COSC 1020: Week 8

Topics: Aggregation

To do: Chapter 8, Lab 8

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Outline

- **Introduction**
- **Aggregation API**
- **Collections**
- **Algorithm complexity**
- **Further example usage**

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Outline

- **Introduction**
- **Aggregation API**
- **Collections**
- **Algorithm complexity**
- **Further example usage**

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Introduction

Motivation

- Our everyday world is full of objects.
  - cars
  - audio/video (A/V) systems
  - computers
- Typically, systems (objects) of even moderate complexity are comprised of subsystems.
  - Car: body, wheels, engine, …
  - A/V system: Receiver, monitor, speakers, …
  - Computers: processor, memory, IO devices, …
- Indeed, the subsystems often are comprised of subsubsystems...

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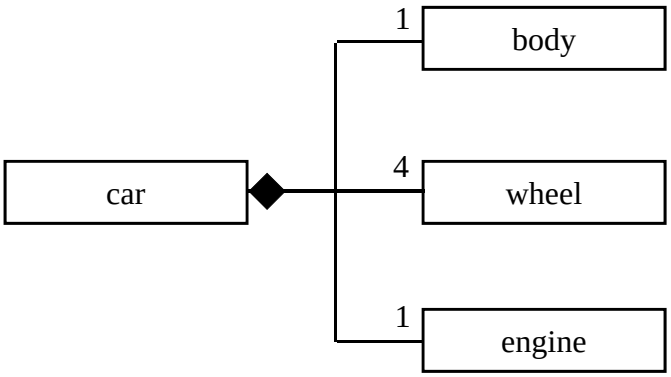
Introduction

Motivation

- Example: Because a car is comprised of a body, wheel and engine, we can capture it via UML aggregation (has-a) representation.
- We say that the car aggregates its components.



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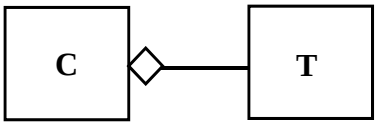
Introduction

Aggregation

- A typical software system uses several classes, including the app.
- It is useful to depict the interrelationships that hold.
- Aggregation (has-a): Class C aggregates class T if C has T as an attribute.
- We call C the aggregate class.
- We call T the component or aggregated class.



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Introduction

Class aggregation

- Our software world is full of objects.
  - Investment
  - Portfolio
  - CreditCard
- Typically, objects of even moderate complexity are comprised of objects.
  - Investment: Stock
  - Portfolio: Investment(s)
  - CreditCard: Dates
- Indeed, the Portfolio is comprised of Investments, which are comprised of Stocks.

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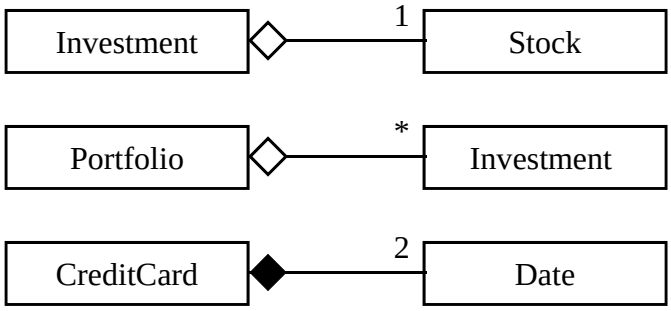
Introduction

Class aggregation

- Examples: We have introduced three has-a relationships; these can be captured via UML.
- We say that the aggregate class aggregates its component (aggregated) class(es) .



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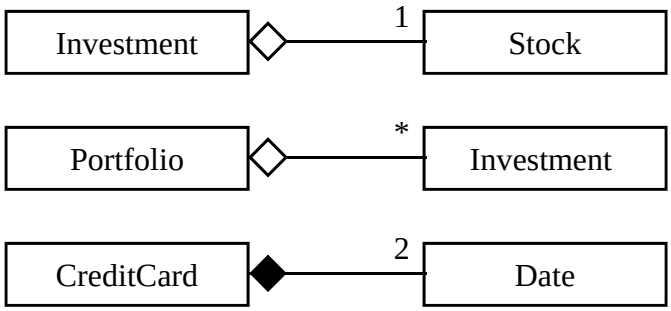
Introduction

Multiplicity

- In addition to the aggregate and aggregated classes, aggregation is characterized via multiplicity.
- Multiplicity is the number of attributes in the aggregate class that are of the aggregated type.



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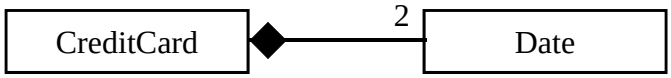
Introduction

Composition

- An aggregation between an aggregate class C and an aggregated class T is called a composition if creating an instance of C automatically leads to creating one or more instances of T.



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Introduction

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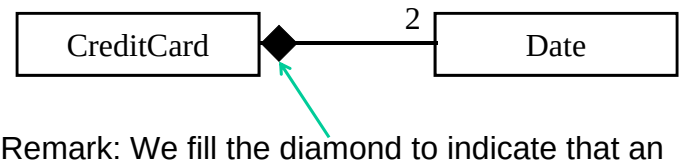

- Remark: We fill the diamond to indicate that an aggregate is a composition.

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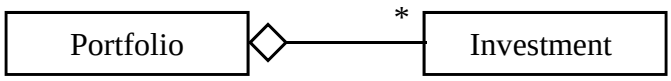
Introduction

Collection

- An aggregation between an aggregate class C and an aggregated class T is called a collection if, rather than forcing all components to be created with the aggregate, an app is allowed to create/add components at any time.



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Outline

- Introduction
- **Aggregation API**
- Collections
- Algorithm complexity
- Further example usage

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Aggregation API

Construction of aggregations (non-compositions)

- The aggregate class expects an app to create needed components (aggregated classes)…
- … and then pass the needed references to the aggregate constructor.

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Aggregation API

Construction of aggregations (non-compositions)

- The aggregate class expects an app to create needed components (aggregated classes)…
- … and then pass the needed references to the aggregate constructor.

Example API

Constructor Summary

Investment(Stock aStock, int aQuantity, double aBValue)
Construct an investment having the passed fields.

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Aggregation API

Construction of aggregations (non-compositions)

- The aggregate class expects an app to create needed components (aggregated classes)…
- … and then pass the needed references to the aggregate constructor.

Example usage

- Create an investment

```
Stock stk = new Stock("TD");
Investment inv = new Investment(stk, 15, 24.45);
```

.

Aggregation API

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Example usage

- Create an investment

```
Stock stk = new Stock("TD");
Investment inv = new Investment(stk, 15, 24.45);
```

Alternatively

```
Investment inv=new Investment(new Stock("TD"),15,24.45);
```

.

Aggregation API

Construction of aggregations (non-compositions)

- The aggregate class expects an app to create needed components (aggregated classes)…
- … and then pass the needed references to the aggregate constructor.

Example usage

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Stock stk = new Stock("TD");
Investment inv = new Investment(stk, 15, 24.45);
```

Alternatively

```
Investment inv=new Investment(new Stock("TD"),15,24.45);
```

- Remark: It is permissible to pass a null reference for the component.

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Aggregation API

Construction of compositions

- In a composition, the aggregate cannot leave it to an app to create components.
- The components are integral to the aggregate and have the same lifetime as the aggregate.
- The constructor creates the components internally as part of its implementation.
- Inspection of the Constructor API does not necessarily reveal presence of aggregated objects.

Aggregation API

Construction of compositions

- In a composition, the aggregate cannot leave it to an app to create components.
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Example API

Constructor Summary

CreditCard(int no, String aName, double aLimit)

Construct a credit card having the passed...

Aggregation API

Construction of compositions

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Example API

Constructor Summary

CreditCard(int no, String aName, double aLimit)

Construct a credit card having the passed...

- Remark: This constructor will implicitly create issue and expiry Date objects (see, java.util.Date).

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Aggregation API

Construction of compositions

- In a composition, the aggregate cannot leave it to an app to create components.
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- Inspection of the Constructor API does not necessarily reveal presence of aggregated objects.

Example usage

- Create a CreditCard

```
CreditCard myCard = new CreditCard(666, “Poe”, 5000.00);
```

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Aggregation API

Construction of compositions

- In a composition, the aggregate cannot leave it to an app to create components.
- The components are integral to the aggregate and have the same lifetime as the aggregate.
- The constructor creates the components internally as part of its implementation.
- Inspection of the Constructor API does not necessarily reveal presence of aggregated objects.

Example usage

- Create a CreditCard

```
CreditCard myCard = new CreditCard(666, “Poe”, 5000.00);
```

- Remark: Issue and expiry Date objects have been created for myCard.

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Aggregation API

Component access

- An aggregate class must provide a way to access its components.
- Otherwise, an app would have no way to avail itself to the component objects.

Aggregation API

Component access

- An aggregate class must provide a way to access its components.
- Otherwise, an app would have no way to avail itself to the component objects.
- Example usage

```
Stock stk = new Stock("TD");
Investment inv = new Investment(stk, 15, stk.getPrice());
Stock stk2 = inv.getStock();
```

Aggregation API

Component access

- An aggregate class must provide a way to access its components.
- Otherwise, an app would have no way to avail itself to the component objects.
- Example usage

```
Stock stk = new Stock("TD");
Investment inv = new Investment(stk, 15, stk.getPrice());
Stock stk2 = inv.getStock();
CreditCard myCard = new CreditCard(666, "Poe", 5.00);
Date myIssue = myCard.getIssueDate();
Date myExpiry = myCard.getExpiryDate();
```

Aggregation API

Component access

- An aggregate class must provide a way to access its components.
- Otherwise, an app would have no way to avail itself to the component objects.
- Example usage

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Stock stk = new Stock("TD");
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CreditCard myCard = new CreditCard(666, "Poe", 5.00);
Date myIssue = myCard.getIssueDate();
Date myExpiry = myCard.getExpiryDate();
```

- Remark: We do not need to use new, as the components already have been created.

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Aggregation API

Component access

- A question of interest: Should the component accessor return
  - a reference to the component per se

  or
  - a reference to a copy of the component?

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Aggregation API

Component access

- A question of interest: Should the component accessor return
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  or
  - a reference to a copy of the component?
- Either approach will allow the app to retrieve information about the component.

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Aggregation API

Component access

- A question of interest: Should the component accessor return
  - a reference to the component per se

  or
  - a reference to a copy of the component?
- Either approach will allow the app to retrieve information about the component.
- However,
  - Reference to the component per se: Allows the app to modify (mutate) the original component.
  - Reference to a copy of the component: Does not allow app to modify the component, only the copy.

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Aggregation API

Component access

- A question of interest: Should the component accessor return
  - Reference to the component: Allows modification of component by app

  or
  - Reference to a copy of component: Does not allow modification of component by app.

Aggregation API

Component access

- A question of interest: Should the component accessor return
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- Answer (in two parts):

Aggregation API

Component access

- A question of interest: Should the component accessor return
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- Answer (in two parts):
  - If the app created the component, then it should be able to modify it. →Non-composition aggregations should return reference to component.

Aggregation API

Component access

- A question of interest: Should the component accessor return
  - Reference to the component: Allows modification of component by app

  or
  - Reference to a copy of component: Does not allow modification of component by app.
- Answer (in two parts):
  - If the app created the component, then it should be able to modify it. →Non-composition aggregations should return reference to component.
  - If the app did not create the component, then it should not be able to modify it. → Compositions should return reference to copy of component

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Aggregation API

Component access and mutation

- Compare the results of an accessor returning reference to component vs. reference to copy of component.
- Reference to component

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Aggregation API

Component access and mutation

- Compare the results of an accessor returning reference to component vs. reference to copy of component.
- Reference to component

```
Investment inv = new Investment(new Stock(“TD”),2,24.45);
output.println(inv.getStock()); // prints TD
Stock stk = inv.getStock();
stk.setSymbol(“RY”);
output.println(stk); // prints Royal
output.println(inv.getStock()); // prints Royal
```

-

Aggregation API

Component access and mutation

- Compare the results of an accessor returning reference to component vs. reference to copy of component.
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Investment inv = new Investment(new Stock("TD"),2,24.45);
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Stock stk = inv.getStock();
stk.setSymbol("RY");
output.println(stk); // prints Royal
output.println(inv.getStock()); // prints Royal
```

- Remark: Investment aggregates, but not as a composition.

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Aggregation API

Component access and mutation

- Compare the results of an accessor returning reference to component vs. reference to copy of component.
- Reference to copy of component

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Aggregation API

Component access and mutation

- Compare the results of an accessor returning reference to component vs. reference to copy of component.
- Reference to copy of component

```
CreditCard myCard = new CreditCard(1, “Wildes”);
output.println(myCard.getIssueDate()); // time is creation time
Date myIssue = myCard.getIssueDate();
myIssue.setTime(0); // see java.util.Date
output.println(myIssue); // time is 0
output.println(myCard.getIssueDate()); // time is creation time
```

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Aggregation API

Component access and mutation

- Compare the results of an accessor returning reference to component vs. reference to copy of component.
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```
CreditCard myCard = new CreditCard(1, “Wildes”);
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myIssue.setTime(0); // see java.util.Date
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```

- Remark: CreditCard aggregates as a composition.

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Aggregation API

Aggregation mutation

- Non-composition aggregations typically do not provide mutator methods to change the components.
  - Mutation can be accomplished via the references returned by the collection's accessor methods.

Aggregation API

Aggregation mutation

- Non-composition aggregations typically do not provide mutator methods to change the components.
  - Mutation can be accomplished via the references returned by the collection's accessor methods.
- Compositions must provide mutator methods to change components
  - No reference is provided to the actual components (only reference to a copy of the components).
  - Typically, such mutators come with restrictions (preconditions) in an attempt to maintain consistent state in the component objects.
  - Example: The CreditCard class has a mutator method setExpiryDate that only works if the passed date is not null and is after the issue date.

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Aggregation API

Recapitulation

Feature in Aggregate	Aggregation (non-composition)	Composition
constructor	Expects a component ref to be passed as a parameter; null okay.	No ref. passed; component created by constructor.
accessor	Must be present in API; returns a component ref.	Must be present in API; returns ref. to component copy.
mutator	Not needed; can mutate via accessor.	Possibly; but with restrictions (preconditions).

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Outline

- Introduction
- Aggregation API
- **Collections**
- Algorithm complexity
- Further example usage

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Collections

Basics

- In many cases, an object has a whole collection of components.
- Moreover, the number of components can vary dynamically.
- Examples
  - A course has a collection of students.
  - A portfolio has a collection of investments.

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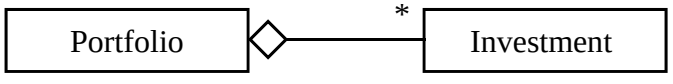
Collections

Basics

- In Java, there are several mechanisms to deal with collections.
  - arrays
  - The Vector class
  - … and others we will see latter.
- Some classes are designed to hide/encapsulate the mechanism that is used to maintain the collection.
  - The Portfolio class.



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Collections

Construction

- Since the number of components in a collection can vary dynamically...
- … the components can not be created internally by a constructor (as they are with a composition)
- … the components can not be passed as parameters to the constructor (as they are with other aggregates).

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Collections

Construction

- Since the number of components in a collection can vary dynamically...
- … the components can not be created internally by a constructor (as they are with a composition)
- … the components can not be passed as parameters to the constructor (as they are with other aggregates).
- Standard solution
  - A constructor must be provided that creates an empty collection (and/or one with initial contents).
  - A method must be provided for adding components (to a previously created) collection.

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Collections

Construction

- Since the number of components in a collection can vary dynamically…
- …should a block of memory sufficient to encompass all anticipated components be allocated upfront at construction?
- …should memory be allocated dynamically as components are added?

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Collections

Construction

- Since the number of components in a collection can vary dynamically…
- …should a block of memory sufficient to encompass all anticipated components be allocated upfront at construction?
- …should memory be allocated dynamically as components are added?
- In practice, both solutions are encountered
  - Upfront allocation is referred to as static allocation.
  - Allocation as components are added is referred to as dynamic allocation.

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Collections

Construction

- Example constructors

Portfolio

Constructor Summary

Portfolio(java.lang.String title, int max)

Construct an empty portfolion having the passed name and capable of holding the specified number of investments.

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Collections

Construction

- Example constructors

Portfolio

Constructor Summary

Portfolio(java.lang.String title, int max)

Construct an empty portfolion having the passed name and capable of holding the specified number of investments.

- Illustrative usage

  Portfolio myPortfolio = new Portfolio(“value”, 10);

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Collections

Construction

- Example constructors

GlobalCredit

Constructor Summary

GlobalCredit(java.lang.String name)

Constuct a GC processing centre having the name name.

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Collections

Construction

- Example constructors

GlobalCredit

Constructor Summary

GlobalCredit(java.lang.String name)

Constuct a GC processing centre having the name name.

- Illustrative usage

```
GlobalCredit myCntr = new GlobalCredit("1020Credit");
```

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Collections

Adding components

- A collection must provide a method for inserting components.
- Often, this method is called “add”.
- When a component is to be added, two conditions for concern might arise.
  1. The collection is full
  2. The component already is present

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Collections

Adding components

- When a component is to be added, two conditions for concern might arise.
  1. The collection is full
     - Applies only to static allocation. (By definition, dynamic allocation structures are never full).

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Collections

Adding components

- When a component is to be added, two conditions for concern might arise.
  1. The collection is full
     - Applies only to static allocation. (By definition, dynamic allocation structures are never full).
     - The add method must signal failure to caller.
     - Typically, failure/success signaled by making add have a boolean return.

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Collections

Adding components

- When a component is to be added, two conditions for concern might arise.
  2. The component is already present
     - Something to be added already was added previously.
     - We distinguish two different contexts.

Collections

Adding components

- When a component is to be added, two conditions for concern might arise.

  2. The component is already present
     - Something to be added already was added previously.
     - We distinguish two different contexts.
       i. List

       ii. Set

Collections

Adding components

- When a component is to be added, two conditions for concern might arise.

  2. The component is already present
     - Something to be added already was added previously.
     - We distinguish two different contexts.
       i. List contexts allow duplication: The component is added to the collection; add method returns void (components always added).

       ii. Set

Collections

Adding components

- When a component is to be added, two conditions for concern might arise.

  2. The component is already present
     - Something to be added already was added previously.
     - We distinguish two different contexts.
       i. List contexts allow duplication: The component is added to the collection; add method returns void (components always added).
       ii. Set contexts do not allow duplication:The duplicate component is not added to the collection; add method returns false.

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Collections

Adding components

- Method add return summary:
  - Set context (no duplication) + static allocation
    → boolean return
  - Set context (no duplication) + dynamic allocation
    → boolean return
  - List contexts (allows duplication) + static allocation
    → boolean return
  - List contexts (allows duplication) + dynamic allocation
    → void return

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Collections

Adding components

- Example add methods

Portfolio

Method Summary

boolean add(Investment inv)

Attempt to add the passed investment to this portfolio.

Collections

Adding components

- Example add methods

Portfolio

Method Summary

boolean add(Investment inv)

Attempt to add the passed investment to this portfolio.

- Remarks: Class Portfolio
  - Has a fixed capacity → static allocation.
  - Accepts duplications → list context.

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Collections

Adding components

- Example add methods

Portfolio

Method Summary

boolean add(Investment inv)

Attempt to add the passed investment to this portfolio.

- Illustrative usage

```
Portfolio myPortfolio = new Portfolio("value", 10);
Investment i1 =new Investment(new Stock("TD"),15,24.45);
boolean success = myPortfolio.add(i1);
```

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Collections

Adding components

- Example add methods

GlobalCredit

Method Summary

boolean add(CreditCard card)

Attempt to add the passed credit card to this GCC.

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Collections

Adding components

- Example add methods

GlobalCredit

Method Summary

boolean add(CreditCard card)

Attempt to add the passed credit card to this GCC.

- Remarks: Class GlobalCredit
  - Has no set capacity → dynamic allocation.
  - Does not accept duplicates → set context.

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Collections

Adding components

- Example add methods

GlobalCredit

Method Summary

boolean add(CreditCard card)

Attempt to add the passed credit card to this GCC.

- Illustrative usage

```
GlobalCredit myCntr = new GlobalCredit("1020Credit");
CreditCard myCard = new CreditCard(1, "Wildes");
boolean success = myCntr.add(myCard);
```

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Collections

Interlude: Sets vs. Lists

- Sets and lists are two fundamental ADTs (Abstract Data Types) that abstract real world collections of common interest.

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Collections

Interlude: Sets vs. Lists

- Sets and lists are two fundamental ADTs (Abstract Data Types) that abstract real world collections of common interest.
- Some collections only allow a component to be represented once.
  - The collection of integers [1,10].
  - The collection of credit cards by an issuer with given ID numbers.
  - We refer to such collections as sets.

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Collections

Interlude: Sets vs. Lists

- Sets and lists are two fundamental ADTs (Abstract Data Types) that abstract real world collections of common interest.
- Some collections only allow a component to be represented once.
  - The collection of integers [1,10].
  - The collection of credit cards by an issuer with given ID numbers.
  - We refer to such collections as sets.
- Some collections allow a component to be represented more than once.
  - The collection of roots of a polynomial.
  - The collection of investments in a stock portfolio.
  - We refer to such collections as lists.

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Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

Create a new portfolio

1. **Acquire necessary info: Prompt user and read response.**
2. **Construct a Portfolio.**

Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

```
output.print("Enter number of investments: ");
```

Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

```
output.print("Enter number of investments: ");
int num = input.nextInt( );
```

Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

```
output.print("Enter number of investments: ");
int num = input.nextInt( );
output.print("Enter portfolio name: ");
String name = input.nextLine( );
```

Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

```
output.print("Enter number of investments: ");
int num = input.nextInt( );
output.print("Enter portfolio name: ");
String name = input.nextLine( );
Portfolio pf = new Portfolio(name, num);
```

Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

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output.print("Enter number of investments: ");
int num = input.nextInt( );
output.print("Enter portfolio name: ");
String name = input.nextLine( );
Portfolio pf = new Portfolio(name, num);
```

loop over number of investments: know num; use for
{ add investment to portfolio

}

Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

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output.print("Enter number of investments: ");
int num = input.nextInt( );
output.print("Enter portfolio name: ");
String name = input.nextLine( );
Portfolio pf = new Portfolio(name, num);
```

loop over number of investments: know num; use for
{ add investment to portfolio
1. acquire necessary info. to create investment: prompt & read
2. construct investment
3. add investment
}

Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

```
output.print("Enter number of investments: ");
int num = input.nextInt( );
output.print("Enter portfolio name: ");
String name = input.nextLine( );
Portfolio pf = new Portfolio(name, num);
for (int i = 0; i < num; i++)
{



}
```

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Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

```
output.print("Enter number of investments: ");
int num = input.nextInt( );
output.print("Enter portfolio name: ");
String name = input.nextLine( );
Portfolio pf = new Portfolio(name, num);
for (int i = 0; i < num; i++)
{ output.println("Enter stock symbol, number of shares, price per share");
  output.println("press ENTER after each item.");




}
```

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Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

```
output.print("Enter number of investments: ");
int num = input.nextInt( );
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String name = input.nextLine( );
Portfolio pf = new Portfolio(name, num);
for (int i = 0; i < num; i++)
{ output.println("Enter stock symbol, number of shares, price per share");
  output.println("press ENTER after each item.");
  pf.add



}
```

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Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

```
output.print(“Enter number of investments: ”);
int num = input.nextInt( );
output.print(“Enter portfolio name: ”);
String name = input.nextLine( );
Portfolio pf = new Portfolio(name, num);
for (int i = 0; i < num; i++)
{ output.println(“Enter stock symbol, number of shares, price per share”);
  output.println(“press ENTER after each item.”);
  pf.add
  (
  )
}
```

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Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

```
output.print(“Enter number of investments: ”);
int num = input.nextInt( );
output.print(“Enter portfolio name: ”);
String name = input.nextLine( );
Portfolio pf = new Portfolio(name, num);
for (int i = 0; i < num; i++)
{ output.println(“Enter stock symbol, number of shares, price per share”);
  output.println(“press ENTER after each item.”);
  pf.add
  (new Investment(new Stock(input.nextLine()), input.nextInt(), input.nextDouble()
  );
}
```

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Collections

Adding components

- Example: Read several investments from a user and add them to a portfolio.

```
output.print("Enter number of investments: ");
int num = input.nextInt( );
output.print("Enter portfolio name: ");
String name = input.nextLine( );
Portfolio pf = new Portfolio(name, num);
for (int i = 0; i < num; i++)
{ output.println("Enter stock symbol, number of shares, price per share");
  output.println("press ENTER after each item.");
  pf.add
  (new Investment(new Stock(input.nextLine()), input.nextInt(), input.nextDouble()
  );
}
output.println("Portfolio" + name + "created.");
```

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Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

86

Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

Create a new processing centre

1. **Acquire necessary info: Prompt user and read response.**
2. **Construct a GlobalCredit.**

87

Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

```
output.print("Enter name of processing centre: ");
String name = input.nextLine( );
```

88

Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

```
output.print("Enter name of processing centre: ");
String name = input.nextLine( );
GlobalCredit gcc  = new GlobalCredit(name);
```

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Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

```
output.print("Enter name of processing centre: ");
String name = input.nextLine( );
GlobalCredit gcc  = new GlobalCredit(name);
```

loop over set of cards: Don't know cardinality in advance;
but can define sentinel → use while (true) + break
(add card to processing centre

)

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Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

```
output.print("Enter name of processing centre: ");
String name = input.nextLine( );
GlobalCredit gcc  = new GlobalCredit(name);
```

loop over set of cards: Don't know cardinality in advance; but can define sentinel → use while (true) + break
(add card to processing centre
1. Acquire necessary info. To create card: prompt & read
2. Break if card num == 0, the sentinel
3. Construct card
4. Add card
)

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Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

```
output.print("Enter name of processing centre: ");
String name = input.nextLine( );
GlobalCredit gcc  = new GlobalCredit(name);
while (true)
{




}
```

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Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

```
output.print("Enter name of processing centre: ");
String name = input.nextLine( );
GlobalCredit gcc  = new GlobalCredit(name);
while (true)
{ output.print("Enter card number (0 to quit): ");
  int num = input.nextInt( );




}
```

93

Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

```
output.print("Enter name of processing centre: ");
String name = input.nextLine( );
GlobalCredit gcc  = new GlobalCredit(name);
while (true)
{ output.print("Enter card number (0 to quit): ");
  int num = input.nextInt( );
  if (num == 0) break; // this is the way out of loop




}
```

94

Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

```
output.print("Enter name of processing centre: ");
String name = input.nextLine( );
GlobalCredit gcc  = new GlobalCredit(name);
while (true)
{ output.print("Enter card number (0 to quit): ");
  int num = input.nextInt( );
  if (num == 0) break; // this is the way out of loop
  output.print("Enter name: ");
  String who = input.nextLine( );

}
```

95

Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

```
output.print("Enter name of processing centre: ");
String name = input.nextLine( );
GlobalCredit gcc  = new GlobalCredit(name);
while (true)
{ output.print("Enter card number (0 to quit): ");
  int num = input.nextInt( );
  if (num == 0) break; // this is the way out of loop
  output.print("Enter name: ");
  String who = input.nextLine( );
  gcc.add(new CreditCard(num, who));
}
```

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Collections

Adding components

- Example: Read several credit cards from user and add them to a processing centre.

```
output.print("Enter name of processing centre: ");
String name = input.nextLine( );
GlobalCredit gcc  = new GlobalCredit(name);
while (true)
{ output.print("Enter card number (0 to quit): ");
  int num = input.nextInt( );
  if (num == 0) break; // this is the way out of loop
  output.print("Enter name: ");
  String who = input.nextLine( );
  gcc.add(new CreditCard(num, who));
}
output.println("Processing centre " + name + "created.");
```

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Collections

Component access

- A collection must provide a method for accessing its components.
- For the simplest aggregations and compositions, e.g.,
  - Investment
  - CreditCard
- The API documented one accessor per component, with the components distinguished by name, e.g.,
  - getStock
  - getIssueDate

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Collections

Component access

- A collection must provide a method for accessing its components.
- For the simplest aggregations and compositions, e.g.,
  - Investment
  - CreditCard
- The API documented one accessor per component, with the components distinguished by name, e.g.,
  - getStock
  - getIssueDate
- The approach seen so far will not work for collections, e.g.,
  - Portfolio holds numerous un-named investments.

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Collections

Component access

- We consider component access for collections via systematic traversal in two ways:
  1. Indexed traversal:
  2. Iterator traversal:
- The API of a collection should document methods for one or both approaches.

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Collections

Component access

- We consider component access for collections via systematic traversal in two ways:
  1. Indexed traversal: Think of the components as numbered, i.e., having a numerical index; to access, ask for components by index.
  2. Iterator traversal:
- The API of a collection should document methods for one or both approaches.

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Collections

Component access

- We consider component access for collections via systematic traversal in two ways:
  1. Indexed traversal: Think of the components as numbered, i.e., having a numerical index; to access, ask for components by index.
  2. Iterator traversal: The traversal operates at a higher level of abstraction than index-based. It automatically guarantees that all elements are visited without missing one and without repeated visits to the same element. The client is not concerned with indexing or ordering of elements
- The API of a collection should document methods for one or both approaches.

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Collections

Component access: Indexed traversal

- Think of the components as having a numerical index
- It is not necessary the ordering of the indices reflect the order of insertion into the collection.
- What is necessary is that there be a 1 to 1 mapping between indices and components.
- Remark: Recall our earlier discussion of arrays.

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Collections

Component access: Indexed traversal

- Two methods are of interest.

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Collections

Component access: Indexed traversal

- Two methods are of interest.
  1. int size( )

     Returns the number of components in the collection, with 0 return indicating empty. For non-empty collections, the legal range of indices is [0,size-1].

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Collections

Component access: Indexed traversal

- Two methods are of interest.
  1. int size( )

     Returns the number of components in the collection, with 0 return indicating empty. For non-empty collections, the legal range of indices is [0,size-1].
  2. type get(int index)

     Returns a reference to the component with the passed index. The return has the type of the component.

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Collections

Component access: Indexed traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

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Collections

Component access: Indexed traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

```
Portfolio pf = Portfolio.getRandom();
```

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Collections

Component access: Indexed traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

```
Portfolio pf = Portfolio.getRandom();
for (int j=0; j<pf.size(); j++)
{



}
```

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Collections

Component access: Indexed traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

```
Portfolio pf = Portfolio.getRandom();
for (int j=0; j<pf.size(); j++)
{   output.print(pf.get(j).getStock().getSymbol() +"\t");



}
```

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Collections

Component access: Indexed traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

```
Portfolio pf = Portfolio.getRandom();
for (int j=0; j<pf.size(); j++)
{   output.print(pf.get(j).getStock().getSymbol() +"\t");
    output.print(pf.get(j).getQty() + "\t");

}
```

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Collections

Component access: Indexed traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

```
Portfolio pf = Portfolio.getRandom();
for (int j=0; j<pf.size(); j++)
{   output.print(pf.get(j).getStock().getSymbol() +"\t");
    output.print(pf.get(j).getQty() + "\t");
    output.println(pf.get(j).getBookValue());
}
```

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Collections

Component access: Iterator-based traversal

- An *enhanced* for loop is employed.
- Let E be the type of element e that are components of a collection bag

```
for (E e : bag)
{
        // visit element e
}
```

- Remark: The colon, **:**, in the syntax can be read as “in”.

Collections

Component access: Iterator-based traversal

- An *enhanced* for loop is employed.
- Let E be the type of element e that are components of a collection bag

```
for (E e : bag)
{
        // visit element e
}
```

- Remark: The colon, **:**, in the syntax can be read as “in”.
- This type of traversal is simple, but inflexible: You must traverse; you can’t ask about a particular element.
- To tell if a class supports iterator-based traversal, consult the API and see if it implements the Iterable interface.

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Collections

Component access: Iterator-based traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

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Collections

Component access: Iterator-based traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

```
Portfolio pf = Portfolio.getRandom();
```

116

Collections

Component access: Iterator-based traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

```
Portfolio pf = Portfolio.getRandom();
for (Investment inv : pf)
{



}
```

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Collections

Component access: Iterator-based traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

```
Portfolio pf = Portfolio.getRandom();
for (Investment inv : pf)
{   output.print(inv.getStock().getSymbol() +"\t");



}
```

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Collections

Component access: Iterator-based traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

```
Portfolio pf = Portfolio.getRandom();
for (Investment inv : pf)
{   output.print(inv.getStock().getSymbol() +"\t");
    output.print(inv.getQty() + "\t");

}
```

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Collections

Component access: Iterator-based traversal

- Example usage: Iterate over the components of a Portfolio and report on contents.

```
Portfolio pf = Portfolio.getRandom();
for (Investment inv : pf)
{   output.print(inv.getStock().getSymbol() +"\t");
    output.print(inv.getQty() + "\t");
    output.println(inv.getBookValue());
}
```

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Collections

Component search

- Search is concerned with determining whether or not a given collection contains a specific, given component.
- Examples
  - Does a Portfolio contain a Stock with a given symbol?
  - Does a GlobalCredit contain a CreditCard with a given num?

Collections

Component search

- Search is concerned with determining whether or not a given collection contains a specific, given component.
- Examples
  - Does a Portfolio contain a Stock with a given symbol?
  - Does a GlobalCredit contain a CreditCard with a given num?
- There are two possible outcomes of a search.
  1. Success: The desired component is found and is returned as a reference.
  2. Failure: The desired component is not found, null may be returned.

Collections

Component search

- Search is concerned with determining whether or not a given collection contains a specific, given component.
- Examples
  - Does a Portfolio contain a Stock with a given symbol?
  - Does a GlobalCredit contain a CreditCard with a given num?
- There are two possible outcomes of a search.
  1. Success: The desired component is found and is returned as a reference.
  2. Failure: The desired component is not found, null may be returned.
- Remark: There may be more than one component in a collection that satisfies the search conditions.

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Collections

Component search

- We can implement search by leveraging either of the access methods that we have found for collections (indexed or iterator).

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Collections

Component search

- We can implement search by leveraging either of the access methods that we have found for collections (indexed or iterator).
  - Set up a loop that visits every component of the collection.

125

Collections

Component search

- We can implement search by leveraging either of the access methods that we have found for collections (indexed or iterator).
  - Set up a loop that visits every component of the collection.
  - For each component, check to see if it satisfies the search condition.

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Collections

Component search

- We can implement search by leveraging either of the access methods that we have found for collections (indexed or iterator).
  - Set up a loop that visits every component of the collection.
  - For each component, check to see if it satisfies the search condition.
  - If so, then exit the loop and return the component.

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Collections

Component search

- We can implement search by leveraging either of the access methods that we have found for collections (indexed or iterator).
  - Set up a loop that visits every component of the collection.
  - For each component, check to see if it satisfies the search condition.
  - If so, then exit the loop and return the component.
  - If the end of the collection is encountered, then exit the loop and return null.

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Collections

Component search

- Example (partial) implementation

129

Collections

Component search

- Example (partial) implementation

```
// assume inv a valid investment and pf a valid portfolio
```

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Collections

Component search

- Example (partial) implementation

```
// assume inv a valid investment and pf a valid portfolio
boolean found = false;
```

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Collections

Component search

- Example (partial) implementation

```
// assume inv a valid investment and pf a valid portfolio
boolean found = false;
for (int j=0; j<pf.size(); j++)
{


}
```

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Collections

Component search

- Example (partial) implementation

```
// assume inv a valid investment and pf a valid portfolio
boolean found = false;
for (int j=0; j<pf.size(); j++)
{       Investment current = pf.get(j);


}
```

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Collections

Component search

- Example (partial) implementation

```
// assume inv a valid investment and pf a valid portfolio
boolean found = false;
for (int j=0; j<pf.size(); j++)
{       Investment current = pf.get(j);
        if (current.equals(inv))
          found = true;
}
```

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Outline

- Introduction
- Aggregation API
- Collections
- **Algorithm complexity**
- Further example usage

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Algorithm complexity

Analysis of algorithms

- In general, execution time increases with the size of input.
- For example, searching for an item in a collection takes longer as the size of the collection increases.

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Algorithm complexity

Analysis of algorithms

- In general, execution time increases with the size of input.
- For example, searching for an item in a collection takes longer as the size of the collection increases.
- To formalize
  - Let n be the size of the input (e.g., collection size).
  - Let $T(n)$ represent the running time of an algorithm as a function of input size, n.

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Algorithm complexity

Example

- How long will it take our simple search algorithm to execute?

```
// assume inv a valid investment and pf a valid portfolio
boolean found = false;
for (int j=0; j<pf.size(); j++)
{       Investment current = pf.get(j);
        if (current.equals(inv))
          found = true;
}
```

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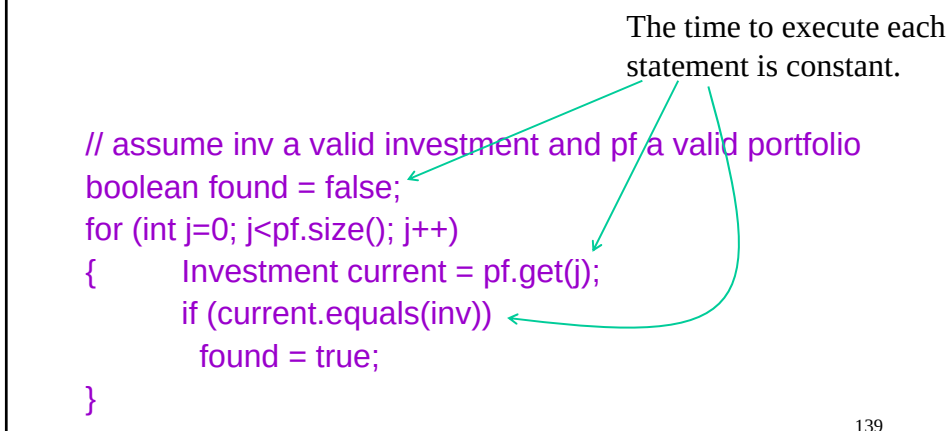
Algorithm complexity

Example

- How long will it take our simple search algorithm to execute?

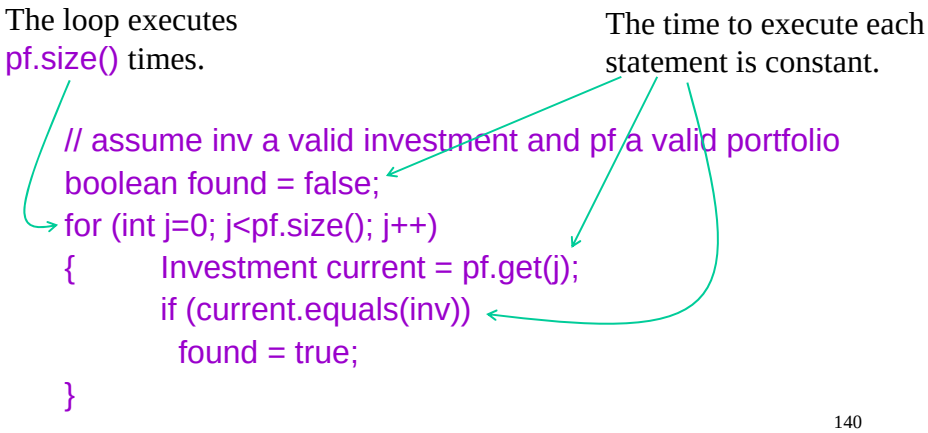


139

Algorithm complexity

Example

- How long will it take our simple search algorithm to execute?

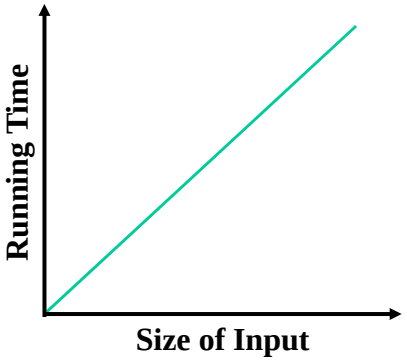


140

Algorithm complexity

Example

- Overall, we have shown that run time, $T(n)$, essentially depends directly on n = pf.size().
- In particular, the running time of our search algorithm depends linearly on the size of input n.

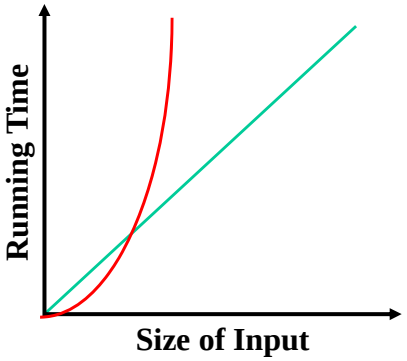


141

Algorithm complexity

Alternatively

- Other algorithms might execute at a rate that grows more rapidly than linearly with size of input.
- Such an algorithm is superlinear in complexity.
- In general, linear is preferred over superlinear.

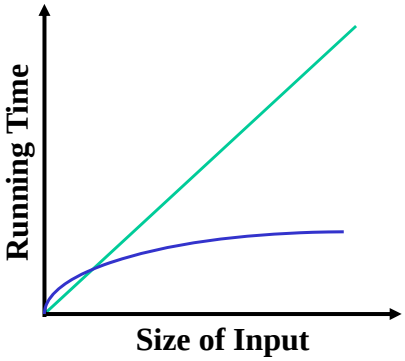


142

Algorithm complexity

Alternatively

- Yet other algorithms might have execution rates that grow slower than linearly with size of input.
- Such an algorithm is sublinear in complexity.
- In general, sublinear is preferable over linear.

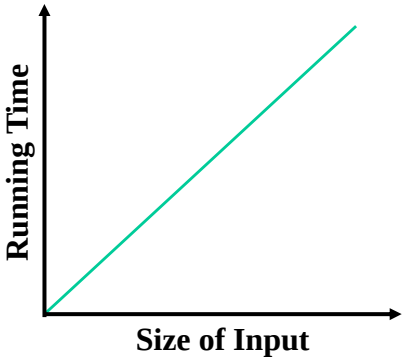


143

Algorithm complexity

Back to our search algorithm

- Overall, we have shown that $T(n)$ essentially depends directly on n.
- In particular, the running time of our search algorithm depends linearly on the size of input n.
- We *write* $T(n)$ is $O(n)$.
- We *say* $T(n)$ is Big-Oh n.

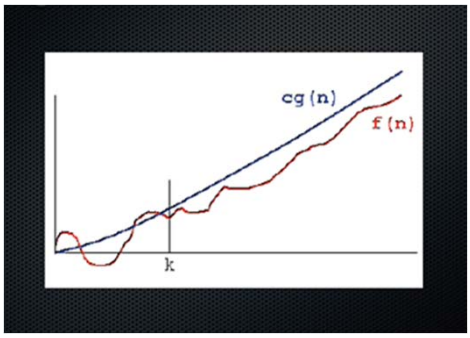


144

Algorithm complexity

Big-Oh

- Informally, *f(n)* is *O(g(n))* if *f(n)* is some constant times *g(n)*.



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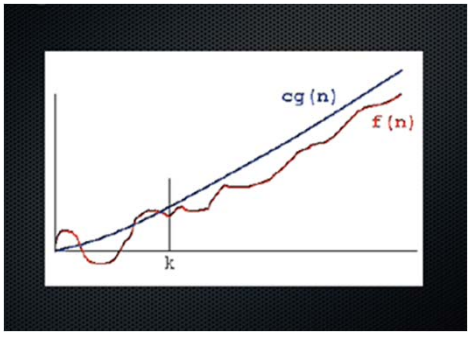
Algorithm complexity

Big-Oh

- Informally, *f(n)* is *O(g(n))* if *f(n)* is some constant times *g(n)*.
- Formally, *f(n)* is *O(g(n))* iff there exist positive constants C and K such that
  $$f(n) \le C \cdot g(n)$$
  for all $n \ge K$.



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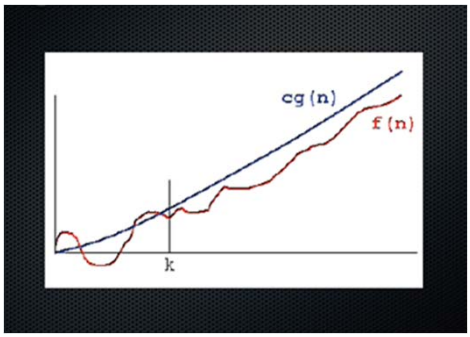
Algorithm complexity

Big-Oh

- Informally, $f(n)$ is $O(g(n))$ if $f(n)$ is some constant times $g(n)$.
- Formally, $f(n)$ is $O(g(n))$ iff there exist positive constants C and K such that
  $$f(n) \leq C \cdot g(n)$$
  for all $n \geq K$.
- Big-Oh gives us an estimate of how fast running time grows as n grows and is thus a useful and standard characterization of algorithm efficiency.



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Algorithm complexity

Exhaustive search

- The search algorithm we have considered is called *exhaustive search*.
- We consider each component of the collection, start to finish, until one matches the target or we reach the end.

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Algorithm complexity

Exhaustive search

- The search algorithm we have considered is called *exhaustive search*.
- We consider each component of the collection, start to finish, until one matches the target or we reach the end.
- We say that such a search algorithm is linear in the number of components in the collection.
  - For a collection of N components, we must consider N items in the worst case.

Algorithm complexity

Exhaustive search

- The search algorithm we have considered is called *exhaustive search*.
- We consider each component of the collection, start to finish, until one matches the target or we reach the end.
- We say that such a search algorithm is linear in the number of components in the collection.
  - For a collection of N components, we must consider N items in the worst case.
- Interestingly, better (sublinear) search algorithms are available, although they rely on some structuring of the collection.
  - You will hear more about such improvements as your computer science education advances.

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Outline

- Introduction
- Aggregation API
- Collections
- Algorithm complexity
- **Further example usage**

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Further example usage

Using Investment

152

Further example usage

```
Using Investment
// assume the usual
import type.lib.*;
public class InvestmentTest
{ public static void main(String[ ] args)
  {
```

153

Further example usage

```
Using Investment
// assume the usual
import type.lib.*;
public class InvestmentTest
{ public static void main(String[ ] args)
  { Stock stk1 = new Stock("TD");
```

154

Further example usage

```
Using Investment
// assume the usual
import type.lib.*;
public class InvestmentTest
{ public static void main(String[ ] args)
  { Stock stk1 = new Stock("TD");
    output.println("stk1= " + stk1.toString()); // TD…
```

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Further example usage

```
Using Investment
// assume the usual
import type.lib.*;
public class InvestmentTest
{ public static void main(String[ ] args)
  { Stock stk1 = new Stock("TD");
    output.println("stk1= " + stk1.toString()); // TD…
    Investment inv1 = new Investment(stk1,100,stk1.getPrice());
```

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Further example usage

```
Using Investment
// assume the usual
import type.lib.*;
public class InvestmentTest
{ public static void main(String[ ] args)
  { Stock stk1 = new Stock("TD");
    output.println("stk1= " + stk1.toString()); // TD…
    Investment inv1 = new Investment(stk1,100,stk1.getPrice());
    output.println("inv1= " + inv1.toString()); // TD inv…
```

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Further example usage

```
Using Investment
// assume the usual
import type.lib.*;
public class InvestmentTest
{ public static void main(String[ ] args)
  { Stock stk1 = new Stock("TD");
    output.println("stk1= " + stk1.toString()); // TD…
    Investment inv1 = new Investment(stk1,100,stk1.getPrice());
    output.println("inv1= " + inv1.toString()); // TD inv…
    output.println("inv1.getQty()= " + inv1.getQty()); // 100
```

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Further example usage

```
Using Investment
// assume the usual
import type.lib.*;
public class InvestmentTest
{ public static void main(String[ ] args)
  { Stock stk1 = new Stock("TD");
    output.println("stk1= " + stk1.toString()); // TD…
    Investment inv1 = new Investment(stk1,100,stk1.getPrice());
    output.println("inv1= " + inv1.toString()); // TD inv…
    output.println("inv1.getQty()= " + inv1.getQty()); // 100
    output.println("inv1.getBookValue()= " + inv1.getBookValue()); // TD$
```

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Further example usage

```
Using Investment
// assume the usual
import type.lib.*;
public class InvestmentTest
{ public static void main(String[ ] args)
  { Stock stk1 = new Stock("TD");
    output.println("stk1= " + stk1.toString()); // TD…
    Investment inv1 = new Investment(stk1,100,stk1.getPrice());
    output.println("inv1= " + inv1.toString()); // TD inv…
    output.println("inv1.getQty()= " + inv1.getQty()); // 100
    output.println("inv1.getBookValue()= " + inv1.getBookValue()); // TD$
    output.println("inv1.getStock().toString()= " +
                   inv1.getStock().toString()); // TD…
```

160

Further example usage

Using Investment

```
// assume the usual
import type.lib.*;
public class InvestmentTest
{ public static void main(String[ ] args)
  { Stock stk1 = new Stock("TD");
    output.println("stk1= " + stk1.toString()); // TD…
    Investment inv1 = new Investment(stk1,100,stk1.getPrice());
    output.println("inv1= " + inv1.toString()); // TD inv…
    output.println("inv1.getQty()= " + inv1.getQty()); // 100
    output.println("inv1.getBookValue()= " + inv1.getBookValue()); // TD$
    output.println("inv1.getStock().toString()= " +
                   inv1.getStock().toString()); // TD…
    output.println("inv1.getStock().getSymbol()= " +
                   inv1.getStock().getSymbol()); // TD
```

161

Further example usage

Using Investment

```
// assume the usual
import type.lib.*;
public class InvestmentTest
{ public static void main(String[ ] args)
  { Stock stk1 = new Stock("TD");
    output.println("stk1= " + stk1.toString()); // TD…
    Investment inv1 = new Investment(stk1,100,stk1.getPrice());
    output.println("inv1= " + inv1.toString()); // TD inv…
    output.println("inv1.getQty()= " + inv1.getQty()); // 100
    output.println("inv1.getBookValue()= " + inv1.getBookValue()); // TD$
    output.println("inv1.getStock().toString()= " +
                   inv1.getStock().toString()); // TD…
    output.println("inv1.getStock().getSymbol()= " +
                   inv1.getStock().getSymbol()); // TD
   // continued on next slide
```

162

Further example usage

```
Using Investment
    // continued from previous slide
```


Further example usage

```
Using Investment
    // continued from previous slide
    Stock stk2 = new Stock("BMO");
    output.println("stk2= " + stk2.toString()); // BMO…
```

Further example usage

Using Investment

```
// continued from previous slide
Stock stk2 = new Stock("BMO");
output.println("stk2= " + stk2.toString()); // BMO…
Investment inv2 = new Investment(stk2,100,stk2.getPrice());
output.println("inv2= " + inv2.toString()); // BMO inv…
```

165

Further example usage

Using Investment

```
// continued from previous slide
Stock stk2 = new Stock("BMO");
output.println("stk2= " + stk2.toString()); // BMO…
Investment inv2 = new Investment(stk2,100,stk2.getPrice());
output.println("inv2= " + inv2.toString()); // BMO inv…
output.println("inv1.equals(inv2)= " + inv1.equals(inv2)); // false
```

166

Further example usage

Using Investment

```
// continued from previous slide
Stock stk2 = new Stock("BMO");
output.println("stk2= " + stk2.toString()); // BMO…
Investment inv2 = new Investment(stk2,100,stk2.getPrice());
output.println("inv2= " + inv2.toString()); // BMO inv…
output.println("inv1.equals(inv2)= " + inv1.equals(inv2)); // false
Stock stk3 = inv1.getStock();
output.println("stk3= " + stk3.toString()); // TD…
```

167

Further example usage

Using Investment

```
// continued from previous slide
Stock stk2 = new Stock("BMO");
output.println("stk2= " + stk2.toString()); // BMO…
Investment inv2 = new Investment(stk2,100,stk2.getPrice());
output.println("inv2= " + inv2.toString()); // BMO inv…
output.println("inv1.equals(inv2)= " + inv1.equals(inv2)); // false
Stock stk3 = inv1.getStock();
output.println("stk3= " + stk3.toString()); // TD…
stk3.setSymbol("RY");
output.println("reset stk3's symbol to RY");
output.println("stk3= " + stk3.toString()); // RY…
```

168

Further example usage

```
Using Investment
    // continued from previous slide
    Stock stk2 = new Stock("BMO");
    output.println("stk2= " + stk2.toString()); // BMO…
    Investment inv2 = new Investment(stk2,100,stk2.getPrice());
    output.println("inv2= " + inv2.toString()); // BMO inv…
    output.println("inv1.equals(inv2)= " + inv1.equals(inv2)); // false
   Stock stk3 = inv1.getStock();
   output.println("stk3= " + stk3.toString()); // TD…
   stk3.setSymbol("RY");
   output.println("reset stk3's symbol to RY");
   output.println("stk3= " + stk3.toString()); // RY…
   output.println("inv1.getStock()= " + inv1.getStock().toString())
```

169

Further example usage

```
Using Investment
    // continued from previous slide
    Stock stk2 = new Stock("BMO");
    output.println("stk2= " + stk2.toString()); // BMO…
    Investment inv2 = new Investment(stk2,100,stk2.getPrice());
    output.println("inv2= " + inv2.toString()); // BMO inv…
    output.println("inv1.equals(inv2)= " + inv1.equals(inv2)); // false
   Stock stk3 = inv1.getStock();
   output.println("stk3= " + stk3.toString()); // TD…
   stk3.setSymbol("RY");
   output.println("reset stk3's symbol to RY");
   output.println("stk3= " + stk3.toString()); // RY…
   output.println("inv1.getStock()= " + inv1.getStock().toString());//RY…
```

170

Further example usage

```
Using Investment
    // continued from previous slide
    Stock stk2 = new Stock("BMO");
    output.println("stk2= " + stk2.toString()); // BMO…
    Investment inv2 = new Investment(stk2,100,stk2.getPrice());
    output.println("inv2= " + inv2.toString()); // BMO inv…
    output.println("inv1.equals(inv2)= " + inv1.equals(inv2)); // false
   Stock stk3 = inv1.getStock();
   output.println("stk3= " + stk3.toString()); // TD…
   stk3.setSymbol("RY");
   output.println("reset stk3's symbol to RY");
   output.println("stk3= " + stk3.toString()); // RY…
   output.println("inv1.getStock()= " + inv1.getStock().toString());//RY…
   // continued on next slide
```

171

Further example usage

```
Using Investment
   // continued from previous slide




  }
}
```

172

Further example usage

```
Using Investment
   // continued from previous slide
   stk2.setSymbol("RY");
   output.println("reset stk2's symbol to RY");
   output.println("stk2= " + stk2.toString()); // RY…


  }
 }
```


Further example usage

```
Using Investment
   // continued from previous slide
   stk2.setSymbol("RY");
   output.println("reset stk2's symbol to RY");
   output.println("stk2= " + stk2.toString()); // RY…
   output.println("inv2.getStock()=" + inv2.getStock().toString());

  }
}
```

Further example usage

```
Using Investment
   // continued from previous slide
   stk2.setSymbol("RY");
   output.println("reset stk2's symbol to RY");
   output.println("stk2= " + stk2.toString()); // RY…
   output.println("inv2.getStock()=" + inv2.getStock().toString()); //RY…

  }
}
```


Further example usage

```
Using Investment
   // continued from previous slide
   stk2.setSymbol("RY");
   output.println("reset stk2's symbol to RY");
   output.println("stk2= " + stk2.toString()); // RY…
   output.println("inv2.getStock()=" + inv2.getStock().toString()); //RY…
   output.println("inv1.equals(inv2)= " + inv1.equals(inv2)); // false
  }
}
```

Further example usage

Using Investment: Lessons learned

- We have seen that the Investment constructor uses the Stock object passed as a component of the Investment.
- We also have seen that the getStock accessor method returns a reference to this component.
- This allows the user to change the state of the Investment object, sometimes with strange results.
- Investment could protect against such changes by
  - Setting its component to a copy of the passed Stock object in the constructor
  - Returning a copy of its component in getStock

177

Further example usage

Using Investment: Lessons learned

- In general, to ensure that users cannot change components of an object without the object's methods,…
- …one must make a deep copy of the components passed to/from the object.
- A deep copy is a copy where the subcomponents and subsubcomponents also are copied.

178

Further example usage

Iterating through a Portfolio

```
// assume the usual template stuff
import type.lib.*;
public class PortfolioTest
{ public static void main(String[ ] args)
  {
```

179

Further example usage

Iterating through a Portfolio

```
// assume the usual template stuff
import type.lib.*;
public class PortfolioTest
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
     output.println(ptf1.toString()); // My e.g. Portfolio: 0
```

180

Further example usage

Iterating through a Portfolio

```
// assume the usual template stuff
import type.lib.*;
public class PortfolioTest
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    output.println(ptf1.toString()); // My e.g. Portfolio: 0
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
```

181

Further example usage

Iterating through a Portfolio

```
// assume the usual template stuff
import type.lib.*;
public class PortfolioTest
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    output.println(ptf1.toString()); // My e.g. Portfolio: 0
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
```

182

Further example usage

Iterating through a Portfolio

```
// assume the usual template stuff
import type.lib.*;
public class PortfolioTest
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    output.println(ptf1.toString()); // My e.g. Portfolio: 0
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
    stk1 = new Stock("RY");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
```

183

Further example usage

Iterating through a Portfolio

```
// assume the usual template stuff
import type.lib.*;
public class PortfolioTest
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    output.println(ptf1.toString()); // My e.g. Portfolio: 0
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
    stk1 = new Stock("RY");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    output.println(ptf1.toString()); // My e.g. Portfolio: 3
```

184

Further example usage

Iterating through a Portfolio

```
// assume the usual template stuff
import type.lib.*;
public class PortfolioTest
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    output.println(ptf1.toString()); // My e.g. Portfolio: 0
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
    stk1 = new Stock("RY");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    output.println(ptf1.toString()); // My e.g. Portfolio: 3
   // continued on next slide
```

185

Further example usage

Iterating through a Portfolio

```
    // continued from previous slide
```

186

```
} }
```

Further example usage

Iterating through a Portfolio

```
    // continued from previous slide
    output.println("Traverse over investments using indexing");
```

187

```
} }
```

Further example usage

Iterating through a Portfolio

```
    // continued from previous slide
    output.println("Traverse over investments using indexing");
    int ptf1cnt = ptf1.size();
    for (int j=0; j<ptf1cnt; j++)
    {

    }
```

188

```
} }
```

Further example usage

Iterating through a Portfolio

```
    // continued from previous slide
    output.println("Traverse over investments using indexing");
    int ptf1cnt = ptf1.size();
    for (int j=0; j<ptf1cnt; j++)
    { Investment inv = ptf1.get(j);
      output.println(inv);
    }
```

189

```
} }
```

Further example usage

Iterating through a Portfolio

```
    // continued from previous slide
    output.println("Traverse over investments using indexing");
    int ptf1cnt = ptf1.size();
    for (int j=0; j<ptf1cnt; j++)
    { Investment inv = ptf1.get(j);
      output.println(inv);
    }
    output.println("Traverse over investments using iterator.");
```

190

```
} }
```

Further example usage

Iterating through a Portfolio

```
    // continued from previous slide
    output.println("Traverse over investments using indexing");
    int ptf1cnt = ptf1.size();
    for (int j=0; j<ptf1cnt; j++)
    { Investment inv = ptf1.get(j);
      output.println(inv);
    }
    output.println("Traverse over investments using iterator.");
    for (Investment inv : ptf1)
```

191

```
} }
```

Further example usage

Iterating through a Portfolio

```
    // continued from previous slide
    output.println("Traverse over investments using indexing");
    int ptf1cnt = ptf1.size();
    for (int j=0; j<ptf1cnt; j++)
    { Investment inv = ptf1.get(j);
      output.println(inv);
    }
    output.println("Traverse over investments using iterator.");
    for (Investment inv : ptf1)
      output.println(inv);
```

192

```
} }
```

Further example usage

Iterating through a Portfolio

```
    // continued from previous slide
    output.println("Traverse over investments using indexing");
    int ptf1cnt = ptf1.size();
    for (int j=0; j<ptf1cnt; j++)
    { Investment inv = ptf1.get(j);
      output.println(inv);
    }
    output.println("Traverse over investments using iterator.");
    for (Investment inv : ptf1)
      output.println(inv);
    stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,150,stk1.getPrice()));
```

193

```
} }
```

Further example usage

Iterating through a Portfolio

```
    // continued from previous slide
    output.println("Traverse over investments using indexing");
    int ptf1cnt = ptf1.size();
    for (int j=0; j<ptf1cnt; j++)
    { Investment inv = ptf1.get(j);
      output.println(inv);
    }
    output.println("Traverse over investments using iterator.");
    for (Investment inv : ptf1)
      output.println(inv);
    stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,150,stk1.getPrice()));
    output.println("Traverse again over investments using iterator.);
```

194

```
} }
```

Further example usage

Iterating through a Portfolio

```
    // continued from previous slide
    output.println("Traverse over investments using indexing");
    int ptf1cnt = ptf1.size();
    for (int j=0; j<ptf1cnt; j++)
    { Investment inv = ptf1.get(j);
      output.println(inv);
    }
    output.println("Traverse over investments using iterator.");
    for (Investment inv : ptf1)
      output.println(inv);
    stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,150,stk1.getPrice()));
    output.println("Traverse again over investments using iterator.");
    for (Investment inv : ptf1)
      output.println(inv);
} }
```

195

Further example usage

Iterating through a Portfolio: Test

```
% java PortfolioTest
```

196

Further example usage

Iterating through a Portfolio: Test

```
% java PortfolioTest
My e.g. Portfolio: 0
My e.g. Portfolio: 3
Traverse over investments using indexing
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
Traverse over investments using iterator
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
Traverse again over investments using iterator
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=39.03
RY Royal Bank of Canada QTY=100 BV=59.99
TD Toronto-Dominion Bank QTY=150 BV=81.32
%
```

197

Further example usage

Iterating through a Portfolio: Test

```
% java PortfolioTest
My e.g. Portfolio: 0
My e.g. Portfolio: 3
Traverse over investments using indexing
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
Traverse over investments using iterator
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
Traverse again over investments using iterator
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=39.03
RY Royal Bank of Canada QTY=100 BV=59.99
TD Toronto-Dominion Bank QTY=150 BV=81.32
%
```

198

Further example usage

Iterating through a Portfolio: Test

```
% java PortfolioTest
My e.g. Portfolio: 0
My e.g. Portfolio: 3
Traverse over investments using indexing
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
Traverse over investments using iterator
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
Traverse again over investments using iterator
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=39.03
RY Royal Bank of Canada QTY=100 BV=59.99
TD Toronto-Dominion Bank QTY=150 BV=81.32
%
```

199

Further example usage

Iterating through a Portfolio: Test

```
% java PortfolioTest
My e.g. Portfolio: 0
My e.g. Portfolio: 3
Traverse over investments using indexing
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
Traverse over investments using iterator
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
Traverse again over investments using iterator
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=39.03
RY Royal Bank of Canada QTY=100 BV=59.99
TD Toronto-Dominion Bank QTY=150 BV=81.32
%
```

200

Further example usage

Iterating through a Portfolio: Test

```
% java PortfolioTest
My e.g. Portfolio: 0
My e.g. Portfolio: 3
Traverse over investments using indexing
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
Traverse over investments using iterator
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
Traverse again over investments using iterator
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=39.03
RY Royal Bank of Canada QTY=100 BV=59.99
TD Toronto-Dominion Bank QTY=150 BV=81.32
%
```

201

Further example usage

A Portfolio can be modified in strange ways

```
// assume the usual
import type.lib.*;
public class PortfolioTest2
{ public static void main(String[ ] args)
 {
```

202

Further example usage

A Portfolio can be modified in strange ways

```
// assume the usual
import type.lib.*;
public class PortfolioTest2
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio(“My e.g. Portfolio”, 10);
```

203

Further example usage

A Portfolio can be modified in strange ways

```
// assume the usual
import type.lib.*;
public class PortfolioTest2
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio(“My e.g. Portfolio”, 10);
    Stock stk1 = new Stock(“TD”);
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
```

204

Further example usage

A Portfolio can be modified in strange ways

```
// assume the usual
import type.lib.*;
public class PortfolioTest2
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
```

205

Further example usage

A Portfolio can be modified in strange ways

```
// assume the usual
import type.lib.*;
public class PortfolioTest2
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
    stk1 = new Stock("RY");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
```

206

Further example usage

A Portfolio can be modified in strange ways

```
// assume the usual
import type.lib.*;
public class PortfolioTest2
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
    stk1 = new Stock("RY");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    output.println(ptf1.toString()); // My e.g. Portfolio: 3
```

207

Further example usage

A Portfolio can be modified in strange ways

```
// assume the usual
import type.lib.*;
public class PortfolioTest2
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
    stk1 = new Stock("RY");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    output.println(ptf1.toString()); // My e.g. Portfolio: 3
   // continued on next slide
```

208

Further example usage

A Portfolio can be modified in strange ways

```
   // continued from previous slide









 }
}
```

209

Further example usage

A Portfolio can be modified in strange ways

```
   // continued from previous slide
   for (Investment inv : ptf1)
      output.println(inv);
   output.println();









 }
}
```

210

Further example usage

A Portfolio can be modified in strange ways

```
   // continued from previous slide
   for (Investment inv : ptf1)
      output.println(inv);
   output.println();
   Investment inv1 = ptf1.get(0);
```

```
 }
}
```

211

Further example usage

A Portfolio can be modified in strange ways

```
   // continued from previous slide
   for (Investment inv : ptf1)
      output.println(inv);
   output.println();
   Investment inv1 = ptf1.get(0);
   stk1 = inv1.getStock();
   stk1.setSymbol("RY");
   output.println("Changed first investment to RY");
```

```
 }
}
```

212

Further example usage

A Portfolio can be modified in strange ways

```
   // continued from previous slide
   for (Investment inv : ptf1)
      output.println(inv);
   output.println();
   Investment inv1 = ptf1.get(0);
   stk1 = inv1.getStock();
   stk1.setSymbol("RY");
   output.println("Changed first investment to RY");
   output.println(ptf1.toString());
    for (Investment inv : ptf1)
      output.println(inv);
 }
}
```

213

Further example usage

A Portfolio can be modified in strange ways: Test

```
% java PortfolioTest2
```

214

Further example usage

A Portfolio can be modified in strange ways: Test

```
% java PortfolioTest2
My e.g. Portfolio: 3
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99

Changed first investment to RY
My e.g. Portfolio: 3
RY Royal Bank of Canada QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
%
```

215

Further example usage

A Portfolio can be modified in strange ways: Test

```
% java PortfolioTest2
My e.g. Portfolio: 3
TD Toronto-Dominion Bank QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99

Changed first investment to RY
My e.g. Portfolio: 3
RY Royal Bank of Canada QTY=100 BV=81.32
BMO Bank of Montreal QTY=50 BV=60.15
RY Royal Bank of Canada QTY=100 BV=59.99
%
```

Remark

- Not only was the app able to change a Stock in an Investment,…
- …but it was able to leave behind an inconsistency between the Stock and the BV of the Investment.

Further example usage

Making a deep copy of a Portfolio

```
// assume the usual
import type.lib.*;
public class PortfolioDeepCopy
{ public static void main(String[ ] args)
  {
```

217

Further example usage

Making a deep copy of a Portfolio

```
// assume the usual
import type.lib.*;
public class PortfolioDeepCopy
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
```

218

Further example usage

Making a deep copy of a Portfolio

```
// assume the usual
import type.lib.*;
public class PortfolioDeepCopy
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
```

219

Further example usage

Making a deep copy of a Portfolio

```
// assume the usual
import type.lib.*;
public class PortfolioDeepCopy
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
```

220

Further example usage

Making a deep copy of a Portfolio

```
// assume the usual
import type.lib.*;
public class PortfolioDeepCopy
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
    stk1 = new Stock("RY");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
```

221

Further example usage

Making a deep copy of a Portfolio

```
// assume the usual
import type.lib.*;
public class PortfolioDeepCopy
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
    stk1 = new Stock("RY");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    output.println("\nPortfolio ptf1 is:");
    output.println(ptf1.toString());
```

222

Further example usage

Making a deep copy of a Portfolio

```
// assume the usual
import type.lib.*;
public class PortfolioDeepCopy
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
    stk1 = new Stock("RY");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    output.println("\nPortfolio ptf1 is:");
    output.println(ptf1.toString());
   for (Investment inv : ptf1)
      output.println(inv);
```

223

Further example usage

Making a deep copy of a Portfolio

```
// assume the usual
import type.lib.*;
public class PortfolioDeepCopy
{ public static void main(String[ ] args)
  { Portfolio ptf1 = new Portfolio("My e.g. Portfolio", 10);
    Stock stk1 = new Stock("TD");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    stk1 = new Stock("BMO");
    ptf1.add(new Investment(stk1,50,stk1.getPrice()));
    stk1 = new Stock("RY");
    ptf1.add(new Investment(stk1,100,stk1.getPrice()));
    output.println("\nPortfolio ptf1 is:");
    output.println(ptf1.toString());
   for (Investment inv : ptf1)
      output.println(inv);
    // continued on next slide
```

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Further example usage

Making a deep copy of a Portfolio

```
// continued from previous slide
```

Further example usage

Making a deep copy of a Portfolio

```
// continued from previous slide
// make deep copy
```

Further example usage

Making a deep copy of a Portfolio

```
// continued from previous slide
// make deep copy
Portfolio ptf1c = new Portfolio("My e.g. Portfolio", 10);
```

Further example usage

Making a deep copy of a Portfolio

```
// continued from previous slide
// make deep copy
Portfolio ptf1c = new Portfolio("My e.g. Portfolio", 10);
for (Investment inv : ptf1)
{



}
```

Further example usage

Making a deep copy of a Portfolio

```
// continued from previous slide
// make deep copy
Portfolio ptf1c = new Portfolio("My e.g. Portfolio", 10);
for (Investment inv : ptf1)
{  Stock stkc = new Stock(inv.getStock().getSymbol());


}
```

Further example usage

Making a deep copy of a Portfolio

```
// continued from previous slide
// make deep copy
Portfolio ptf1c = new Portfolio("My e.g. Portfolio", 10);
for (Investment inv : ptf1)
{  Stock stkc = new Stock(inv.getStock().getSymbol());
   Investment invc = new Investment(stkc, inv.getQty(),
                                    inv.getBookValue());

}
```

Further example usage

Making a deep copy of a Portfolio

```
// continued from previous slide
// make deep copy
Portfolio ptf1c = new Portfolio("My e.g. Portfolio", 10);
for (Investment inv : ptf1)
{  Stock stkc = new Stock(inv.getStock().getSymbol());
   Investment invc = new Investment(stkc, inv.getQty(),
                                            inv.getBookValue());
   ptf1c.add(invc);
}
```

Further example usage

Making a deep copy of a Portfolio

```
// continued from previous slide
// make deep copy
Portfolio ptf1c = new Portfolio("My e.g. Portfolio", 10);
for (Investment inv : ptf1)
{  Stock stkc = new Stock(inv.getStock().getSymbol());
   Investment invc = new Investment(stkc, inv.getQty(),
                                            inv.getBookValue());
   ptf1c.add(invc);
}
output.println("\nMade deep copy ptf1c of ptf1:");
ooutput.println(ptf1c.toString());
for (Investment inv : ptf1c)
   output.println(inv);
```

Further example usage

Making a deep copy of a Portfolio

```
// continued from previous slide
// make deep copy
Portfolio ptf1c = new Portfolio("My e.g. Portfolio", 10);
for (Investment inv : ptf1)
{  Stock stkc = new Stock(inv.getStock().getSymbol());
   Investment invc = new Investment(stkc, inv.getQty(),
                                                    inv.getBookValue());
   ptf1c.add(invc);
}
output.println("\nMade deep copy ptf1c of ptf1:");
ooutput.println(ptf1c.toString());
for (Investment inv : ptf1c)
   output.println(inv);
// continued on next slide
```

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Further example usage

Making a deep copy of a Portfolio

```
// continued from previous slide
```

```
 }
}
```

234

Further example usage

Making a deep copy of a Portfolio

```
    // continued from previous slide
    // Change first investment in ptf1 to RY
```

```
  }
}
```

235

Further example usage

Making a deep copy of a Portfolio

```
    // continued from previous slide
    // Change first investment in ptf1 to RY
    Investment inv1 = ptf1.get(0);
```

```
  }
}
```

236

Further example usage

Making a deep copy of a Portfolio

```
    // continued from previous slide
    // Change first investment in ptf1 to RY
    Investment inv1 = ptf1.get(0);
    stk1 = inv1.getStock();
```

```
  }
}
```


Further example usage

Making a deep copy of a Portfolio

```
    // continued from previous slide
    // Change first investment in ptf1 to RY
    Investment inv1 = ptf1.get(0);
    stk1 = inv1.getStock();
    stk1.setSymbol("RY");
```

```
  }
}
```

Further example usage

Making a deep copy of a Portfolio

```
   // continued from previous slide
   // Change first investment in ptf1 to RY
   Investment inv1 = ptf1.get(0);
   stk1 = inv1.getStock();
   stk1.setSymbol("RY");
   output.println("\nChanged first investment in ptf1 to RY");
   output.println("\nptf1 is now:");
   output.println(ptf1.toString());
   for (Investment inv : ptf1)
      output.println(inv);




 }
}
```

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Further example usage

Making a deep copy of a Portfolio

```
   // continued from previous slide
   // Change first investment in ptf1 to RY
   Investment inv1 = ptf1.get(0);
   stk1 = inv1.getStock();
   stk1.setSymbol("RY");
   output.println("\nChanged first investment in ptf1 to RY");
   output.println("\nptf1 is now:");
   output.println(ptf1.toString());
   for (Investment inv : ptf1)
      output.println(inv);
   output.println("\nptf1c is now:");
   output.println(ptf1c.toString());
   for (Investment inv : ptf1c)
      output.println(inv);
 }
}
```

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Further example usage

Making a deep copy of a Portfolio: Test

% java PortfolioDeepCopy

241

Further example usage

Making a deep copy of a Portfolio: Test

% java PortfolioDeepCopy

- Try this out for yourself.
- Make sure you understand the results…
- …and the computations that led to them.

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Outline

- Introduction
- Aggregation API
- Collections
- Algorithm complexity
- Further example usage
- **Appendix: Java class Vector**

243

Java class Vector

Recall arrays

- In retrospect, we recognize that the array provides us with a way to hold collections.
  - Indeed, arrays provide a generic collection mechanism in that we can specify the type held.

244

Java class Vector

Recall arrays

- In retrospect, we recognize that the array provides us with a way to hold collections.
  - Indeed, arrays provide a generic collection mechanism in that we can specify the type held.
- Further, we recall that once an array has been constructed in Java (necessarily with a specific length), its length stays fixed from then on.
  - Apparently, arrays (in Java) provide an example of static allocation (once they have been created).

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Java class Vector

Recall arrays

- In retrospect, we recognize that the array provides us with a way to hold collections.
  - Indeed, arrays provide a generic collection mechanism in that we can specify the type held.
- Further, we recall that once an array has been constructed in Java (necessarily with a specific length), its length stays fixed from then on.
  - Apparently, arrays (in Java) provide an example of static allocation (once they have been created).
- If you want something akin to an array that can be resized after creation, then Java provides the Vector class.

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Vectors

Basics

- A Vector is a container for *objects* that grows automatically.
  - Here we see another Java provided approach to dealing with collections.
  - In this case, we encounter dynamic allocation (as opposed to the static allocation of arrays).

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Vectors

Basics

- A Vector is a container for *objects* that grows automatically.
  - Here we see another Java provided approach to dealing with collections.
  - In this case, we encounter dynamic allocation (as opposed to the static allocation of arrays).
- The Vector class is in java.util., hence we must explicitly import it into out programs

  import java.util.Vector;

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Vectors

Basics

- A Vector is a container for *objects* that grows automatically.
  - Here we see another Java provided approach to dealing with collections.
  - In this case, we encounter dynamic allocation (as opposed to the static allocation of arrays).
- The Vector class is in java.util., hence we must explicitly import it into out programs

  import java.util.Vector;
- We declare and construct an instance of a Vector object in the following fashion

  Vector studNames = new Vector();

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Vectors

Basics

- Given declaration and construction

  Vector studNames = new Vector();
- Subsequently we can insert elements with the add method.

```
while (true)
{ output.print("Enter a student name (return to end): ");
   String s = input.nextLine();
   if (s.equals(""))
     break;
   else
     studNames.add(s); // adds to end of the vector
 }
```

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Vectors

Basics

- We can set the value at an arbitrary position in a vector via the set method.

  studNames.set(1, “Steve”); // position 1 now has Steve

2

251

Vectors

Basics

- We can set (i.e., replace) the value at an arbitrary position in a vector via the set method.

  studNames.set(1, “Steve”); // position 1 now has Steve

- We also can insert an object in the middle of a vector, while moving all the other elements down by one position.

  studNames.add(1, “Eshrat”); // position 1 has Eshrat;
  // whatever was at 1 now at 2

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Vectors

Basics

- We can set (i.e., replace) the value at an arbitrary position in a vector via the set method.

  studNames.set(1, “Steve”); // position 1 now has Steve

- We also can insert an object in the middle of a vector, while moving all the other elements down by one position.

  studNames.add(1, “Eshrat”); // position 1 has Eshrat;
  // whatever was at 1 now at 2

- We can access the number of elements in a vector with the size method.

  int n = studNames.size();

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Vectors

Basics

- Getting data back out of a Vector is a bit more involved.
- A Vector can hold *objects* of any type.
- Indeed, when an object is inserted into a Vector, its reference is automatically converted to that of type Object, the Java abstraction of all other objects.

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Vectors

Basics

- Getting data back out of a Vector is a bit more involved.
- A Vector can hold *objects* of any type.
- Indeed, when an object is inserted into a Vector, its reference is automatically converted to that of type Object, the Java abstraction of all other objects.
- When reading an object back out, we use the get method; typically we cast to the object's original type

```
for (int j=0; j<studNames.size(); j++)
{ String s = (String) studNames.get(j);
  ...
}
```

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Vectors

Basics

- Getting data back out of a Vector is a bit more involved.
- A Vector can hold *objects* of any type.
- Indeed, when an object is inserted into a Vector, its reference is automatically converted to that of type Object, the Java abstraction of all other objects.
- When reading an object back out, we use the get method; typically we cast to the object's original type

```
for (int j=0; j<studNames.size(); j++)
{ String s = (String) studNames.get(j);
  ...
}
```

- Remember: If in doubt about what you are about to cast, then use instanceof.

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Vectors

Storing primitive types in a Vector

- We can store an *object* of any class in a Vector.
- In contrast, *primitive types* (integers, floating-point numbers, truth values) cannot be stored in a Vector directly as they are not objects.

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Vectors

Storing primitive types in a Vector

- We can store an *object* of any class in a Vector.
- In contrast, *primitive types* (integers, floating-point numbers, truth values) cannot be stored in a Vector directly as they are not objects.
- We resort to the notion of wrapper classes.
  - The classes Integer, Double, Boolean, etc. can be used to wrap numbers and truth values inside appropriate classes.
- Let's see how this is done…

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Vectors

Storing primitive types in a Vector

- Example: Getting a floating point number into a Vector

```
Double aMark = new Double(75.57);
Vector marks = new Vector();
marks.add(aMark);
```

Vectors

Storing primitive types in a Vector

- Example: Getting a floating point number into a Vector

```
Double aMark = new Double(75.57);
Vector marks = new Vector();
marks.add(aMark);
```

alternatively

```
Vector marks = new Vector();
marks.add(new Double(75.57));
```

Vectors

Storing primitive types in a Vector

- Example: Getting a floating point number into a Vector

```
Double aMark = new Double(75.57);
Vector marks = new Vector();
marks.add(aMark);
```

alternatively

```
Vector marks = new Vector();
marks.add(new Double(75.57));
```

- Example: Getting a floating point number out of a Vector

```
double aMarkPrim = ((Double)marks.get(0)).doubleValue();
```

Notice that here we need to

1. Access via get method of Vector
2. Cast to Double
3. Invoke the doubleValue method of Double

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Vectors

Storing primitive types in a Vector

- Example: Getting a floating point number into a Vector

```
Double aMark = new Double(75.57);
Vector marks = new Vector();
marks.add(aMark);
```

alternatively

```
Vector marks = new Vector();
marks.add(new Double(75.57));
```

- Example: Getting a floating point number out of a Vector

```
double aMarkPrim = ((Double)marks.get(0)).doubleValue();
```

Notice that here we need to

1. Access via get method of Vector
2. Cast to Double
3. Invoke the doubleValue method of Double

Remark: Yes this is a hassle!

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Vectors

Storing primitive types in a Vector

- Example: Getting an integer number into a Vector

```
Integer aNum = new Integer(12);
Vector nums = new Vector();
nums.add(aNum);
```

alternatively

```
Vector nums = new Vector();
nums.add(new Integer(12));
```

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Vectors

Storing primitive types in a Vector

- Example: Getting an integer number into a Vector

```
Integer aNum = new Integer(12);
Vector nums = new Vector();
nums.add(aNum);
```

alternatively

```
Vector nums = new Vector();
nums.add(new Integer(12));
```

- Example: Getting an integer number out of a Vector

```
int aNumPrim = ((Integer)nums.get(0)).intValue();
```

Notice that here we need to

1. Access via get method of Vector
2. Cast to Integer
3. Invoke the intValue method of Integer

264

Vectors

Converting vectors to arrays

- Because of the overhead in getting data out of a vector, we often
  - Use a vector for reading in a data set of unknown size
  - Convert the vector to an array for subsequent data processing.

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Vectors

Converting vectors to arrays

- Because of the overhead in getting data out of a vector, we often
  - Use a vector for reading in a data set of unknown size
  - Convert the vector to an array for subsequent data processing.
    1. Create a new array with length equal to the size of the vector.
    2. Copy the vector elements into the array elements.

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Vectors

Converting vectors to arrays

- Because of the overhead in getting data out of a vector, we often
  - Use a vector for reading in a data set of unknown size
  - Convert the vector to an array for subsequent data processing.
    1. Create a new array with length equal to the size of the vector.
    2. Copy the vector elements into the array elements.
- This approach allows us to combine the strength of vectors (dynamic growth) with the strength of an array (ease of access to individual elements).
- Let's see how this is done…

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Vectors

Converting vectors to arrays

```
String s;
Vector inputVector = new Vector();
while (true)
{ output.print("Enter a student name (return to end): ");
   s = input.nextLine();
    if (s.equals(""))
       break; // this is the way out of the loop
    else
       inputVector.add(s);
}
```

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Vectors

Converting vectors to arrays

```
String s;
Vector inputVector = new Vector();
while (true)
{ output.print("Enter a student name (return to end): ");
  s = input.nextLine();
   if (s.equals(""))
      break; // this is the way out of the loop
   else
       inputVector.add(s);
}
String[ ]  studNames = new String[inputVector.size()];
```

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Vectors

Converting vectors to arrays

```
String s;
Vector inputVector = new Vector();
while (true)
{ output.print("Enter a student name (return to end): ");
  s = input.nextLine();
   if (s.equals(""))
      break; // this is the way out of the loop
   else
       inputVector.add(s);
}
String[ ]  studNames = new String[inputVector.size()];
inputVector.copyInto(studNames); // copies vector to array
```

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Vectors

Example: Improvements to MarksAnalysis

- We will make use of the Vector class to allow for arbitrary amounts of input, …
- …without the user telling in advance how much input to expect.

```
public class MarksAnalysis
{ public static void main(String[ ] args)
  { // declaration
    // input
    // computation
    // output
  }
}
```

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Vectors

Example: Improvements to MarksAnalysis

```
// declaration and input
```

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Vectors

Example: Improvements to MarksAnalysis

```
// declaration and input
double mark;
double[ ] marks = null;
Vector inputVector = new Vector();
```

273

Vectors

Example: Improvements to MarksAnalysis

```
// declaration and input
double mark;
double[ ] marks = null;
Vector inputVector = new Vector();
while (true)
{



}
```

274

Vectors

Example: Improvements to MarksAnalysis

```
// declaration and input
double mark;
double[ ] marks = null;
Vector inputVector = new Vector();
while (true)
{ output.print("Enter a mark (negative to stop): ");
  mark = input.nextDouble();


}
```

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Vectors

Example: Improvements to MarksAnalysis

```
// declaration and input
double mark;
double[ ] marks = null;
Vector inputVector = new Vector();
while (true)
{ output.print("Enter a mark (negative to stop): ");
  mark = input.nextDouble();
  if (mark < 0) break; // this is the way out of the loop

}
```

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Vectors

Example: Improvements to MarksAnalysis

```
// declaration and input
double mark;
double[ ] marks = null;
Vector inputVector = new Vector();
while (true)
{ output.print("Enter a mark (negative to stop): ");
  mark = input.nextDouble();
  if (mark < 0) break; // this is the way out of the loop
  inputVector.add(new Double(mark));
}
```

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Vectors

Example: Improvements to MarksAnalysis

```
// declaration and input
double mark;
double[ ] marks = null;
Vector inputVector = new Vector();
while (true)
{ output.print("Enter a mark (negative to stop): ");
  mark = input.nextDouble();
  if (mark < 0) break; // this is the way out of the loop
  inputVector.add(new Double(mark));
}
if (inputVector.size() != 0)
{



}
```

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Vectors

Example: Improvements to MarksAnalysis

```
// declaration and input
double mark;
double[ ] marks = null;
Vector inputVector = new Vector();
while (true)
{ output.print("Enter a mark (negative to stop): ");
  mark = input.nextDouble();
  if (mark < 0) break; // this is the way out of the loop
  inputVector.add(new Double(mark));
}
if (inputVector.size() != 0)
{ marks = new double[inputVector.size()];


}
```

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Vectors

Example: Improvements to MarksAnalysis

```
// declaration and input
double mark;
double[ ] marks = null;
Vector inputVector = new Vector();
while (true)
{ output.print("Enter a mark (negative to stop): ");
  mark = input.nextDouble();
  if (mark < 0) break; // this is the way out of the loop
  inputVector.add(new Double(mark));
}
if (inputVector.size() != 0)
{ marks = new double[inputVector.size()];
   for (int j=0; j<marks.length; j++)
       marks[j] = ((Double) inputVector.get(j)).doubleValue();
}
```

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Vectors

Example: Improvements to MarksAnalysis

```
// declaration and input
double mark;
double[ ] marks = null;
Vector inputVector = new Vector();
while (true)
{ output.print("Enter a mark (negative to stop): ");
  mark = input.nextDouble();
  if (mark < 0) break; // this is the way out of the loop
  inputVector.add(new Double(mark));
}
if (inputVector.size() != 0)
{ marks = new double[inputVector.size()];
   for (int j=0; j<marks.length; j++)
      marks[j] = ((Double) inputVector.get(j)).doubleValue();
}
```

Remark: We cannot use the Vector method copyInto as the array we copying to has primitive type elements, double.

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Vectors

Example: Improvements to MarksAnalysis

```
// declaration and input
double mark;
double[ ] marks = null;
Vector inputVector = new Vector();
while (true)
{ output.print("Enter a mark (negative to stop): ");
  mark = input.nextDouble();
  if (mark < 0) break; // this is the way out of the loop
  inputVector.add(new Double(mark));
}
if (inputVector.size() != 0)
{ marks = new double[inputVector.size()];
   for (int j=0; j<marks.length; j++)
      marks[j] = ((Double) inputVector.get(j)).doubleValue();
}
```

Remark:

- We see that input flexibility has come at the cost of more complicated code.
- This is typical.

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Vectors

Example: Improvements to MarksAnalysis

```
// computation and output
```

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Vectors

Example: Improvements to MarksAnalysis

```
// computation and output
if (marks == null)
  output.println("No marks entered.");
```

284

Vectors

Example: Improvements to MarksAnalysis

```
// computation and output
if (marks == null)
  output.println("No marks entered.");
else
{




}
```

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Vectors

Example: Improvements to MarksAnalysis

```
// computation and output
if (marks == null)
  output.println("No marks entered.");
else
{ double sum = 0;
  for (int j=0; j< marks.length; j++)
     sum += marks[j];

}
```

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Vectors

Example: Improvements to MarksAnalysis

```
// computation and output
if (marks == null)
   output.println("No marks entered.");
else
{ double sum = 0;
  for (int j=0; j< marks.length; j++)
     sum += marks[j];
  output.println("The class average is " + sum / marks.length);
}
```

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Vectors

Example: Improvements to MarksAnalysis

```
public class MarksAnalysis
{ public static void main(String[ ] args)
  { // declaration
    // input
    // computation
    // output
  }
}
```

Remark: Implementation complete.

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Summary

- Introduction
- Aggregation API
- Collections
- Algorithm complexity
- Further example usage
- Appendix: Java class Vector

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