DM536 / DM550 Part 1
Introduction to Programming

Peter Schneider-Kamp

petersk@imada.sdu.dk

http://imada.sdu.dk/~petersk/DM536/

Additional Project Support Hours

- get help with your project on Wednesday 08-12
- TAs will be in or around IMADA terminal room
- code word "Slartibartfast"
- Until then …
- … go and DO something! ☺

DICTIONARIES

Generalized Mappings

- list = mapping from integer indices to values
- dictionary = mapping from (almost) any type to values
- indices are called *keys* and pairs of keys and values *items*

- empty dictionaries created using curly braces "{}"
- Example: `en2da = {}`

- keys are assigned to values using same syntax as for sequences
- Example:
```
en2da["queen"] = "dronning"
print en2da
```

- curly braces "{" and "}" can be used to create dictionary
- Example: `en2da = {"queen" : "dronning", "king" : "konge"}`

Dictionary Operations

- printing order can be different: `print en2da`
- access using indices: `en2da["king"] == "konge"`
- KeyError when key not mapped: `print en2da["prince"]`
- length is number of items: `len(en2da) == 2`
- in operator tests if key mapped: `"king" in en2da == True`
  `"prince" in en2da == False`
- keys() metod gives list of keys:
  `en2da.keys() == ["king", "queen"]`
- values() method gives list of values:
  `en2da.values() == ["konge", "dronning"]`
- useful e.g. for test if value is used:
  `"prins" in en2da.values() == False`

Dictionaries as Sets

- dictionaries can be used as sets
- **Idea:** assign None to all elements of the set
- Example: representing the set of primes smaller than 20

  primes = {2: None, 3: None, 5: None, 7: None, 11: None, 13: None, 17: None, 19: None}

- then in operator can be used to see if value is in set
- Example:

  15 in primes == False

  17 in primes == True

- for lists, needs steps proportional to number of elements
- for dictionary, needs (almost) constant number of steps

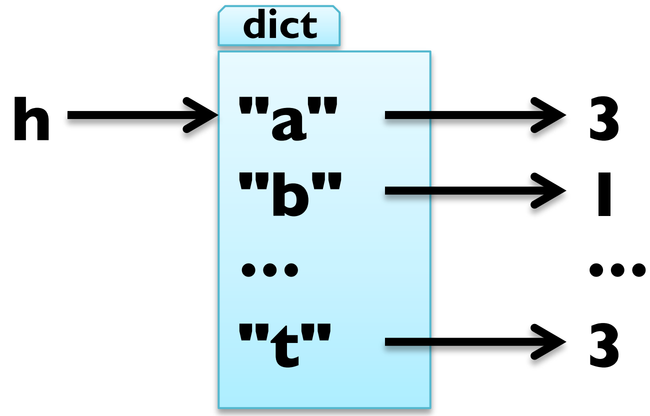
Counting Letter Frequency

- **Goal:** count frequency of letters in a string (*histogram*)
- many possible implementations, e.g.:
  - create 26(+3?) counter variables for each letterl; use chained conditionals (if … elif … elif …) to increment
  - create a list of length 26(+3?); increment the element at index n-1 if the n-th letter is encountered
  - create a dictionary with letters as keys and integers as values; increment using index access
- all these implementations work (differently)
- big differences in *runtime* and *ease of implementation*
- choice of data structure is a *design decision*

Counting with Dictionaries

- fast and counts all characters – no need to fix before!

```
def histogram(word):
    d = {}
    for char in word:
        if char not in d:
            d[char] = 1
        else:
            d[char] += 1
    return d
```

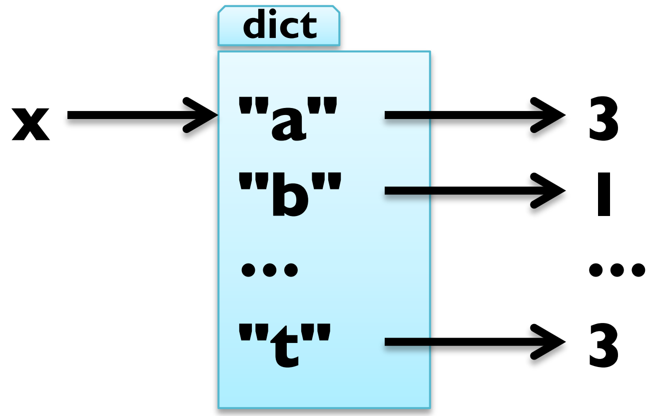


- Example: h = histogram("slartibartfast")
  h == {"a":3, "b":1, "f":1, "i":1, "l":1, "s":2, "r":2, "t":3}

Counting with Dictionaries

- fast and counts all characters – no need to fix before!

```
def histogram(word):
    d = {}
    for char in word:
        if char not in d:
            d[char] = 1
        else:
            d[char] += 1
    return d
```



- access using the get(k, d) method:

```
h.get("t", 0) == 3
h.get("z", 0) == 0
```

Traversing Dictionaries

- using a for loop, you can traverse all keys of a dictionary
- Example:

```
for key in en2da:
    print key, en2da[key]
```

- you can also traverse all values of a dictionary
- Example:

```
for value in en2da.values():
    print value
```

- finally, you can traverse all items of a dictionary
- Example:

```
for item in en2da.items():
    print item[0], item[1]        # key, value
```

Reverse Lookup

- given dict. d and key k, finding value v with v == d[k] easy
- this is called a dictionary *lookup*
- given dict. d and value v, finding key k with v == d[k] hard
- there might be more than one key mapping to v (cf. example)
- Possible implementation 1:

```
def reverse_lookup(d, v):
    result = []
    for key in d:
        if d[key] == v:
            result.append(key)
    return result
```

- returns empty list, when no key maps to value v

Reverse Lookup

- given dict. d and key k, finding value v with v == d[k] easy
- this is called a dictionary *lookup*
- given dict. d and value v, finding key k with v == d[k] hard
- there might be more than one key mapping to v (cf. example)
- Possible implementation 2:

```
def reverse_lookup(d, v):
    for k in d:
        if d[k] == v:
            return k
    raise ValueError
```

- gives error when no key maps to value v

Reverse Lookup

- given dict. d and key k, finding value v with v == d[k] easy
- this is called a dictionary *lookup*
- given dict. d and value v, finding key k with v == d[k] hard
- there might be more than one key mapping to v (cf. example)
- Possible implementation 2:

```
def reverse_lookup(d, v):
    for k in d:
        if d[k] == v:
            return k
    raise ValueError, "value not found in dictionary"
```

- gives error when no key maps to value v

Dictionaries and Lists

- lists cannot be keys, as they are mutable
- list can be values stored in dictionaries
- Example: inverting a dictionary

```
def invert_dict(d):
    inv = {}
    for key in d:
        val = d[key]
        if val not in inv:
            inv[val] = [key]
        else:
            inv[val].append(key)
    return inv
```

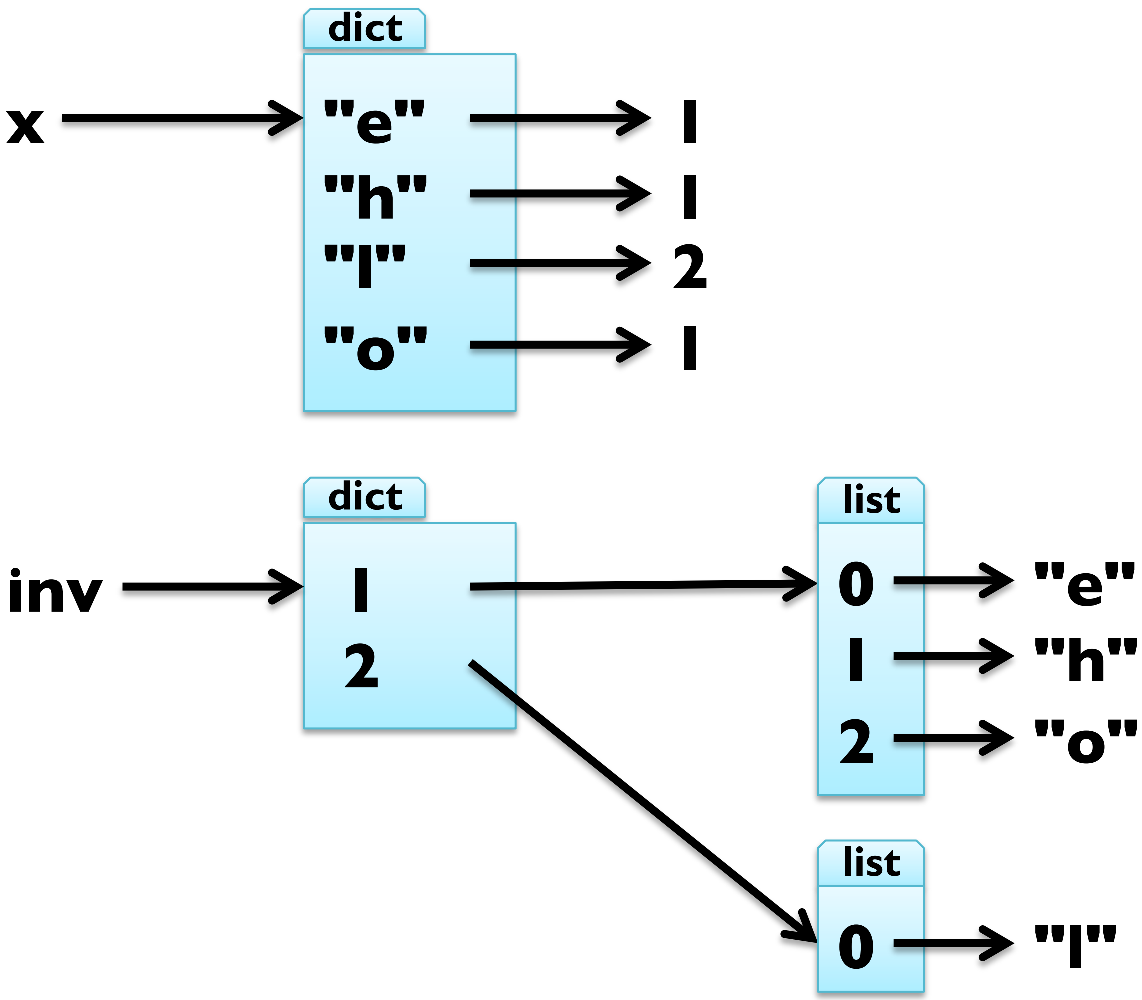
Dictionaries and Lists

- lists cannot be keys, as they are mutable
- list can be values
- Example: inverting a dictionary

```
def invert_dict(d):
    inv = {}
    for key in d:
        val = d[key]
        if val not in inv:
            inv[val] = []
        inv[val].append(key)
    return inv
```

- Example: `print invert_dict(histogram("hello"))`

Dictionaries and Lists



- Example: print invert_dict(histogram("hello"))

Memoizing

- Fibonacci numbers lead to exponentially many calls:

```
def fib(n):
    if n in [0,1]: return n
    return fib(n-1) + fib(n-2)
```

- keeping previously computed values (*memos*) helps:

```
known = {0:0, 1:1}
def fib_fast(n):
    if n in known:
        return known[n]
    res = fib_fast(n-1) + fib_fast(n-2)
    known[n] = res
    return res
```

Global Variables

- known is created outside fib_fast and belongs to __main__
- such variables are called *global*
- many uses for global variables (besides memoization)
- Example 1: flag for controlling output

```
debug = True
def pythagoras(a,b):
    if debug:     print "pythagoras with a =d", a, " and b = d", b
    result = math.sqrt(a**2 + b**2)
    if debug:     print "result of pythagoras:", result
    return result
```

Global Variables

- known is created outside fib_fast and belongs to __main__
- such variables are called *global*
- many uses for global variables (besides memoization)
- Example 2: track number of calls

```
num_calls = 0
def pythagoras(a,b):
    global num_calls
    num_calls += 1
    return math.sqrt(a**2 + b**2)
```

- gives UnboundLocalError as num_calls is local to pythagoras
- declare num_calls to be global using a global statement

Long Integers

- Python uses 32 or 64 bit for int
- this limits the numbers that can be represented:
  - 32 bit: from -2**31 to 2**31–1
  - 64 bit: from -2**63 to 2**63–1

- for larger numbers, Python automatically uses long integers
- Example:

  fib(93) == 12200160415121876738L

- long integers work just like int, only with "L" as suffix
- Example: 2**64 + 2**64 == 2**65

  fib(100)**fib(20) # has 139016 digits :-o

Debugging Larger Datasets

- debugging larger data sets, simple printing can be too much

1. scale down the input – start with the first n lines; a good value for n is a small value that still exhibits the problem
2. scale down the output – just print a part of the output; when using strings and lists, slices are very handy
3. check summaries and types – check that type and len(…) of objects is correct by printing them instead of the object
4. write self-checks – include some *sanity checks*, i.e., test Boolean conditions that should definitely hold
5. pretty print output – even larger sets can be easier to interpret when printed in a more human-readable form

TUPLES

Tuples as Immutable Sequences

- tuple = immutable sequence of values
- like lists, tuples are indexed by integers

- tuples can be enclosed in parentheses "(" and ")"
- Example:

```
t1 = "D", "o", "u", "g", "l", "a", "s"
t2 = (65, 100, 97, 109, 115)
t3 = 42,        # or (42,) - but not (42)
```

- tuples can be created from sequences using `tuple(iterable)`
- Example:

```
t1 == tuple("Douglas")
tuple(["You", 2]) == ("You", 2)
```

Tuples as Immutable Sequences

- tuple = immutable sequence of values
- like lists, tuples are indexed by integers

- tuples can be accessed using indices and slices
- Example:

```
t = "D", "o", "u", "g", "l", "a", "s"
t[3] == "g"
t[1:3] == ("o", "u")
```

- tuples cannot be changed, but they can be concatenated
- Example:

```
u = ("d",) + t[1:]
```

Tuple Assignment

- remember, how to exchange two values:
  - Solution 1 (new variable): `z = y; y = x; x = z`
  - Solution 2 (parallel assign.): `x, y = y, x`
- now, we see that this is a tuple assignment
- assignment to a tuple is assignment to each tuple element
- works not only with other tuple, but with any sequence
- Example:

```
x, y, z = [23, 42, -3.0]
name = "Peter Schneider-Kamp"
first, last = name.split()
```

Tuples as Return Values

- useful to return more than one value in a function
- but functions only return one value
- tuples can be used to contain multiple values
- Example 1: built-in function divmod(x,y)

```
t = divmod(10, 3)
print t
quot, rem = divmod(101, 17)
```

- Example 2: extract username, hostname, and domain

```
def decompose(email):
    username, rest = email.split("@")
    rest = rest.split(".")
    return username, rest[0], ".".join(rest[1:])
```

Variable-Length Argument Tuples

- functions can take a variable number of arguments
- arguments are passed as one tuple (*gather*)
- Example 1: function that works similar to print statement

```
def printf(*args):         # * indicates variable arguments
    for arg in args:       # iterates through tuple
        print arg,         # prints one argument
    print                  # prints new line
```

- Example 2: prints all arguments n times

```
def printn(n, *args):
    for arg in args * n:
        print arg
```

Tuples instead of Arguments

- tuples cannot directly be used instead for normal parameters
- Example:

```
t = (42, 23)
print divmod(t)          # gives TypeError
```

- using "*" we can declare that a tuple should be *scattered*
- Example:

```
print divmod(*t)         # prints (1, 19)
```

Lists and Tuples

- built-in function zip() combines two sequences
- Example 1:

  zip([1, 2, 3], ["c", "b", "a"]) == [(1, "c"), (2, "b"), (3, "a")]
- Example 2:

  zip("You", "suck!") == [("Y", "s"), ("o", "u"), ("u", "c")]

- iteration through list of tuples using tuple assignment
- Example:

```
t = [(1, "c"), (2, "b"), (3, "a")]
for num, ch in t:
    print "we have paired", num, "and", ch
```

Lists and Tuples

- with zip(), for loop, and tuple assignment we can iterate through two sequences in parallel
- Example 1: sum of product of elements (*dot product*)

```
def dot_product(x, y):
    res = 0
    for a, b in zip(x, y):
        res += a*b
    return res
dot_product([1, 4, 3], [4, 5, 6])
```

- Example 2: the same shorter …

```
def dot_product(x, y):
    return reduce(lambda x, y: x + y[0] * y[1], zip(x, y), 0)
```

Dictionaries and Tuples

- dictionaries return a list of tuples with the items() method
- Example: d = {"a" : 3, "b" : 2, "c" : 1}
  d.items() == [("a", 3), ("c", 1), ("b", 2)]

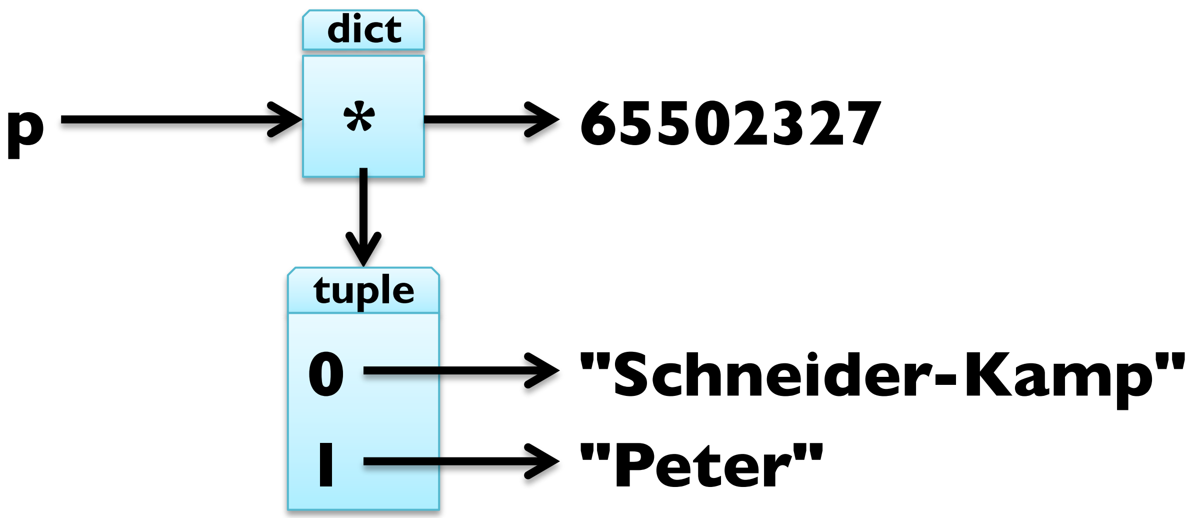
- tuples can also be used to create new dictionary using dict()
- Example: t = [("a", 3), ("c", 1), ("b", 2)]
  dict(t) == {"a" : 3, "b" : 2, "c" : 1}

- combine with zip() for easy dictionary generation
- Example: d = dict(zip("abcdefg", range(7,0,-1)))

- with tuple assignment and for loop, easy traversal
- Example: for key, val in d.items(): print key, val

Dictionaries and Tuples

- tuples can be used as dictionary keys (they are immutable)
- Example: p = {}; first = "Peter"; last = "Schneider-Kamp"
  p[last, first] = 65502327
- traversal by for loop and tuple assignment
- Example 1: for last, first in p: print first, last, p[last, first]
- Example 2: for (last, first), num in p.items(): print last, first, num



Dictionaries and Tuples

- tuples can be used as dictionary keys (they are immutable)
- Example: p = {}; first = "Peter"; last = "Schneider-Kamp"
  p[last, first] = 65502327
- traversal by for loop and tuple assignment
- Example 1: for last, first in p: print first, last, p[last, first]
- Example 2: for (last, first), num in p: print last, first, num

Comparing Tuples

- comparing tuples same as comparing any sequence
- like with strings, sequences are compared lexicographically
- Example: (3,) > (2, 2, 2)
  (1, 2, 3, 4, 5) < (1, 2, 3, 5,5)
- tuples can be used to sort lists after arbitrary criteria
- Example: sort list of words after their length, shortest last

```
def sort_by_length(words):
    t = [];  res = []
    for word in words:          t.append((len(word), word))
    t.sort(reverse=True)
    for length, word in t:      res.append(word)
    return res
```

Comparing Tuples

- comparing tuples same as comparing any sequence
- like with strings, sequences are compared lexicographically
- Example: (3,) > (2, 2, 2)

  (1, 2, 3, 4, 5) < (1, 2, 3, 5,5)
- tuples can be used to sort lists after arbitrary criteria
- Example: sort list of words after their length, shortest last

```
def sort_by_length(words):
    t = map(lambda x: (len(x), x), words)
    t.sort(reverse=True)
    return map(lambda pair: pair[1], t)
```

Sequences of Sequences

- most sequences can contain other types of sequences
- string is an exception, as it only contains characters
- can always use a list of characters instead of string
- lists usually preferred to tuples (they are mutable)
- in some situtations, tuples more often used:
  1. tuples are more "easy" to construct, e.g. return n, n**2
  2. tuples can be dictionary keys (they are immutable)
  3. tuples are safer due to "aliasing", so use them e.g. as sequence arguments to functions
- methods sort() and reverse() not available for tuples
- use functions sorted(iterable) and reversed(iterable) instead

Debugging Shape Errors

- lists, dictionaries, and tuples are *data structures*
- combining this, we obtain compound data structures
- this gives rise to new errors, so called shape errors
- a shape error is when the structure of the compound data structure does not fit its use
- Example:

```
d = {("Schneider-Kamp", "Peter") : 65502327}
for last, first, number in d:      print number
```

- use structshape module for debugging
- available from http://thinkpython.com/code/structshape.py
- Example:

```
from structshape import structshape
structshape(d) == "dict of 1 tuple of 2 str->int"
```