Lecture 13: Representing software designs

- **Viewpoints**
- **Structural representations**
  - e.g. dependency graphs
- **Functional representations**
  - e.g. dataflow diagrams
- **Behavioral representations**
  - e.g. statecharts
- **Data Modeling representations**
  - e.g. entity relationship diagrams

Representing Designs

From abstractions to systems

- abstractions allow us to ignore implementation details of procedures and data structures
- for large systems we need to abstract away even more detail
- we need to represent higher level abstractions

Design representations will:

- help us to see the big picture
- allow us to communicate our designs with others
  - customers, managers, other developers, …
  - people with varying technical expertise
- allow us to measure various quality attributes
  - completeness, consistency, complexity, …

Viewpoints *(a.k.a. "projections")*

A viewpoint

- tells you which details you can ignore when forming an abstraction
- defines which details are relevant and which are not
- a viewpoint has:
  - an owner (the person interested in this abstraction)
  - a domain (the area of interest)
  - a representation scheme

Example: Building a house

- Useful viewpoints:
  - the architect's viewpoint (plan views, elevations, etc)
  - the plumber's viewpoint (routing diagrams for pipework, fittings layouts, etc)
  - the electrician's viewpoint (wiring diagrams, etc)
  - the buyer's viewpoint (artist's impression, floorplans, etc)
  - etc…
- These must all be consistent eventually!

Viewpoints can overlap

- Some aspects of a design are common to several viewpoints

Key Software Design Viewpoints

Source: *Adapted from Budgen, 1994*

Structural viewpoints

- domain: static properties (structure) of the software
- representations: structure charts, dependency graphs, etc.

Functional viewpoints

- domain: the tasks performed by the software, information flow
- representations: dataflow diagrams, procedural abstractions, etc.

Behavioral viewpoints

- domain: cause and effect within the program
- representations: state transition diagrams, statecharts, petri nets, etc.

Data-modeling viewpoints

- domain: the data objects and the relationships between them
- representations: entity relationship diagrams, object hierarchies

Ownership?

- *Each of these viewpoints will be of interest to different people*
  - *e.g. structural viewpoints are of interest to managers for planning purposes*
  - *e.g. functional viewpoints are of interest to requirements analysts and users*

Notational forms

Text

- often hard to see the big picture
- natural language is ambiguous
- best used in small chunks (e.g. for executive summaries)

Diagrams

- good for showing relationships and structure…
- …if they're kept simple:
  - small number of symbols (e.g. 2 types of box, 2 types of arrow)
  - must represent an abstraction *(e.g. a flow chart contains nearly all the detail of code, so is not an abstraction)*
  - should be easy to sketch informally!

Mathematical Expressions (formal specifications)

- very precise, very concise
- but require much training
- cannot (yet?) express all viewpoints (e.g. timing is difficult to express)

Structural notations

Objects modeled

- usually program components
  - compilation units,
  - modules,
  - procedures
  - …

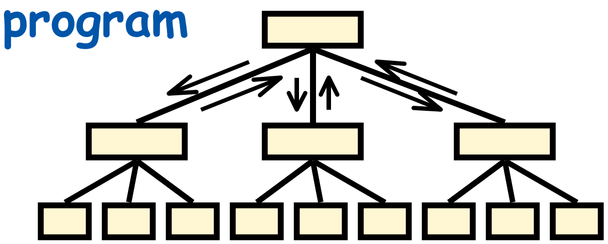
Relationships modeled

- structural relationships between components
- static relationships only
  - "calls/controls"
  - "uses"
  - …

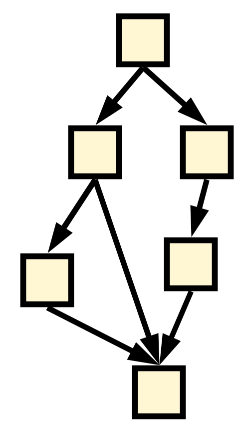
Note: structural notations deal with structure of the program, not structure of the data.

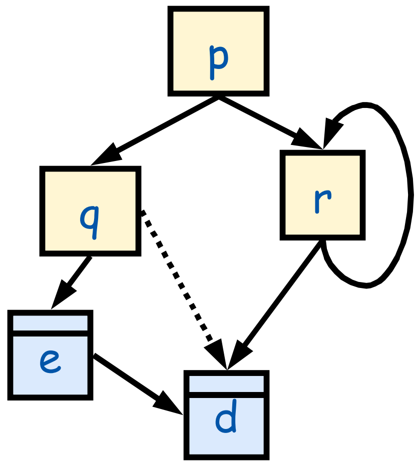
Example notations

- Structure charts
  - hierarchical decomposition of program

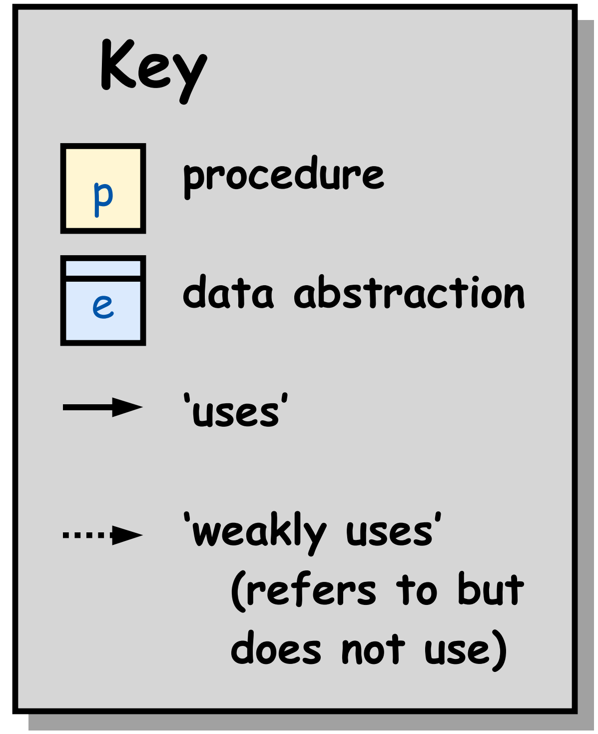


- Dependency graphs
  - show the (static) control flow





The Dependency Graph



Notes:

- all edges must be directed
- all nodes must be labeled with the name of the procedure
- only one edge between any two nodes (no matter how many times the procedure is called)
- recursive procedures (& data abstractions) use themselves

Useful for:

- debugging, integration, measuring coupling

Functional notations

See also: *van Vliet 1999, sections 11.2.1 and 11.2.2*

Objects modeled

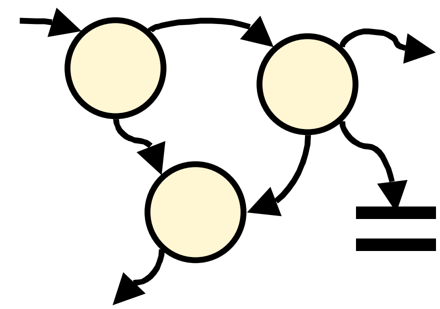
- Program components
  - modules,
  - procedures,
- Processes
  - these do not necessarily correspond to components of the program

Relationships modeled

- information flow
- inputs and outputs
  - "communicates with".
  - "sends data to"
  - "received data from"

Example notations

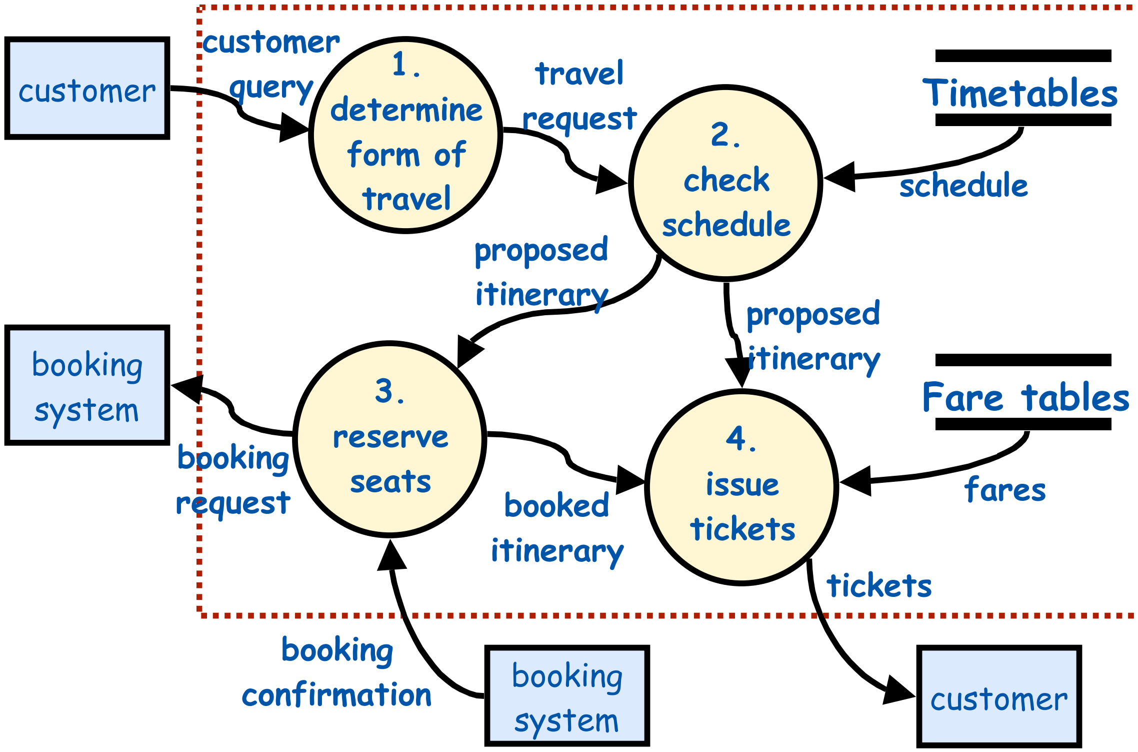
- Dataflow diagrams
  - show processes that transform data

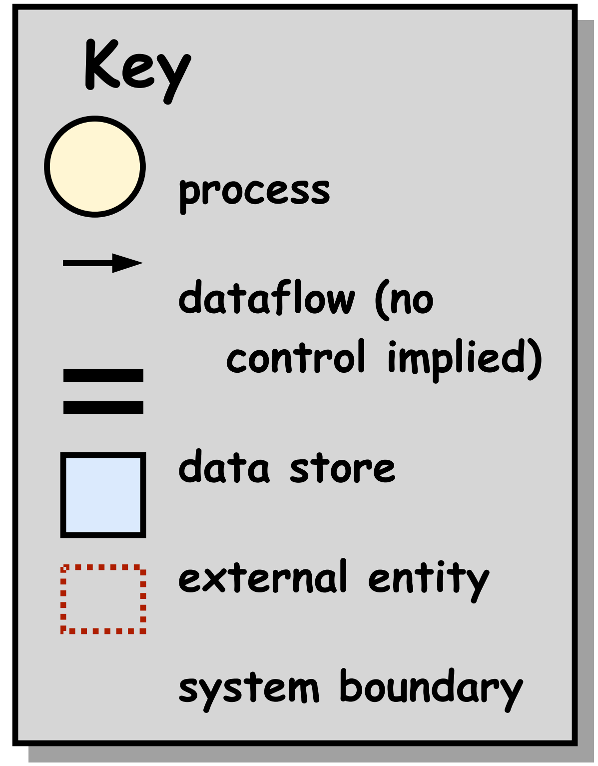


- Procedural abstractions
  - (although these combine structural viewpoint info too!)
- Pseudo-code

The Dataflow Diagram (DFD)

See also: *van Vliet 1999, pp322-325*





Notes:

- every process, flow, and datastore must be labeled
- representation is hierarchical
  - each process will be represented separately as a lower level DFD
- processes are normally numbered for cross reference
- processes transform data
  - can't have the same data flowing out of a process as flows into it

Behavioral notations

Objects modeled

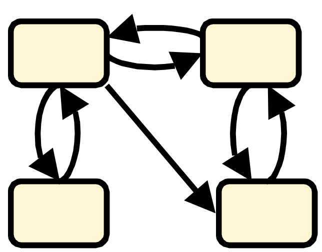
- Dynamic properties
  - events, states, actions, conditions

Relationships modeled

- cause and effect
- sequencing / parallelism

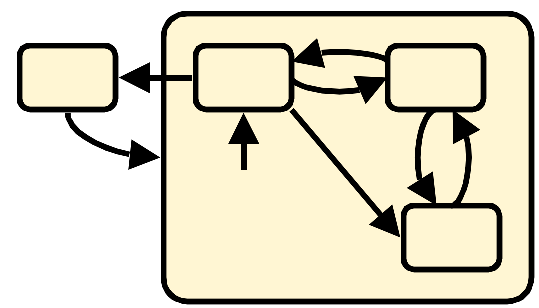
Example notations

- State Transition Diagrams
  - model the program as a finite state machine



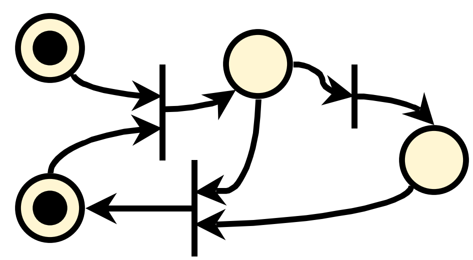
Statecharts

- like an STD but with superstates and conditional transitions



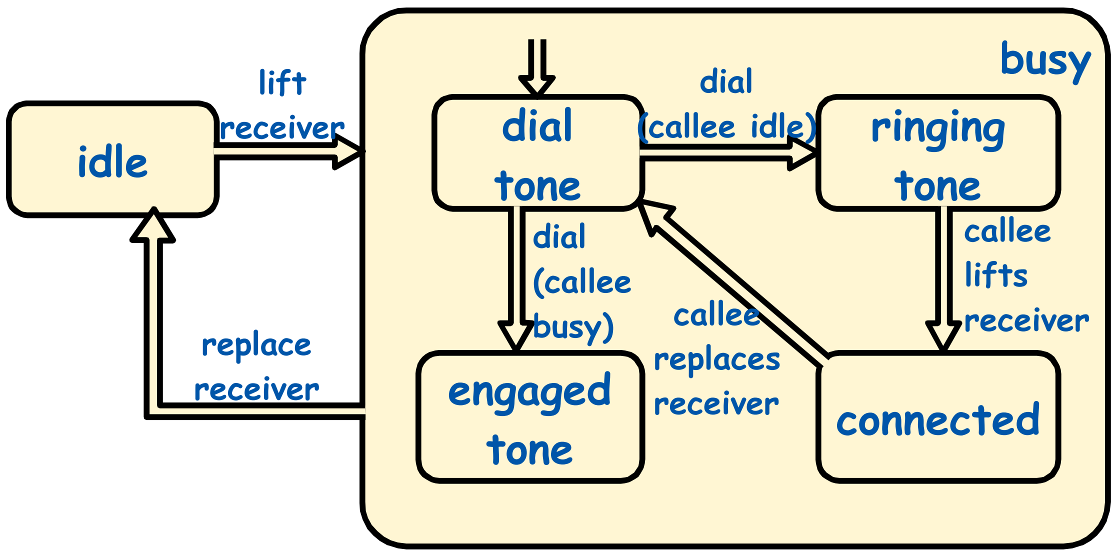
Petri nets

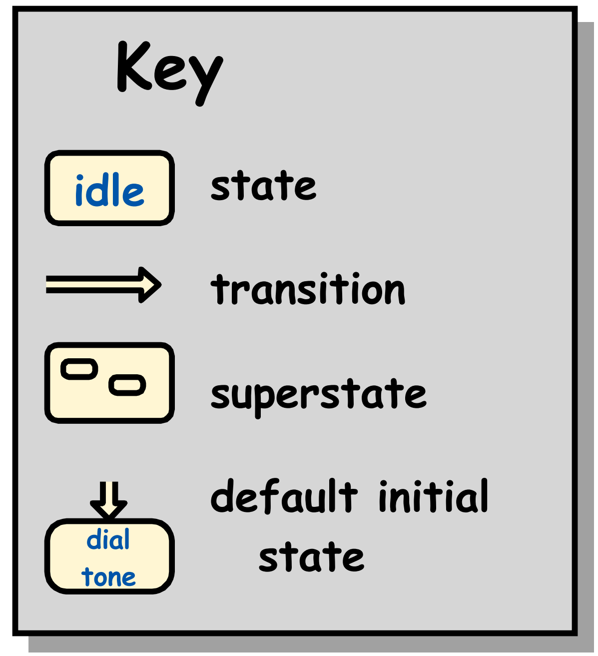
- for modeling process synchronization



Statecharts

Source: *Adapted from Easterbrook & Nuseibeh, 1996*





Notes:

all states and transitions must be labeled

transitions may be conditional (conditions shown in brackets)

states can be grouped into superstates:

- transitions out of superstates may be taken from any substate
- transitions into superstates go to the default substate

Data modelling notations

See also: *van Vliet 1999, sections 9.3.1 and 12.2.1*

Objects modeled

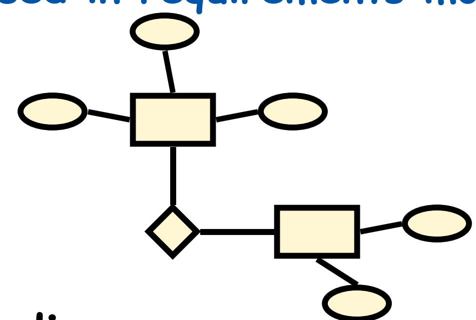
- any kind of data
  - data types,
  - objects,
  - attributes of objects,
  - classes,

Relationships modeled

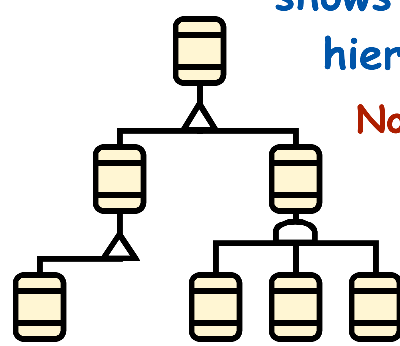
- compositional
  - "part of"
  - "consists of"
- classification
  - "is a kind of"

Example notations

- Entity Relationship Diagrams
  - used in requirements modeling

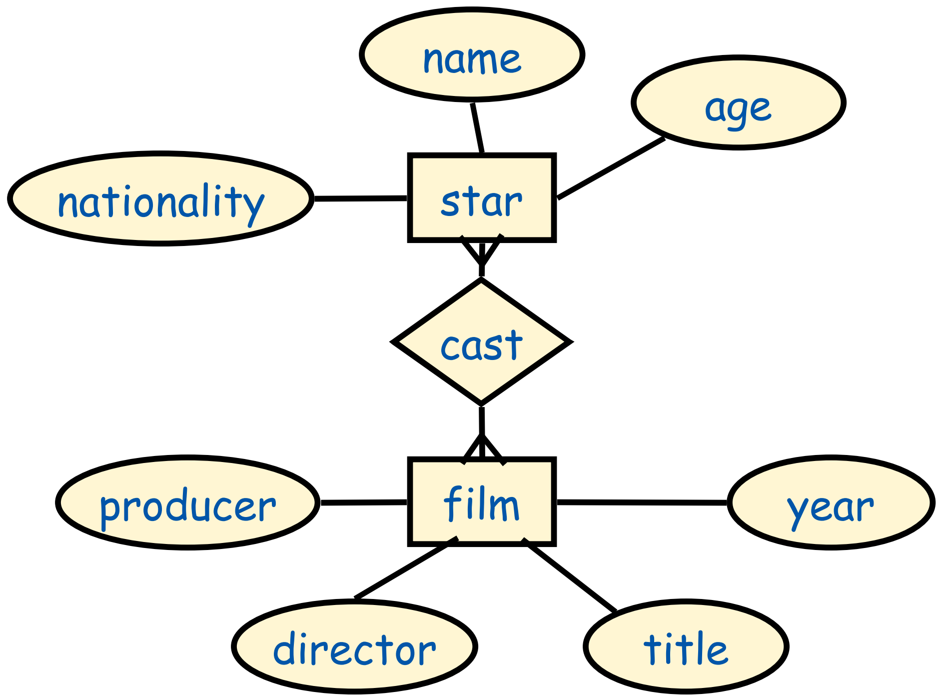


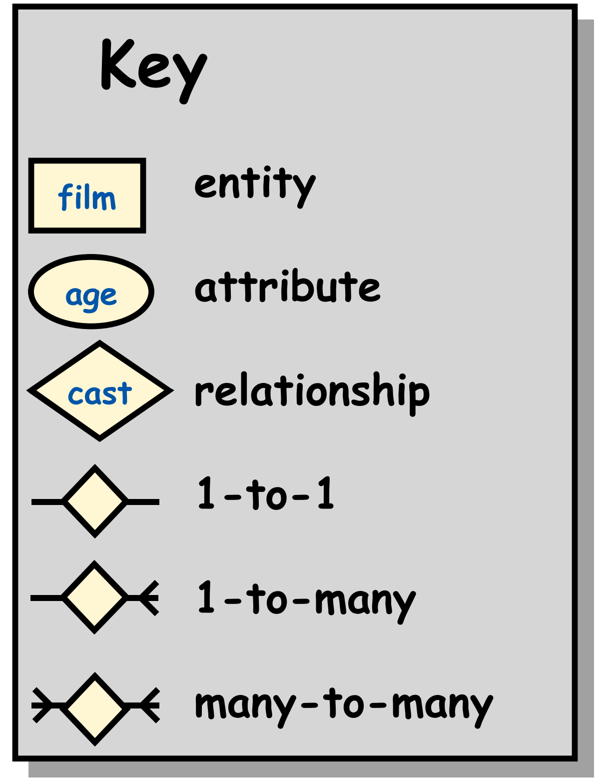
- Class diagrams
  - shows data abstraction hierarchy
    - Note: in OOD, is used as a structural notation for the program!!!



Entity Relationship Diagram

See also: *van Vliet 1999, section 9.3.1*





Notes:

relationships relate entities, not their attributes

there is no standard way to show the cardinality of relationships

Summary

Viewpoints help in creating abstractions

- a viewpoint is an abstraction created for a particular purpose by a particular person
- the viewpoint tells you what information to ignore when creating the abstraction
- each viewpoint has a suitable representation scheme

Useful software design viewpoints:

- structural
- functional
- behavioral
- data modeling

But a notation is not enough…

- you need a method to tell you how to use it.
- We'll see some sample methods later in the course.

References

van Vliet, H. "Software Engineering: Principles and Practice (2nd Edition)" Wiley, 1999.

Chapter 11 covers various aspects of design, and introduces various design methods that combine these various viewpoints. Chapter 9 introduces some of the notations used in requirements engineering, while chapter 12 introduces notations used in object oriented design.

Budgen, D. "Software Design". Addison-Wesley, 1994

chapters 5 and 6 give a good overview of the idea of design viewpoints and an introduction to the more common notations

Easterbrook, S. M. and Nuseibeh, B. A. "Using ViewPoints for Inconsistency Management". Software Engineering Journal, Vol 11, No 1, Jan 1996.

There is a growing body of research on how viewpoints can be used in software development to provide a foundation for tool support. This paper briefly introduces a framework for managing viewpoints, and then shows how they can be used to support evolution and consistency management in large specifications. The paper is available online at http://www.cs.toronto.edu/~sme/papers/1996/NASA-IVV-95-002.pdf