FACULTY OF COMPUTER SCIENCE AND INFORMATION TECHNOLOGY

CSC4202 Design and Analysis of Algorithms

Assignment 2 - Real-Life Carry-On Knapsack

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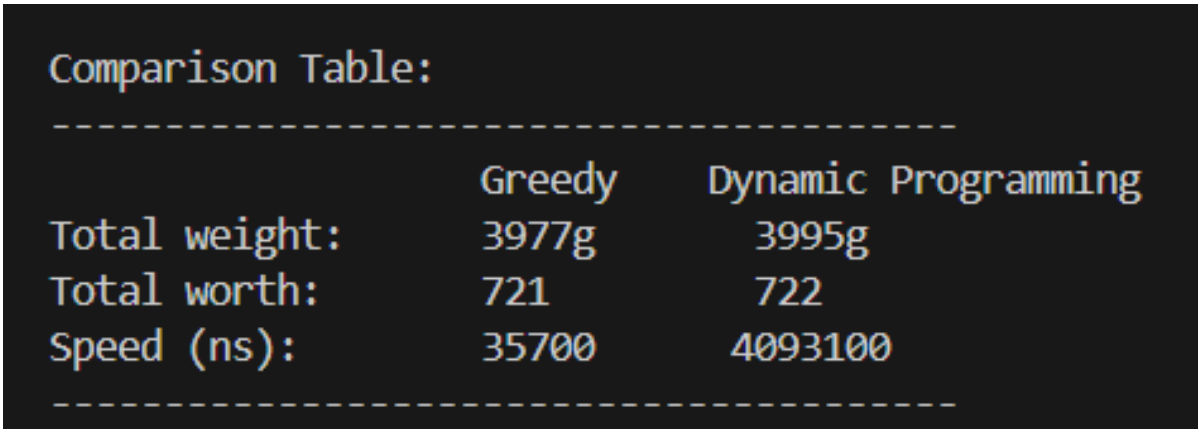
Results

Limit: 4000kg

	Greedy algorithm	Dynamic programming
Total weight	3977g	3995g
Total worth	721	722
Speed	35700ns	4093100ns



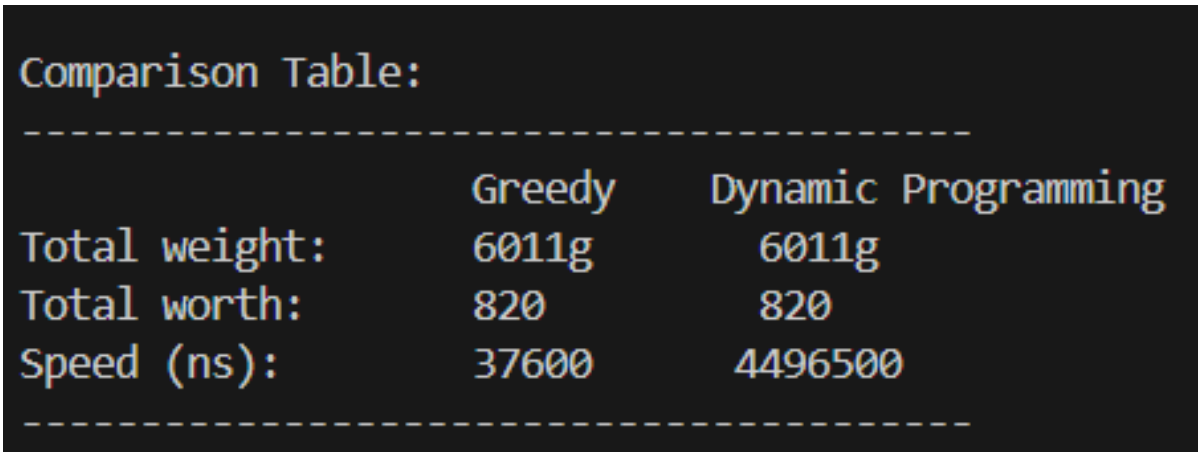
Among the two approaches, Dynamic Programming proves to be the better solution for this problem, as it yields the highest total worth of 722 while remaining within the 4kg weight limit (3995g). Although it requires more computation time compared to the Greedy algorithm, the slight delay is justified by its ability to guarantee an optimal solution. This is especially important in real-world constrained packing scenarios, where every gram and every item's value matters. In contrast, the Greedy algorithm, despite being significantly faster, relies on local heuristics such as the worth-to-weight ratio, which may overlook globally optimal combinations. Therefore, when the goal is to maximize total worth under a fixed capacity, Dynamic Programming offers a more reliable and accurate outcome.

```
Greedy Solution:
Total weight: 3977g
Total worth: 721
Selected items:
- Innergie PocketCell USB-C 6000mAh power bank (Worth: 17, Weight: 14g)
- JBL Reflect Mini Bluetooth Sport Headphones (Worth: 13, Weight: 14g)
- 10 pairs thongs (Worth: 39, Weight: 80g)
- 2 pairs Injinji Women's Run Lightweight No-Show Toe Socks (Worth: 25, Weight: 54g)
- Lightweight Merino Wool Buff (Worth: 20, Weight: 50g)
- Oakley Latch Sunglasses (Worth: 11, Weight: 30g)
- Lenovo X1 Carbon (5th Gen) (Worth: 40, Weight: 112g)
- Laptop Bag (Worth: 7, Weight: 20g)
- 1 fancy tank top (Worth: 24, Weight: 71g)
- Petzl E+LITE Emergency Headlamp (Worth: 8, Weight: 27g)
- 5 pairs black socks (Worth: 26, Weight: 95g)
- 2 pairs Nike Pro shorts (Worth: 30, Weight: 112g)
- Field Notes Pitch Black Memo Book Dot-Graph (Worth: 18, Weight: 68g)
- Peak Design Cuff Camera Wrist Strap (Worth: 6, Weight: 26g)
- Ray Ban Wayfarer Classic (Worth: 10, Weight: 45g)
- 2 Lululemon Cool Racerback (Worth: 36, Weight: 174g)
- Seagate Backup PlusSlim (Worth: 32, Weight: 159g)
- 1 pair Uniqlo leggings (Worth: 37, Weight: 185g)
- The Roost Stand (Worth: 34, Weight: 170g)
- Touchlight (Worth: 2, Weight: 10g)
- 2 Underarmour HeatGear CoolSwitch tank tops (Worth: 27, Weight: 138g)
- 2 pairs Lululemon shorts (Worth: 29, Weight: 184g)
- 1 pair black denim shorts (Worth: 31, Weight: 197g)
- 1 light and stretchylong-sleeve shirt (Gap Fit) (Worth: 23, Weight: 147g)
- Isabella T-Strap Croc sandals (Worth: 28, Weight: 200g)
- Humangear GoBites Duo (Worth: 3, Weight: 22g)
- Anker SoundCore nano Bluetooth Speaker (Worth: 12, Weight: 89g)
- 5 Underarmour Strappy (Worth: 38, Weight: 305g)
- 1 LBD (H&M) (Worth: 19, Weight: 174g)
- Deuter First Aid Kit Active (Worth: 15, Weight: 144g)
- Uniqlo Ultralight Down insulating jacket (Worth: 22, Weight: 235g)
- ThinkPad Compact Bluetooth Keyboard with trackpoint (Worth: 33, Weight: 460g)
- Travelon Micro Scale (Worth: 5, Weight: 125g)
- Vapur Bottle 1L (Worth: 1, Weight: 41g)
```

```
Dynamic Programming Solution:
Total weight: 3995g
Total worth: 722
Selected items:
- Lenovo X1 Carbon (5th Gen) (Worth: 40, Weight: 112g)
- 10 pairs thongs (Worth: 39, Weight: 80g)
- 5 Underarmour Strappy (Worth: 38, Weight: 305g)
- 1 pair Uniqlo leggings (Worth: 37, Weight: 185g)
- 2 Lululemon Cool Racerback (Worth: 36, Weight: 174g)
- The Roost Stand (Worth: 34, Weight: 170g)
- Seagate Backup PlusSlim (Worth: 32, Weight: 159g)
- 1 pair black denim shorts (Worth: 31, Weight: 197g)
- 2 pairs Nike Pro shorts (Worth: 30, Weight: 112g)
- 2 pairs Lululemon shorts (Worth: 29, Weight: 184g)
- Isabella T-Strap Croc sandals (Worth: 28, Weight: 200g)
- 2 Underarmour HeatGear CoolSwitch tank tops (Worth: 27, Weight: 138g)
- 5 pairs black socks (Worth: 26, Weight: 95g)
- 2 pairs Injinji Women's Run Lightweight No-Show Toe Socks (Worth: 25, Weight: 54g)
- 1 fancy tank top (Worth: 24, Weight: 71g)
- 1 light and stretchylong-sleeve shirt (Gap Fit) (Worth: 23, Weight: 147g)
- Uniqlo Ultralight Down insulating jacket (Worth: 22, Weight: 235g)
- Patagonia Torrentshell (Worth: 21, Weight: 301g)
- Lightweight Merino Wool Buff (Worth: 20, Weight: 50g)
- 1 LBD (H&M) (Worth: 19, Weight: 174g)
- Field Notes Pitch Black Memo Book Dot-Graph (Worth: 18, Weight: 68g)
- Innergie PocketCell USB-C 6000mAh power bank (Worth: 17, Weight: 14g)
- Important papers (Worth: 16, Weight: 228g)
- Deuter First Aid Kit Active (Worth: 15, Weight: 144g)
- JBL Reflect Mini Bluetooth Sport Headphones (Worth: 13, Weight: 14g)
- Anker SoundCore nano Bluetooth Speaker (Worth: 12, Weight: 89g)
- Oakley Latch Sunglasses (Worth: 11, Weight: 30g)
- Ray Ban Wayfarer Classic (Worth: 10, Weight: 45g)
- Petzl E+LITE Emergency Headlamp (Worth: 8, Weight: 27g)
- Laptop Bag (Worth: 7, Weight: 20g)
- Peak Design Cuff Camera Wrist Strap (Worth: 6, Weight: 26g)
- Travelon Micro Scale (Worth: 5, Weight: 125g)
- Humangear GoBites Duo (Worth: 3, Weight: 22g)
```

Limit: 7000kg

	Greedy algorithm	Dynamic programming
Total weight	6011g	6011g
Total worth	820	820
Speed	37600ns	4496500ns



With the increased capacity limit of 7000g, both the Greedy and Dynamic Programming algorithms were able to include all available items without constraint, resulting in an identical total weight of 6011g and total worth of 820. This demonstrates that in scenarios where the knapsack capacity exceeds the total weight of all items, both algorithms converge to the same outcome. However, the execution time differs significantly, with the Greedy algorithm completing in just 37,600ns, while the Dynamic Programming approach took 4,496,500ns. Although both achieved optimal results in this unconstrained case, the Greedy algorithm is clearly more efficient in terms of speed. Therefore, in situations where capacity is not a limiting factor, the Greedy approach may be preferred for its simplicity and performance. However, in more constrained scenarios, Dynamic Programming remains essential for guaranteeing optimal solutions.

```
Dynamic Programming Solution:
Total weight: 6011g
Total worth: 820
Selected items:
- Lenovo X1 Carbon (5th Gen) (Worth: 40, Weight: 112g)
- 10 pairs thongs (Worth: 39, Weight: 80g)
- 5 Underarmour Strappy (Worth: 38, Weight: 305g)
- 1 pair Uniqlo leggings (Worth: 37, Weight: 185g)
- 2 Lululemon Cool Racerback (Worth: 36, Weight: 174g)
- Chargers and cables in Mini Bomber Travel Kit (Worth: 35, Weight: 665g)
- The Roost Stand (Worth: 34, Weight: 170g)
- ThinkPad Compact Bluetooth Keyboard with trackpoint (Worth: 33, Weight: 460g)
- Seagate Backup PlusSlim (Worth: 32, Weight: 159g)
- 1 pair black denim shorts (Worth: 31, Weight: 197g)
- 2 pairs Nike Pro shorts (Worth: 30, Weight: 112g)
- 2 pairs Lululemon shorts (Worth: 29, Weight: 184g)
- Isabella T-Strap Croc sandals (Worth: 28, Weight: 200g)
- 2 Underarmour HeatGear CoolSwitch tank tops (Worth: 27, Weight: 138g)
- 5 pairs black socks (Worth: 26, Weight: 95g)
- 2 pairs Injinji Women's Run Lightweight No-Show Toe Socks (Worth: 25, Weight: 54g)
- 1 fancy tank top (Worth: 24, Weight: 71g)
- 1 light and stretchylong-sleeve shirt (Gap Fit) (Worth: 23, Weight: 147g)
- Uniqlo Ultralight Down insulating jacket (Worth: 22, Weight: 235g)
- Patagonia Torrentshell (Worth: 21, Weight: 301g)
- Lightweight Merino Wool Buff (Worth: 20, Weight: 50g)
- 1 LBD (H&M) (Worth: 19, Weight: 174g)
- Field Notes Pitch Black Memo Book Dot-Graph (Worth: 18, Weight: 68g)
- Innergie PocketCell USB-C 6000mAh power bank (Worth: 17, Weight: 14g)
- Important papers (Worth: 16, Weight: 228g)
- Deuter First Aid Kit Active (Worth: 15, Weight: 144g)
- Stanley Classic Vacuum Camp Mug 16oz (Worth: 14, Weight: 454g)
- JBL Reflect Mini Bluetooth Sport Headphones (Worth: 13, Weight: 14g)
- Anker SoundCore nano Bluetooth Speaker (Worth: 12, Weight: 89g)
- Oakley Latch Sunglasses (Worth: 11, Weight: 30g)
- Ray Ban Wayfarer Classic (Worth: 10, Weight: 45g)
- Zip bag of toiletries (Worth: 9, Weight: 236g)
- Petzl E+LITE Emergency Headlamp (Worth: 8, Weight: 27g)
- Laptop Bag (Worth: 7, Weight: 20g)
- Peak Design Cuff Camera Wrist Strap (Worth: 6, Weight: 26g)
- Travelon Micro Scale (Worth: 5, Weight: 125g)
- BlitzWolf Bluetooth Tripod/Monopod (Worth: 4, Weight: 150g)
- Humangear GoBites Duo (Worth: 3, Weight: 22g)
- Touchlight (Worth: 2, Weight: 10g)
- Vapur Bottle 1L (Worth: 1, Weight: 41g)
```

```
Greedy Solution:
Total weight: 6011g
Total worth: 820
Selected items:
- Innergie PocketCell USB-C 6000mAh power bank (Worth: 17, Weight: 14g)
- JBL Reflect Mini Bluetooth Sport Headphones (Worth: 13, Weight: 14g)
- 10 pairs thongs (Worth: 39, Weight: 80g)
- 2 pairs Injinji Women's Run Lightweight No-Show Toe Socks (Worth: 25, Weight: 54g)
- Lightweight Merino Wool Buff (Worth: 20, Weight: 50g)
- Oakley Latch Sunglasses (Worth: 11, Weight: 30g)
- Lenovo X1 Carbon (5th Gen) (Worth: 40, Weight: 112g)
- Laptop Bag (Worth: 7, Weight: 20g)
- 1 fancy tank top (Worth: 24, Weight: 71g)
- Petzl E+LITE Emergency Headlamp (Worth: 8, Weight: 27g)
- 5 pairs black socks (Worth: 26, Weight: 95g)
- 2 pairs Nike Pro shorts (Worth: 30, Weight: 112g)
- Field Notes Pitch Black Memo Book Dot-Graph (Worth: 18, Weight: 68g)
- Peak Design Cuff Camera Wrist Strap (Worth: 6, Weight: 26g)
- Ray Ban Wayfarer Classic (Worth: 10, Weight: 45g)
- 2 Lululemon Cool Racerback (Worth: 36, Weight: 174g)
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- The Roost Stand (Worth: 34, Weight: 170g)
- Touchlight (Worth: 2, Weight: 10g)
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- 2 pairs Lululemon shorts (Worth: 29, Weight: 184g)
- 1 pair black denim shorts (Worth: 31, Weight: 197g)
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- Isabella T-Strap Croc sandals (Worth: 28, Weight: 200g)
- Humangear GoBites Duo (Worth: 3, Weight: 22g)
- Anker SoundCore nano Bluetooth Speaker (Worth: 12, Weight: 89g)
- 5 Underarmour Strappy (Worth: 38, Weight: 305g)
- 1 LBD (H&M) (Worth: 19, Weight: 174g)
- Deuter First Aid Kit Active (Worth: 15, Weight: 144g)
- Uniqlo Ultralight Down insulating jacket (Worth: 22, Weight: 235g)
- ThinkPad Compact Bluetooth Keyboard with trackpoint (Worth: 33, Weight: 460g)
- Important papers (Worth: 16, Weight: 228g)
- Patagonia Torrentshell (Worth: 21, Weight: 301g)
- Chargers and cables in Mini Bomber Travel Kit (Worth: 35, Weight: 665g)
- Travelon Micro Scale (Worth: 5, Weight: 125g)
- Zip bag of toiletries (Worth: 9, Weight: 236g)
- Stanley Classic Vacuum Camp Mug 16oz (Worth: 14, Weight: 454g)
- BlitzWolf Bluetooth Tripod/Monopod (Worth: 4, Weight: 150g)
- Vapur Bottle 1L (Worth: 1, Weight: 41g)
```

Source Code

https://github.com/Chance3009/knapsack

```java
public class Item {
    public String name;
    public int worth;
    public int weight;

    public Item(String name, int worth, int weight) {
        this.name = name;
        this.worth = worth;
        this.weight = weight;
    }

    @Override
    public String toString() {
        return name + " (Worth: " + worth + ", Weight: " + weight + "g)";
    }
}
```

```java
public interface Knapsack {
    void solve();
    int getTotalWorth();
    int getTotalWeight();
    Item[] getSelectedItems();
    long getExecutionTime();
}
```

```java
public class GreedyKnapsack implements Knapsack {
    private Item[] items;
    private int capacity;
    private boolean[] selected;
    private long executionTime;
    private int totalWorth;
    private int totalWeight;

    public GreedyKnapsack(Item[] items, int capacity) {
        this.items = items.clone();  // Make a copy of the array
        this.capacity = capacity;
        this.selected = new boolean[items.length];
    }

    public void solve() {
        long startTime = System.nanoTime();

        // Sort items by worth/weight ratio using selection sort
        for (int i = 0; i < items.length - 1; i++) {
            int maxIndex = i;
            for (int j = i + 1; j < items.length; j++) {
                if ((double)items[j].worth / items[j].weight >
                    (double)items[maxIndex].worth / items[maxIndex].weight) {
                    maxIndex = j;
                }
            }
            if (maxIndex != i) {
                Item temp = items[i];
                items[i] = items[maxIndex];
                items[maxIndex] = temp;
            }
        }

        // Select items
        totalWeight = 0;
        totalWorth = 0;
        for (int i = 0; i < items.length; i++) {
            if (totalWeight + items[i].weight <= capacity) {
                selected[i] = true;
                totalWeight += items[i].weight;
                totalWorth += items[i].worth;
            }
        }

        executionTime = System.nanoTime() - startTime;
    }

    public int getTotalWorth() {
        return totalWorth;
    }

    public int getTotalWeight() {
        return totalWeight;
    }

    public Item[] getSelectedItems() {
        int count = 0;
        for (boolean s : selected) {
            if (s) count++;
        }

        Item[] selectedItems = new Item[count];
        int index = 0;
        for (int i = 0; i < items.length; i++) {
            if (selected[i]) {
                selectedItems[index++] = items[i];
            }
        }
        return selectedItems;
    }

    public long getExecutionTime() {
        return executionTime;
    }
}
```

```java
import java.util.Arrays;

public class DPKnapsack implements Knapsack {
    private Item[] items;
    private int capacity;
    private int[][] dp;
    private boolean[] selected;
    private long executionTime;

    public DPKnapsack(Item[] items, int capacity) {
        this.items = items.clone();  // Make a copy of the array
        this.capacity = capacity;
        this.dp = new int[items.length + 1][capacity + 1];
        this.selected = new boolean[items.length];
    }

    public void solve() {
        long startTime = System.nanoTime();

        // Initialize first row with zeros
        for (int j = 0; j <= capacity; j++) {
            dp[0][j] = 0;
        }

        // Fill the dp table
        for (int i = 1; i <= items.length; i++) {
            Item item = items[i-1];
            for (int j = 0; j <= capacity; j++) {
                // By default, inherit previous state
                dp[i][j] = dp[i-1][j];

                // Try to include current item if it fits
                if (j >= item.weight) {
                    int withItem = item.worth + dp[i-1][j - item.weight];
                    if (withItem > dp[i][j]) {
                        dp[i][j] = withItem;
                    }
                }
            }
        }

        // Trace back
        Arrays.fill(selected, false);
        int j = capacity;
        int remainingCapacity = capacity;
        int remainingProfit = dp[items.length][j];

        for (int i = items.length; i > 0 && remainingCapacity > 0 && remainingProfit > 0; i--) {
            Item item = items[i-1];
            // Check if this item was included by comparing with previous state
            if (remainingCapacity >= item.weight && dp[i][remainingCapacity] != dp[i-1][remainingCapacity
]) {
                selected[i-1] = true;
                remainingProfit -= item.worth;
                remainingCapacity -= item.weight;
            }
        }

        executionTime = System.nanoTime() - startTime;
    }

    public int getTotalWorth() {
        return dp[items.length][capacity];
    }

    public int getTotalWeight() {
        int weight = 0;
        for (int i = 0; i < items.length; i++) {
            if (selected[i]) {
                weight += items[i].weight;
            }
        }
        return weight;
    }

    public Item[] getSelectedItems() {
        int count = 0;
        for (boolean s : selected) {
            if (s) count++;
        }

        Item[] selectedItems = new Item[count];
        int index = 0;
        for (int i = 0; i < items.length; i++) {
            if (selected[i]) {
                selectedItems[index++] = items[i];
            }
        }
        return selectedItems;
    }

    public long getExecutionTime() {
        return executionTime;
    }
}

```

```java
public class Main {
    public static void main(String[] args) {
        Item[] items = new Item[] {
            new Item("Lenovo X1 Carbon (5th Gen)", 40, 112),
            new Item("10 pairs thongs", 39, 80),
            new Item("5 Underarmour Strappy", 38, 305),
            new Item("1 pair Uniqlo leggings", 37, 185),
            new Item("2 Lululemon Cool Racerback", 36, 174),
            new Item("Chargers and cables in Mini Bomber Travel Kit", 35, 665),
            new Item("The Roost Stand", 34, 170),
            new Item("ThinkPad Compact Bluetooth Keyboard with trackpoint", 33, 460),
            new Item("Seagate Backup PlusSlim", 32, 159),
            new Item("1 pair black denim shorts", 31, 197),
            new Item("2 pairs Nike Pro shorts", 30, 112),
            new Item("2 pairs Lululemon shorts", 29, 184),
            new Item("Isabella T-Strap Croc sandals", 28, 200),
            new Item("2 Underarmour HeatGear CoolSwitch tank tops", 27, 138),
            new Item("5 pairs black socks", 26, 95),
            new Item("2 pairs Injinji Women's Run Lightweight No-Show Toe Socks", 25, 54),
            new Item("1 fancy tank top", 24, 71),
            new Item("1 light and stretchylong-sleeve shirt (Gap Fit)", 23, 147),
            new Item("Uniqlo Ultralight Down insulating jacket", 22, 235),
            new Item("Patagonia Torrentshell", 21, 301),
            new Item("Lightweight Merino Wool Buff", 20, 50),
            new Item("1 LBD (H&M)", 19, 174),
            new Item("Field Notes Pitch Black Memo Book Dot-Graph", 18, 68),
            new Item("Innergie PocketCell USB-C 6000mAh power bank", 17, 14),
            new Item("Important papers", 16, 228),
            new Item("Deuter First Aid Kit Active", 15, 144),
            new Item("Stanley Classic Vacuum Camp Mug 16oz", 14, 454),
            new Item("JBL Reflect Mini Bluetooth Sport Headphones", 13, 14),
            new Item("Anker SoundCore nano Bluetooth Speaker", 12, 89),
            new Item("Oakley Latch Sunglasses", 11, 30),
            new Item("Ray Ban Wayfarer Classic", 10, 45),
            new Item("Zip bag of toiletries", 9, 236),
            new Item("Petzl E+LITE Emergency Headlamp", 8, 27),
            new Item("Laptop Bag", 7, 20),
            new Item("Peak Design Cuff Camera Wrist Strap", 6, 26),
            new Item("Travelon Micro Scale", 5, 125),
            new Item("BlitzWolf Bluetooth Tripod/Monopod", 4, 150),
            new Item("Humangear GoBites Duo", 3, 22),
            new Item("Touchlight", 2, 10),
            new Item("Vapur Bottle 1L", 1, 41)
        };

        int capacity = 4000;

        System.out.println("Dynamic Programming Solution:");
        DPKnapsack dp = new DPKnapsack(items, capacity);
        dp.solve();
        printResults(dp);

        System.out.println("\nGreedy Solution:");
        GreedyKnapsack greedy = new GreedyKnapsack(items, capacity);
        greedy.solve();
        printResults(greedy);

        System.out.println("\nComparison Table:");
        System.out.println("----------------------------------------");
        System.out.println("                    Greedy    Dynamic Programming");
        System.out.println("Total weight:       " + greedy.getTotalWeight() + "g       " + dp.getTotalWeight() + "g");
        System.out.println("Total worth:        " + greedy.getTotalWorth() + "        " + dp.getTotalWorth());
        System.out.println("Speed (ns):         " + greedy.getExecutionTime() + "      " + dp.getExecutionTime());
        System.out.println("----------------------------------------");
    }

    private static void printResults(Knapsack knapsack) {
        System.out.println("Total weight: " + knapsack.getTotalWeight() + "g");
        System.out.println("Total worth: " + knapsack.getTotalWorth());
        System.out.println("Selected items:");
        for (Item item : knapsack.getSelectedItems()) {
            System.out.println("- " + item);
        }
    }
}
```