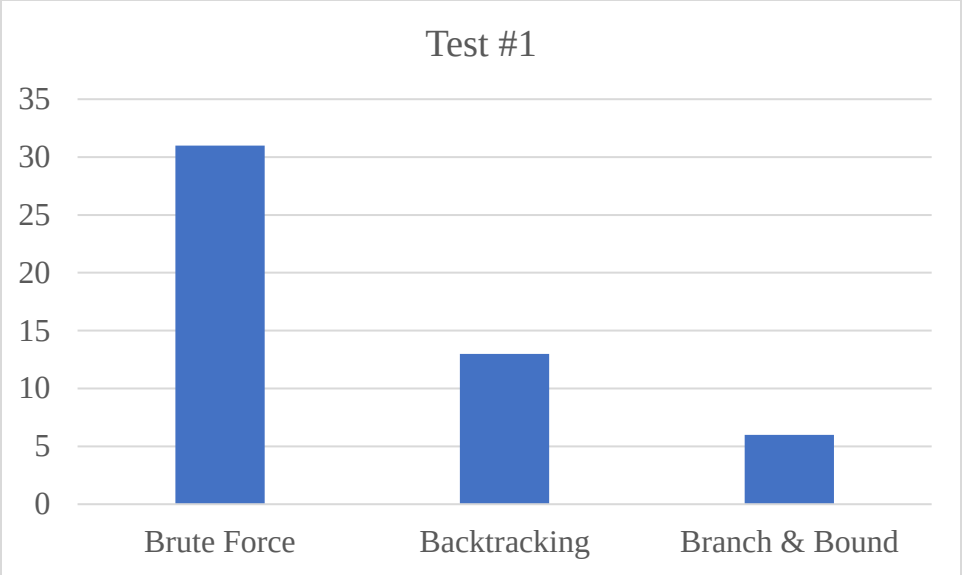
Ocean Lu
CS 3310
Professor Damavandi / Johannsen
12/03/2019

Homework #4: Report

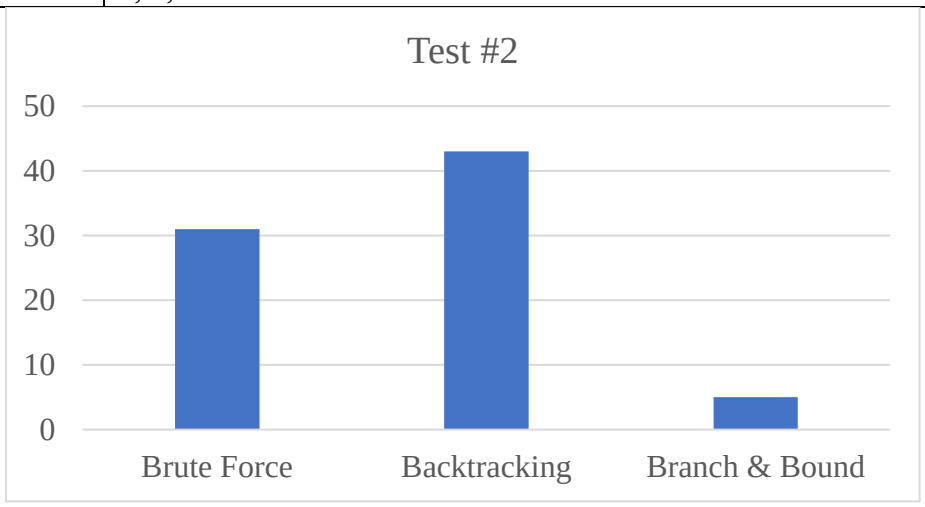
Please view link for source code:
https://colab.research.google.com/drive/1A5GZejz7OMGhruiGJE0L3CTSy5Z-Wax7

1. Does the branch-and-bound solution always perform better than the backtracking solution? If not, for what input did the backtracking solution check less nodes?
   The branch-and-bound solution does not always perform better than the backtracking solution. The types of input the backtracking solution check less nodes are ones where the weight and value are already sorted when the data becomes mapped.
2. Did you find any inputs for which the brute-force algorithm is not much worse than either of the other two solutions?
   The inputs for which the brute-force algorithm is not much worse than the other two solutions when there are less data inputs and when the data is already sorted.
3. On average, how much more efficient are the two solutions discussed in class over the brute-force solution?
   The Backtracking solution may be effective dependent on the type of scenario, as it does iterate through the entirety of the tree, like Brute-force. The branch and bound solution has been by far the most efficient algorithm as it does not go through the entire tree, but focuses on bounded data sets.
4. After running your program on several different inputs, make a table displaying the # of nodes checked for each of the three solutions. (running my program on class exercises?)

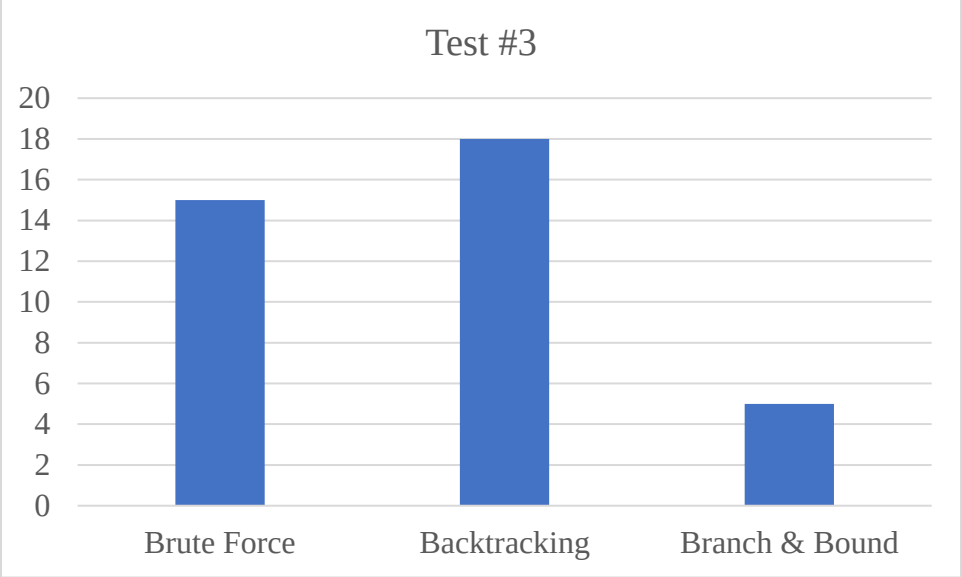
Test #1 (Lecture 20 Ch 6 Pt 1 Exercise slide)	
Data Items:	[‘1’, ‘2’, ‘3’, ‘4’, ‘5’]
Data Weight:	[2, 5, 7, 3, 1]
Data Value:	[20, 30, 35, 12, 3]
Data Mapped:	[('1', 2, 20), ('2', 5, 30), ('3', 7, 35), ('4', 3, 12), ('5', 1, 3)]
Max weight:	13
The Brute Force Solution:	
Nodes Visited	31
The Backtracking Solution:	
Nodes Visited	13
The Branch and Bound Solution	
Nodes Visited	6
Solution	
Total weight:	13
Total value:	70
Items:	1, 3, 4, 5



Test #2 (Lecture 18 Ch 5 Pt 2)	
Data Items:	[‘1’, ‘2’, ‘3’, ‘4’, ‘5’]
Data Weight:	[5, 6, 10, 11, 16]
Data Value:	[1, 1, 1, 1, 1]
Data Mapped:	[('1', 5, 1), ('2', 6, 1), ('3', 10, 1), ('4', 11, 1), ('5', 16, 1)]
Max weight:	21
The Brute Force Solution:	
Nodes Visited	31
The Backtracking Solution:	
Nodes Visited	43
The Branch and Bound Solution	
Nodes Visited	5
Solution	
Total weight:	21
Total value:	3
Items:	1, 2, 3

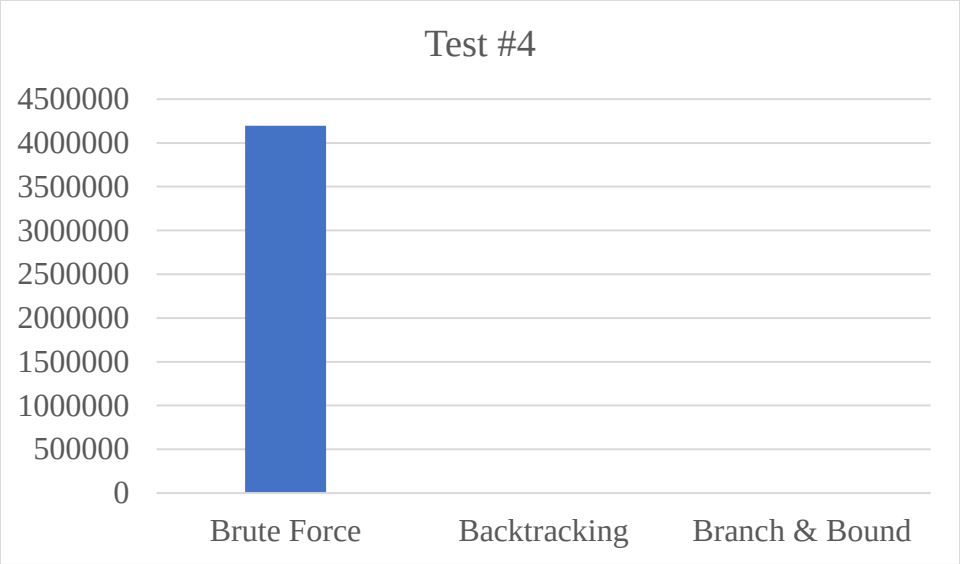


Test #3 (Lecture 18 Ch 5 Pt 3)	
Data Items:	[‘1’, ‘2’, ‘3’, ‘4’]
Data Weight:	[2, 5,10, 5]
Data Value:	[40, 30, 10, 5]
Data Mapped:	[('1', 2, 40), ('2', 5, 30), ('3', 10, 50), ('4', 5, 10)]
The Brute Force Solution:	
Nodes Visited	15
The Backtracking Solution:	
Nodes Visited	18
The Branch and Bound Solution	
Nodes Visited	5
Solution	
Total weight:	12
Total value:	90
Items:	1, 3



Test #4 (My own values)	
Data Items:	['map', 'compass', 'water', 'sandwich', 'glucose', 'tin', 'banana', 'apple', 'cheese', 'beer', 'suntan cream', 'camera', 't-shirt', 'trousers', 'umbrella', 'waterproof trousers', 'waterproof overclothes', 'note-case', 'sunglasses', 'towel', 'socks', 'book']
Data Weight:	[9, 13, 153, 50, 15, 68, 27, 39, 23, 52, 11, 32, 24, 48, 73, 42, 43, 22, 7, 18, 4, 30]
Data Value:	[150, 35, 200, 160, 60, 45, 60, 40, 30, 10, 70, 30, 15, 10, 40, 70, 75, 80, 20, 12, 50, 10]
Data Mapped:	[('map', 9, 150), ('socks', 4, 50), ('suntan cream', 11, 70), ('glucose', 15, 60), ('note-case', 22, 80), ('sandwich', 50, 160), ('sunglasses', 7, 20), ('compass', 13, 35), ('banana', 27, 60), ('waterproof overclothes', 43, 75), ('waterproof trousers', 42, 70), ('water', 153, 200), ('cheese', 23,

	30), ('apple', 39, 40), ('camera', 32, 30), ('towel', 18, 12), ('tin', 68, 45), ('t-shirt', 24, 15), ('umbrella', 73, 40), ('book', 30, 10), ('trousers', 48, 10), ('beer', 52, 10)]
The Brute Force Solution:	
Nodes Visited	4194303
The Backtracking Solution:	
Nodes Visited	781
The Branch and Bound Solution	
Nodes Visited	22
Solution	
Total weight:	396
Total value:	1030
Items:	banana, compass, glucose, map, note-case, sandwich, socks, sunglasses, suntan cream, water, waterproof overclothes, waterproof trousers



Code Analysis:

a. The Brute-Force solution that implicitly builds the entire state space tree.
    a. Code:

```
def totalvalue(comb):
    totwt = totval = 0
    for item, wt, val in comb:
        totwt  += wt
        totval += val
    return (totval, -totwt) if totwt <= max_weight else (0, 0)
```

```
def anycomb(items):
    node = 0
    for r in range(1, len(items)+1):
      for comb in combinations(items, r):
        node = node + 1
    print "Nodes visited ", node
    return (comb
             for r in range(1, len(items)+1)
             for comb in combinations(items, r))
```

```
# a. The Brute-Force solution that implicitly builds the entire state space tree.
print("\nThe Brute-Force solution:")
bag = max(anycomb(data_sorted), key=totalvalue)
val, wt = totalvalue(bag)
print "Total weight: ", -wt
print "Total value: ", val
print("Items: " + ', '.join(sorted(item for item,_,_ in bag)))
```

b. Explanation: The anycomb function allows me to return combinations of any length from the items. The totalvalue function allows me to totalize a combination of items. By choosing the max value between a set of nodes after iterating through all the nodes (all the possibilities), it allows me to see and choose the best case.

c. Output:

```
The Brute-Force solution:
Nodes visited  15
Total weight:  12
Total value:  90
Items: 1, 3
```

b. The Backtracking solution.

a. Code:

```
def totalvalue(comb):
    totwt = totval = 0
    for item, wt, val in comb:
        totwt  += wt
        totval += val
    return (totval, -totwt) if totwt <= max_weight else (0, 0)
```

```
def backtrack(items, limit):
    nodes_visited = 0
    table = [[0 for w in range(limit + 1)] for j in xrange(len(items) + 1)]
    for j in xrange(1, len(items) + 1):
        item, wt, val = items[j-1]
        for w in xrange(1, limit + 1):
            if wt > w:
                table[j][w] = table[j-1][w]
                nodes_visited = nodes_visited + 1
            else:
                table[j][w] = max(table[j-1][w], table[j-1][w-wt] + val)
    result = []
    w = limit
    for j in range(len(items), 0, -1):
        was_added = table[j][w] != table[j-1][w]
        if was_added:
            item, wt, val = items[j-1]
            result.append(items[j-1])
            w -= wt
    print "Nodes visited: ", nodes_visited
    return result
# b. The Backtracking solution.
print("\nThe Backtracking solution:")
bagged = backtrack(data_sorted, max_weight)
val, wt = totalvalue(bagged)
print "Total weight: ", -wt
print "Total value: ", val
print("Items: " + ', '.join(sorted(item for item,_,_ in bagged)))
```

b. Explanation: The totalvalue function allows me to totalize a combination of items. If weight of the nth item is more than Knapsack of capacity W, then this item cannot be included in the optimal solution.

c. Output:

```
The Backtracking solution:
Nodes visited:  18
Total weight:  12
Total value:  90
Items: 1, 3
```

c. The Branch-and-Bound solution. Make sure to use the best-first search version.

a. Code:

```
class State(object):
    def __init__(self, level, benefit, weight, token):
        self.level = level
        self.benefit = benefit
        self.weight = weight
        self.token = token
        self.available = self.token[:self.level]+[1]*(len(data_value)-level)
        self.ub = self.upperbound()

    def upperbound(self): #
        upperbound = 0
        weight_accumulate = 0
        for i in range(len(data_weight)):
            if data_weight[i] * self.available[i] <= max_weight - weight_accumulate:
                weight_accumulate += data_weight[i] * self.available[i]
                upperbound += data_value[i] * self.available[i]
            else:
                upperbound += data_value[i] * (max_weight - weight_accumulate) / data_weight[i] * self.available[i]
                break
        return upperbound

    def develop(self):
        level = self.level + 1
        if self.weight + data_weight[self.level] <= max_weight: #if not overweighted, give left child
            left_weight = self.weight + data_weight[self.level]
            left_benefit = self.benefit + data_value[self.level]
            left_token = self.token[:self.level]+[1]+self.token[self.level+1:]
            left_child = State(level, left_benefit, left_weight, left_token)
        else: left_child = None
        right_child = State(level, self.benefit, self.weight, self.token)
        if left_child != None:
            return [left_child, right_child]
        else: return [right_child]
```

```
# c. The Branch-and-Bound solution. Make sure to use the best-first search version.
print("\nThe Branch-and-Bound solution:")
Root = State(0, 0, 0, [0]*len(data_value))
waiting_States = []
current_state = Root
nodes = 0
while current_state.level < len(data_value):
    waiting_States.extend(current_state.develop())
    waiting_States.sort(key=lambda x: x.ub)
    current_state = waiting_States.pop()
    nodes = nodes + 1
best_solution = current_state
best_item = []
for i in range(len(best_solution.token)):
    if (best_solution.token[i] == 1):
        best_item.append(data_item[i])
print "Nodes visited: ", nodes
print "Total weight: ", best_solution.weight
print "Total value: ", best_solution.benefit
print "Items: " + ', '.join(sorted(best_item))
```

b. Explanation: We first sort the data based on their efficiency (value/weight). The class state allows us to utilize a list of markings if a task is taken, or available. We

define the upper bound with fractional knapsack. The initial upperbound is defined as 0. We want to accumulate weight used to stop the upperbound summation. In the develop(self) function, if it is not overweight, we go towards the left child. Otherwise, we go towards the right. Our root state is defined where we start off with nothing. We initialize a waiting_states list, which will define a list of states waiting to be explored. We sort the waiting_states list based on their upperbound, and explore the one with the largest upperbound, implementing the Greedy algorithm.

c. Output:

```
The Branch-and-Bound solution:
Nodes visited:  5
Total weight:  12
Total value:  90
Items: 1, 3
```

When the user starts the program, they should be asked for the following input:

- How many items are there to potentially take?
  - Code:

```
# When the user starts the program, they should be asked for the following input:
print("How many items are there to potentially take?")
num_items = input()
data_item = []
data_weight = []
data_value = []
```

  - Output: (highlighted is user input)

```
How many items are there to potentially take?
4
```

- What is the weight and profit of each item?
  - Code:

```
# • What is the weight and profit of each item?
for x in range(num_items):
  item = raw_input("Enter item (string): ")
  data_item.append(item)
  weight = input("Enter weight (numeric): ")
  data_weight.append(weight)
  value = input("Enter profit (numeric): ")
  data_value.append(value)
```

- Output: (highlighted is user input)

```
Enter item (string): 1
Enter weight (numeric): 2
Enter profit (numeric): 40
Enter item (string): 2
Enter weight (numeric): 5
Enter profit (numeric): 30
Enter item (string): 3
Enter weight (numeric): 10
Enter profit (numeric): 50
Enter item (string): 4
Enter weight (numeric): 5
Enter profit (numeric): 10
```

- What is the max weight the bag can hold?
  - Code:

```
# • What is the max weight the bag can hold?
print("What is the max weight the bag can hold?")
max_weight = input()
```

  - Output: (highlighted is user input)

```
What is the max weight the bag can hold?
16
```

- Then, I map the data in such that I can use:
  - Code:

```
data_eff = map(truediv, data_value, data_weight)
order = [i[0] for i in sorted(enumerate(data_eff), key=lambda x:x[1], reverse=True)]
#sort data based on their 'efficiency', i.e. value/weight
data_eff = [data_eff[i] for i in order]
data_weight = [data_weight[i] for i in order]
data_value = [data_value[i] for i in order]
data_item = [data_item[i] for i in order]

data_sorted = sorted(zip(data_item, data_weight, data_value), key=lambda (i,w,v):v//w, reverse=True)

print "data entered: ", (data_sorted)
```

  - Output:

```
data entered:  [('1', 2, 40), ('2', 5, 30), ('3', 10, 50), ('4', 5, 10)]
```