Programming Abstractions

CS106B

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Today's topics:

- Recursion ~~Week~~ Fortnight continues!
- Today:
  - More *recursive backtracking* code:
    - Gift card spending optimization

Code Example #1

GIFT CARD SPENDING TARGET

Gift card spending optimization

- You've been given a gift card for your birthday, yay!
- The store has a rule that you must use it in one trip, and any unused balance is forfeited
- You'll be given:
  - `int giftCardAmt`: The amount of the gift card
  - `Set<int> itemsForSale`: A set of prices of items for sale (assume only one of each item is in stock)
- **Task:** Can you find a collection of items to buy that will sum to EXACTLY the amount on the gift card??
- Return:
  - `bool`: true if you can find such a collection, otherwise false

Gift card spending optimization

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- The store has a rule that you must use it in one trip, and any unused balance is forfeited
- You'll be given:
  - `int giftCardAmt`: The amount of the gift card
  - `Vector<Item> itemsForSale`: A set of items of for sale (each has `name` and `price`)
- **Task:** Can you find a collection of items to buy that will sum to EXACTLY the amount on the gift card?
- Return:
  - `bool`: true if you can find such a collection, otherwise false

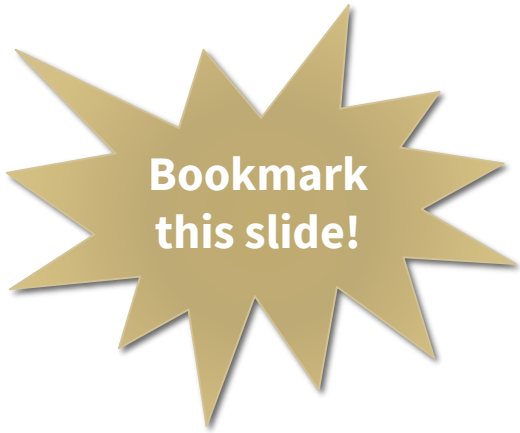
Your Turn:

Help me write some test cases for this function. Come up with at least one basic correctness test, and a couple tricky/edge cases. **Submit yours at pollev.com/cs106b.** One test case per submission, you may submit multiple times.

Format example:

```
4, {1, 2, 5} = false
```

Backtracking template



bool backtrackingRecursiveFunction*(args)* {

- Base case test for success: return true
- Base case test for failure: return false
- Loop over several options for "what to do next":
  1. Tentatively "**choose**" one option
  2. if ("**explore**" with recursive call returns true) return true
  3. else That tentative idea didn't work, so "**un-choose**" that option,
     but don't return false yet!--let the loop explore the other options before giving up!
- None of the options we tried in the loop worked, so return false

}

Backtracking template: applied to Gift Card problem

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What is success for this problem?

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Exactly $0 left on card

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Exactly $0 left on card

What is failure for this problem?

Backtracking template: applied to Gift Card problem

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Exactly $0 left on card

Overspend/negative balance, or no items left to choose.

Backtracking template: applied to Gift Card problem

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Exactly $0 left on card

Overspend/negative balance, or no items left to choose.

What is "one step" for this problem?

What is “one step” in the Gift Card problem?

- We can imagine lining up all the items for sale, and our task is basically to make a binary yes/no decision for purchasing each item
  - The yes’es and no’s can come in any combination, we have to find a combination that sums to our gift card amount

Items:





$1	$5	$3	$2	$10
Y/N: ___	Y/N: ___	Y/N: ___	Y/N: ___	Y/N: ___

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  - The yes’es and no’s can come in any combination, we have to find a combination that sums to our gift card amount

Items:





$1	$5	$3	$2	$10
Y/N: **Y**	Y/N: ___	Y/N: ___	Y/N: ___	Y/N: ___

One step/decision

Delegate the rest to recursion

What is “one step” in the Gift Card problem?

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  - The yes’es and no’s can come in any combination, we have to find a combination that sums to our gift card amount

Items:





$1	$5	$3	$2	$10
Y/N: **Y**	Y/N: ___	Y/N: ___	Y/N: ___	Y/N: ___

One step/decision

If recursion comes back with the answer that no combination works for this set and the remaining funds, reconsider our Y on the banana.

What is “one step” in the Gift Card problem?

- We can imagine lining up all the items for sale, and our task is basically to make a binary yes/no decision for purchasing each item
  - The yes’es and no’s can come in any combination, we have to find a combination that sums to our gift card amount

Items:





$1	$5	$3	$2	$10
Y/N: **Y**	Y/N: ___	Y/N: ___	Y/N: ___	Y/N: ___

One step/decision

Conclusion: one step/decision has two options to “loop” over: Y and N (for one item).

Backtracking template: applied to Gift Card problem

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}

Exactly $0 left on card

Overspend/negative balance, or no items left to choose.

Taking one item, "loop" over Y and N options for that item (we won't actually loop since Y and N are only two options, a loop is excessive)

If both Y and N options for an item fail, we've exhausted all possibilities, so return false.

Comparing our solution and the design template

```
// base case success: card amount is spent down to 0 exactly
if (giftCardAmt == 0) {
    return true;
}
// base case failure: we either overspent, or we need to spend more but there are
//                    no more items for to consider, so we can't succeed
if (giftCardAmt < 0 || index == itemsForSale.size()) {
    return false;
}

// recursive case: consider 1 next item (at `in
Item item = itemsForSale[index];
// Our two choices are that we can either BUY T
//   other additional purchases with less money
itemsToBuy.add(item);
if (canUseFullGiftCard(giftCardAmt - item.price
    return true;
}
// ...or NOT BUY THE ITEM and go on to conider
//    the same amount to spend.
itemsToBuy.remove(itemsToBuy.size() - 1);
if (canUseFullGiftCard(giftCardAmt, itemsForSale, itemsToBuy, index + 1)) {
    return true;
}
return false; // if neither of the two options can work, we have exhau
```

Try both Y and N

bool backtrackingRecursiveFunction*(args)* {

- Base case test for success: return true
- Base case test for failure: return false
- ~~Loop~~ over several options for "what to do next":
  1. Tentatively "**choose**" one option
  2. if ("**explore**" with recursive call returns true) return true
  3. else That tentative idea didn't work, so "**un-choose**" that option,
     but don't return false yet!--let the loop explore the other options before giv
- None of the options we tried in the loop worked, so return false

}

Code Example #2

GIFT CARD SPENDING OPTIMIZATION

Gift card spending optimization

- You've been given a gift card for your birthday, yay!
- The store has a rule that you must use it in one trip, and any unused balance is forfeited
- You'll be given:
  - `int giftCardAmt`: The amount of the gift card
  - `Set<int> itemsForSale`: A set of prices of items for sale (assume only one of each item is in stock)
- **Task:** Of all the collections of items to buy, what is one that will sum the closest to the amount on the gift card?
  - This is a slight loosening of the *exact* match requirement of the original problem

```
// base case success: card amount is spent down to 0 exactly
if (giftCardAmt == 0) {
    return true;
}
// base case failure: we either overspent, or we need to spend more
//                    no more items for to consider, so we can't suc
if (giftCardAmt < 0 || index == itemsForSale.size()) {
    return false;
}

// recursive case: consider 1 next item (at `index`)
Item item = itemsForSale[index];
// Our two choices are that we can either BUY THE ITEM and go on to consider
//   other additional purchases with less money to spend...
itemsToBuy.add(item);
if (canUseFullGiftCard(giftCardAmt - item.price, itemsForSale, itemsToBuy, index + 1))
    return true;
}
// ...or NOT BUY THE ITEM and go on to conider other additional purchases with
//    the same amount to spend.
itemsToBuy.remove(itemsToBuy.size() - 1);
if (canUseFullGiftCard(giftCardAmt, itemsForSale, itemsToBuy, index + 1)) {
    return true;
}
return false; // if neither of the two options can work, we have exhau
```

What do we need to change?