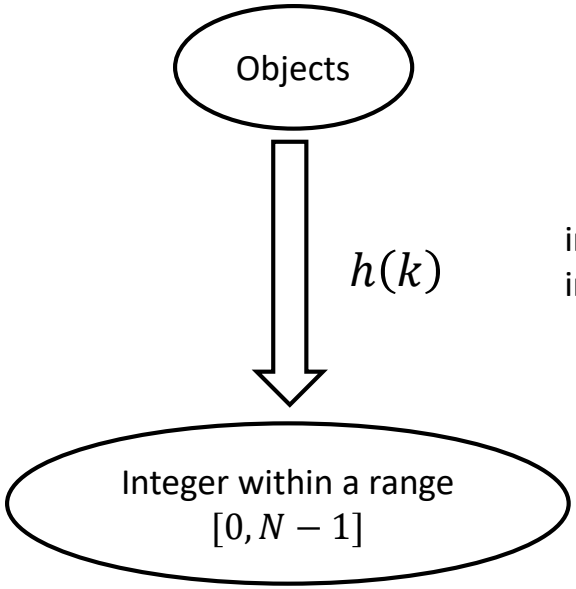
https://research.cs.vt.edu/AVresearch/hashing/index.php

Hash Function - $h(k)$

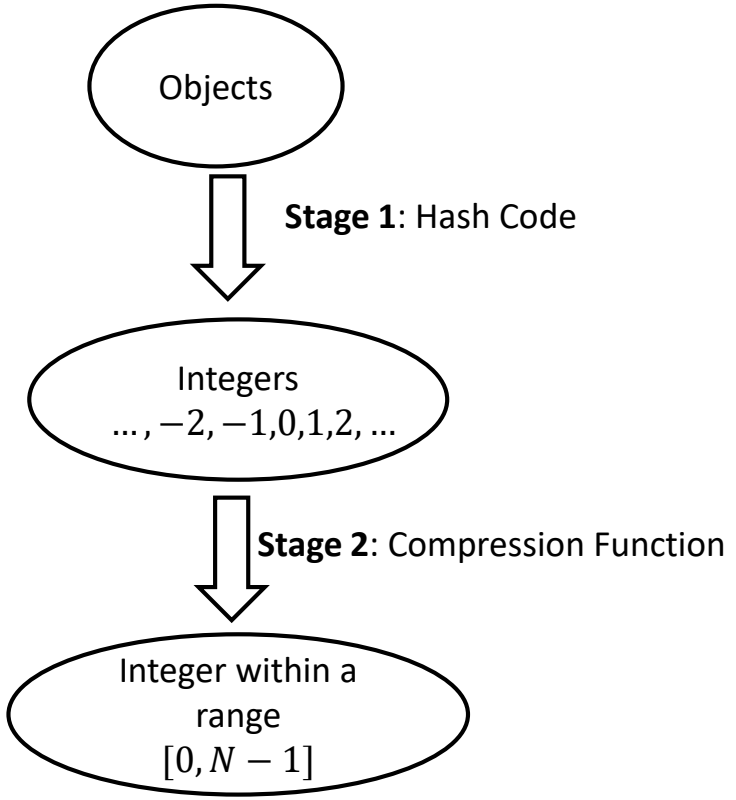




Hash Function - $h(k)$



implemented in two stages



Hash Code

- Bit representation as hash codes

- Polynomial hash codes
  - $x_0 a^{n-1} + x_1 a^{n-2} + \cdots + x_{n-2} a + x_{n-1}$
    - x_i : Coefficients
    - a : Constant

- Cyclic-shift hash codes

Compression Functions

- Division Method $i \ mod \ N$

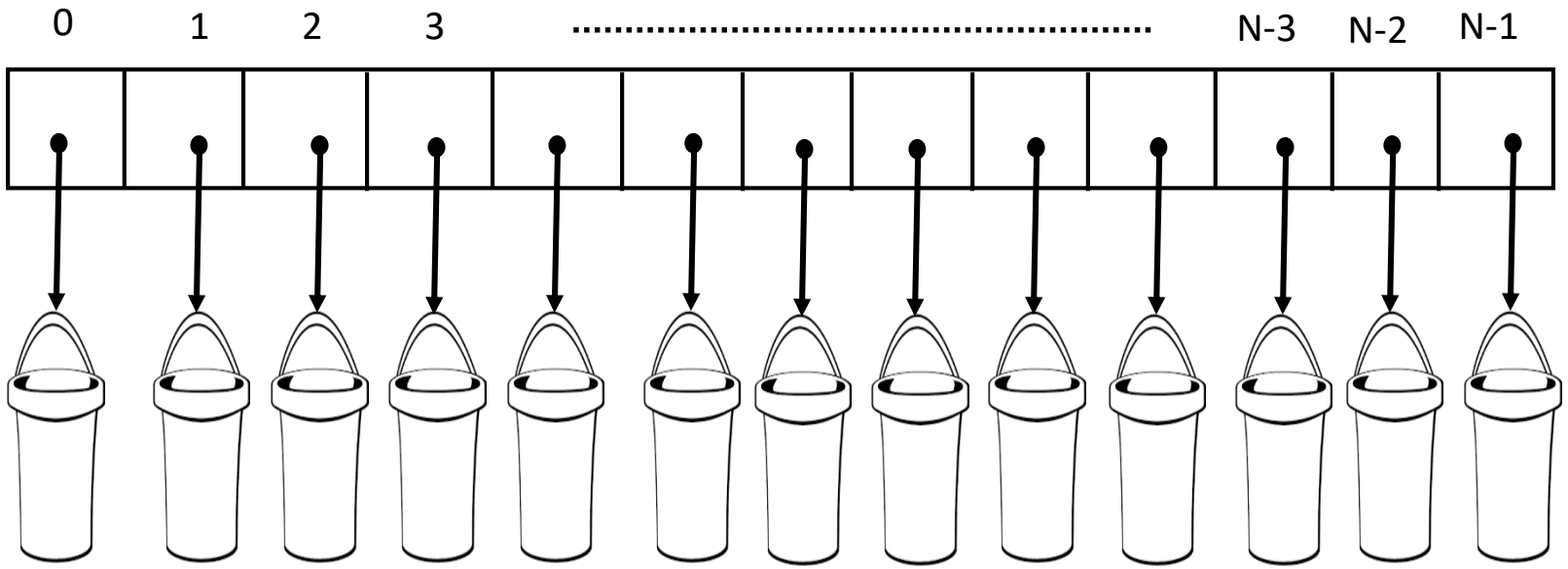
- Multiply-Add-and-Divide (MAD) Method

$$[(ai + b) \ mod \ p] \ mod \ N$$

Collisions

Collision occurs if multiple keys produce same hash value

$$h(k_1) = h(k_2)$$

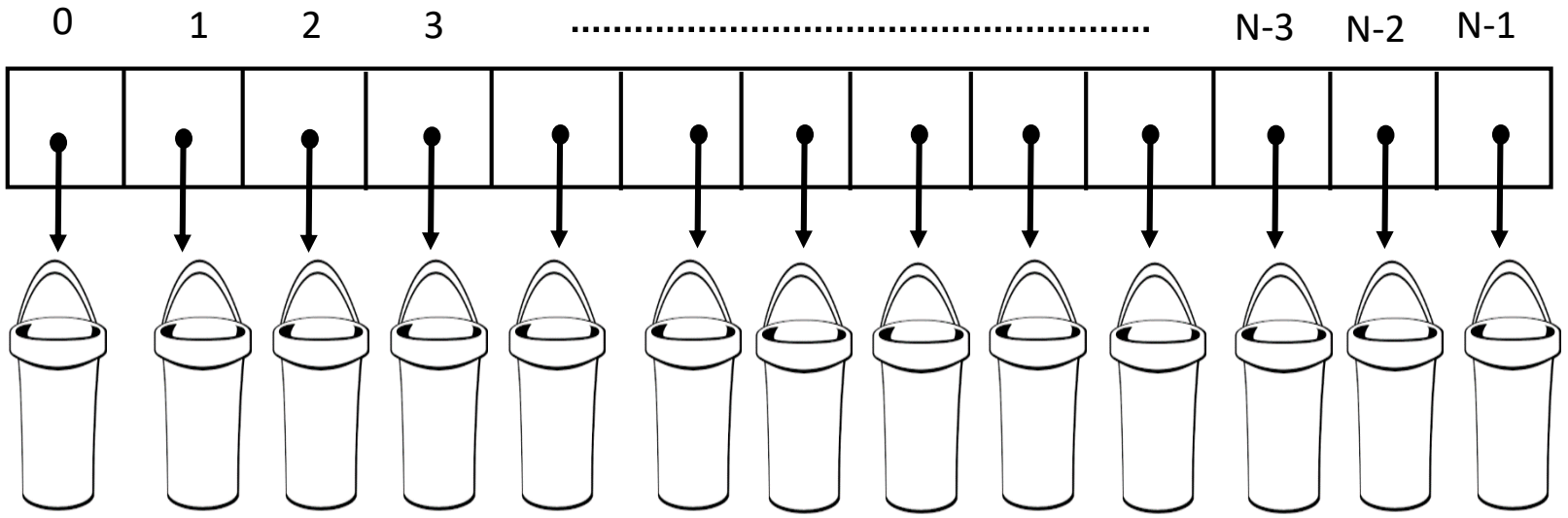


Collision-Handling

- Separate Chaining
- Open Addressing
  - Linear Probing
  - Quadratic Probing
  - Double Hashing

Collision-Handling

- Separate Chaining



- Each bucket contains a list of values v_i whose $h(k_i)$ are same
  - Requires additional *list* data structure
  - Slows down the access as the *list* need to be searched for the key

Open Addressing

- Linear Probing
- Quadratic Probing
- Double Hashing