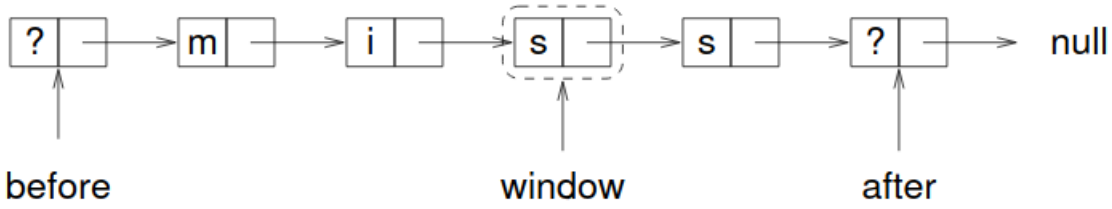
Introduction to Data Structures

- Why study data structures?
- Collections, abstract data types (ADTs), and algorithm analysis
- More on ADTs
- What's ahead?



What are Data Structures?

- Data structures are software artifacts that allow data to be stored, organized and accessed.
- They are more high-level than computer memory (hardware) and lower-level than databases and spreadsheets (which associate meta-data and meaning to the stored data).
- Ultimately data structures have two core functions: put stuff in, and take stuff out.

Why?

- software is complex
  — more than any other man made system
  — even more so in today's highly interconnected world
- software is fragile
  — smallest logical error can cause entire systems to crash
- neither you, nor your software, will work in a vacuum
- the world is unpredictable
- clients are unpredictable!

Software must be correct, efficient, easy to maintain, and reusable.

What will we Study?

Collections

. . . as name suggests, hold a bunch of things. . .

"nearly every nontrivial piece of software involves the use of collections"

Seen arrays — others include queues, stacks, lists, trees, maps, sets, tables. . .

Why so many?

Space efficiency
Time efficiency:

- store (add to collection)
- search (find an object)
- retrieve (read information)
- remove or replace
- clone (make a copy)

Abstract Data Types

Allow user to *abstract* away from implementation detail.

Consider the statement: *I put my lunch in my bag and went to Uni.*

What is meant by the term *bag* in this context?

Most likely it is a *backpack*, or *satchel*, but it could also be a *hand bag*, *shopping bag*, *sleeping bag*, *body bag* ... (but probably not a *bean bag*).

It doesn't actually matter. To parse the statement above, we simply understand that a *bag* is something that we can

1. put things in,
2. carry places, and
3. take things out.

Such a specification is an *Abstract Data Type*.

Algorithm Analysis

We will consider a number of alternative implementations for each ADT. Which is best?

Simplicity and Clarity

All things being equal we prefer simplicity, but they rarely are...

Space Efficiency

- space occupied by data — overheads
- space required by algorithm (eg recursion)
  — can it blow out?

Time Efficiency

Time performance of algorithms can vary greatly.

Finding a word in the dictionary

Algorithm 1:

- Look through each word in turn until you find a match.

Algorithm 2:

- go to half way point
- compare your word with the word found
- if $<$ repeat on earlier half
  else $>$ repeat on later half

Performance

Algorithm 1 (exhaustive search) proportional to $n/2$
Algorithm 2 (binary search) proportional to $\log n$

number of words	Algorithm 1 max. comparisons	Algorithm 2 max. comparisons
10	10	4
100	100	7
1000	1000	10
10000	10000	14
100000	100000	17
1000000	1000000	20

ADTs and Java

Object-oriented programming was originally based around the concept of abstract data types.

Java classes are ideal for implementing ADTs.

ADTs require:

- Some *references* (variables) for holding the data
  (usually hidden from the user)
- Some *operations* that can be performed on the data
  (available to the user)

A class in Java has the general structure...

class declaration

variable declarations `// data held`
method declarations `// operations on the data`

Information Hiding

- Variables can be made `private`

  — no access by users

- Methods can be made `public`

  — used to create and manipulate data structure

This *encapsulation* is good programming practice
— can change

- the way the data is stored
- the way the methods are implemented

without changing the (external) *functionality*.

Advantages of ADTs

- modularity — independent development, re-use, portability, maintainability, upgrading, etc
- delay decisions about final implementation
- separate concerns of application and data structure design
- information hiding (encapsulation) — access by well-defined interface

Also other OO benefits like:

- polymorphism — same operation can be applied to different types
- inheritance — subclasses adopt from parent classes