Lecture 5: Modeling Enterprises

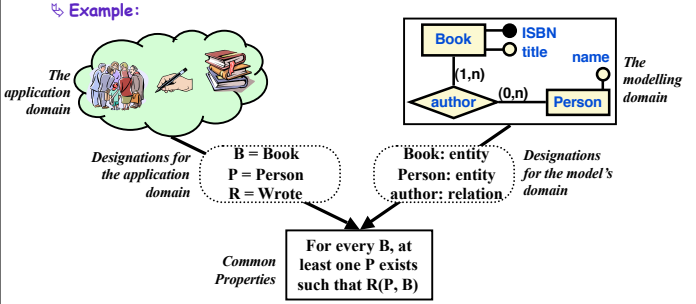
Last Week:
Elicitation Techniques
Interviews, surveys, etc
Cognitive approaches
Contextual approaches

This Week:
Modeling Enterprises
General Modeling Issues
Modeling Human Activity
Decomposition, Means-Ends Analysis
and task dependencies

Next Week:
Modeling Info and Behaviour
Structured and OO methods
ER and Class Hierarchies
State machines

RE involves a lot of modelling

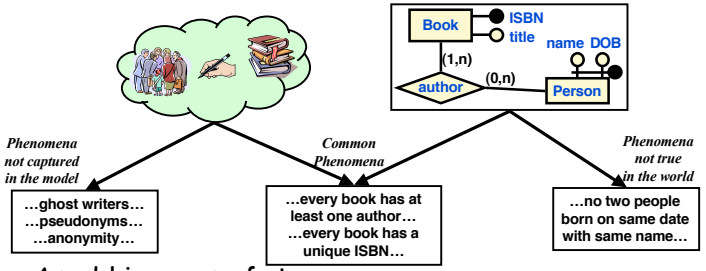
→ A model is more than just a description
- it has its own phenomena, and its own relationships among those phenomena.
  - The model is only useful if the model's phenomena correspond in a systematic way to the phenomena of the domain being modelled.
- Example:



Source: Adapted from Jackson, 1995, p120-122

"It's only a model"

→ There will always be:
- phenomena in the model that are not present in the application domain
- phenomena in the application domain that are not in the model



→ A model is never perfect
- "If the map and the terrain disagree, believe the terrain"
- Perfecting the model is not always a good use of your time…

Source: Adapted from Jackson, 1995, p124-5

Modelling…

→ Modelling can guide elicitation:
- It can help you figure out what questions to ask
- It can help to surface hidden requirements
  - i.e. does it help you ask the right questions?

→ Modelling can provide a measure of progress:
- Completeness of the models -> completeness of the elicitation (?)
  - i.e. if we've filled in all the pieces of the models, are we done?

→ Modelling can help to uncover problems
- Inconsistency in the models can reveal interesting things…
  - e.g. conflicting or infeasible requirements
  - e.g. confusion over terminology, scope, etc
  - e.g. disagreements between stakeholders

→ Modelling can help us check our understanding
- Reason over the model to understand its consequences
  - Does it have the properties we expect?
- Animate the model to help us visualize/validate the requirements

Choice of modelling notation

- natural language
  - extremely expressive and flexible
    - useful for elicitation, and to annotate models for readability
  - poor at capturing key relationships
- semi-formal notation
  - captures structure and some semantics
  - can perform (some) reasoning, consistency checking, animation, etc.
    - E.g. diagrams, tables, structured English, etc.
  - mostly visual - for rapid communication with a variety of stakeholders

UML fits in here

- formal notation
  - precise semantics, extensive reasoning possible
    - Underlying mathematical model (e.g. set theory, FSMs, etc)
  - very detailed models (may be more detailed than we need)
    - RE formalisms are for conceptual modelling, hence differ from most computer science formalisms

Source: Adapted from Loucopoulos & Karakostas, 1995, p72-73

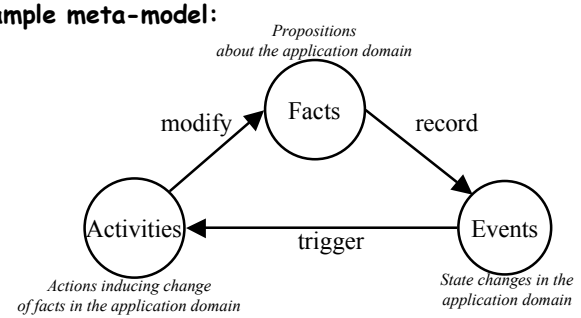
Desiderata for Modelling Notations

- Implementation Independence
  - does not model data representation, internal organization, etc.
- Abstraction
  - extracts essential aspects
    - e.g. things not subject to frequent change
- Formality
  - unambiguous syntax
  - rich semantic theory
- Constructability
  - can construct pieces of the model to handle complexity and size
  - construction should facilitate communication
- Ease of analysis
  - ability to analyze for ambiguity, incompleteness, inconsistency
- Traceability
  - ability to cross-reference elements
  - ability to link to design, implementation, etc.
- Executability
  - can animate the model, to compare it to reality
- Minimality
  - No redundancy of concepts in the modelling scheme
    - i.e. no extraneous choices of how to represent something

Source: Adapted from Loucopoulos & Karakostas, 1995, p77

Meta-Modeling

- Can compare modeling schema using meta-models:
  - What phenomena does each scheme capture?
  - What guidance is there for how to elaborate the models?
  - What analysis can be performed on the models?
- Example meta-model:



Modelling principles

- Facilitate Modification and Reuse
  - Experienced analysts reuse their past experience
    - they reuse components (of the models they have built in the past)
    - they reuse structure (of the models they have built in the past)
  - Smart analysts plan for the future
    - they create components in their models that might be reusable
    - they structure their models to make them easy to modify
- Helpful ideas:
  - Abstraction
    - strip away detail to concentrate on the important things
  - Decomposition (Partitioning)
    - Partition a problem into independent pieces, to study separately
  - Viewpoints (Projection)
    - Separate different concerns (views) and describe them separately
  - Modularization
    - Choose structures that are stable over time, to localize change
  - Patterns
    - Structure of a model that is known to occur in many different applications

Modelling Principle 1: Partitioning

- **Partitioning**
  - captures aggregation/part-of relationship
- **Example:**
  - goal is to develop a spacecraft
  - partition the problem into parts:
    - guidance and navigation;
    - data handling;
    - command and control;
    - environmental control;
    - instrumentation;
    - etc
  - Note: this is not a design, it is a problem decomposition
    - actual design might have any number of components, with no relation to these sub-problems
  - However, the choice of problem decomposition will probably be reflected in the design

Modelling Principle 2: Abstraction

- **Abstraction**
  - A way of finding similarities between concepts by ignoring some details
  - Focuses on the general/specific relationship between phenomena
    - Classification groups entities with a similar role as members of a single class
    - Generalization expresses similarities between different classes in an 'is_a' association
- **Example:**
  - requirement is to handle faults on the spacecraft
  - might group different faults into fault classes

based on location:
- instrumentation fault,
- communication fault,
- processor fault,
- etc

OR

based on symptoms:
- no response from device;
- incorrect response;
- self-test failure;
- etc...

Source: Adapted from Davis, 1990, p48 and Loucopoulos & Karakostas, 1995, p78

Modelling Principle 3: Projection

- **Projection:**
  - separates aspects of the model into multiple viewpoints
    - similar to projections used by architects for buildings
- **Example:**
  - Need to model the requirements for a spacecraft
  - Model separately:
    - safety
    - commandability
    - fault tolerance
    - timing and sequencing
    - Etc...
- **Note:**
  - Projection and Partitioning are similar:
    - Partitioning defines a 'part of' relationship
    - Projection defines a 'view of' relationship
  - Partitioning assumes a the parts are relatively independent

Source: Adapted from Davis, 1990, p48-51

Survey of Modelling Techniques

- **Modelling Enterprises**
  - Goals & objectives
  - Organizational structure
  - Tasks & dependencies
  - Agents, roles, intentionality

Organization modelling: i*, SSM, ISAC
Goal modelling: KAOS, CREWS

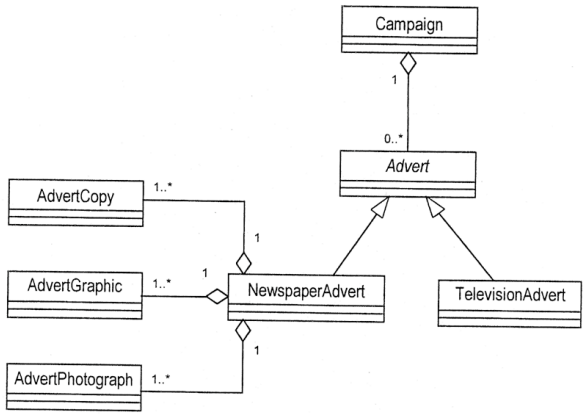
- **Modelling Information & Behaviour**
  - Information Structure
  - Behavioral views
    - Scenarios and Use Cases
    - State machine models
    - Information flow
  - Timing/Sequencing requirements

Information modelling: E-R, Class Diagrams
Structured Analysis: SADT, SSADM, JSD
Object Oriented Analysis: OOA, OOSE, OMT, UML
Formal Methods: SCR, RSML, Z, Larch, VDM

- **Modelling System Qualities** (NFRs)
  - All the 'ilities':
    - Usability, reliability, evolvability, safety, security, performance, interoperability, ...

Quality tradeoffs: QFD, win-win, AHP,
Specific NFRs: Timed Petri nets (performance) Task models (usability) Probabilistic MTTF (reliability)

What is this a model of?



Summary

→ **Modelling plays a central role in RE**
- Allows us to study a problem systematically
- Allows us to test our understanding

→ **Many choices for modelling notation**
- In this course, we'll use (and adapt) various UML notations

→ **All models are inaccurate** (to some extent)
- Use successive approximation
- …but know when to stop perfecting the model
- Every model is created for a purpose
- The purpose is not usually expressed in the model
- …So every model needs an explanation

Motivation for enterprise modeling...

Imagine we have interviewed some stakeholders…

Chief Executive
- When flight is full VIPs are first to be upgraded.
- Discounted tickets should be offered to politicians, since they make important decisions affecting the airline.
- Info about frequent fliers should not be made available to outside contractors.

Chief Security Officer
- The number of bags in the aircraft's hold should tally against the list of passengers on board.
- Passenger lists should not be made available to the public.
- Passengers should check-in only once.

Travel Agent
- An agent is responsible for holding and canceling reservations.
- Tickets offered by an agency have different fares, negotiated with the airline sales department.

Catering Manager
- The food loaded is dictated by the number of passengers travelling in a particular class.
- A predicted number of passengers on a flight must be available 24 hours prior to departure.
- Passengers requiring special meals must indicate their request 24 hours prior to departure.

Airline Sales manager
- A ticket may only be issued when a fare is paid
- For some fares, a reservation can be held and not confirmed.
- When a discounted ticket is booked, the normal book-ahead requirements do not apply.
- All tickets must carry appropriate endorsements relating to the terms and conditions of issue of tickets.

How do we get from here to an agreed specification?

Approaches to Enterprise Modeling

→ **1970's**
- Soft Systems Approaches:
  - involve the entire organisation
  - Be sensitive to political and social context for organisational change
- Examples: SSM, ISAC

→ **1980's**
- Knowledge-based Approaches:
  - Use knowledge representation schemes to build executable domain models
  - capture static and dynamic aspects of the domain
- Examples: RML, Requirements Apprentice, Nature

→ **1990's**
- Teleological Approaches:
  - Requirements are really just goals, so model goal hierarchies
  - Focus on the 'why' question, rather than 'what'/'how'
  - …and use scenarios as concrete examples of how goals are (can be) satisfied
- Examples: KAOS, i*, CREWS,…

→ **2000's …?**

ISAC

→Information Systems Work & Analysis of Changes (ISAC)

- Developed in the 1970's in Sweden
- Emphasizes cooperation between users, developers and sponsors
  - Developers' role is to facilitate the process
- Good for information systems; not applicable to control systems.

→ISAC Process

1. Change Analysis
   - What does the organization want?
   - How flexible is the organization with respect to changes?
2. Activity Study
   - Which activities should we regroup into information systems?
   - Which priorities do the information systems have?
3. Information Analysis
   - Which inputs and outputs do each information system have?
   - What are the quantitative requirements on each information system?
4. Implementation
   - Which technology (info carriers; h/w; s/w) do we use for the information systems?
   - Which activities of each information system are manual, which automatic?

ISAC Change Analysis

1. List problems
   - dissatisfactions with current system
     - list all problems…
     - …then remove any that are trivial or intractable
2. List interest groups
   - these are *"problem owners"*
   - draw matrix of problems against owners
     - This exercise is done with the problem owner's involvement
3. Analyze problems
   - Use cause-effect analysis
     - Eliminate solution-oriented problems, to get to underlying causes
   - performed by domain specialists
   - quantify the problems
4. Make Current Activity Model
   - Notation: A-schemas (similar to dataflow diagrams)
5. Analyze Goals
   - Declarative statement of goals
     - i.e. desired result, not how to get there
   - Result should be a tree of goals
6. Define Change Needs
   - Goals should explain why the problems exist; problems frustrate goals
   - Cluster problems into related groups
     - Each group is a change need
7. Generate Change Alternatives
8. Model desired situations
   - make packages of change alternatives
9. Evaluate Alternatives
10. Choose an alternative

Soft System Methodology (SSM)

→ Background

- Developed by Checkland in late 1970's
- Reality is socially constructed, and therefore requirements are not objective
- Rationale:
  - Problem situations are fuzzy (not structured) and solutions not readily apparent.
  - Impact of a computerization may be negative *(e.g. intro of new system reduced productivity as it removed employee motivation)*
  - Full exploitation of computerization may need radical restructuring of work processes.

→ Approach

- Analyze problem situation using different viewpoints
  - Determining the requirements is a discussion, bargaining and construction process.
- Out of this process emerges not just a specification, but also:
  - plans for a modified organization structure
  - task structures
  - objectives
  - understanding of the environment

SSM Approach

1 Existing situation (unstructured problem)

2 Analyze the problem situation
- Draw a rich picture
- look for problem themes (describe them in natural language)

3 Define relevant systems and root definitions (CATWOE)
- a root definition is a concise description of a human activity system

4 Build a conceptual model
- of the activity system needed to achieve the transformation
- process oriented model, with activities & flow of resources

5 Compare conceptual model with step (2)
- Ordered questioning - questions based on the model
- Event reconstruction - take past events and compare them to the model
- General comparison - look for features of the model that are different from current situation
- Model overlay - point by point comparison of the two models

6 Debate feasible and desirable changes
Three types of change: structural, procedural, attitudinal

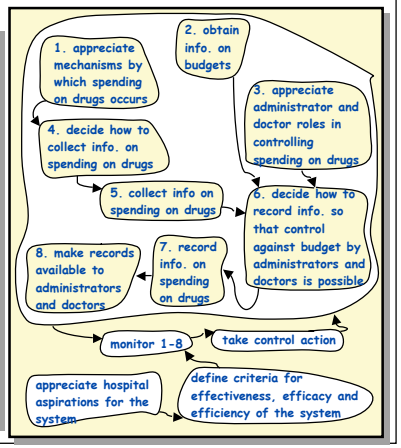
7 Implement changes

SSM modeling

Root definition:

"A hospital-owned system, which provides records of spending on drugs so that control action by administrators and doctors to meet defined budgets can be taken jointly"

Customers: Administrators, Doctors
Actors: not stated
Transformation: Need to know spending on drugs → Need met by recording info.
Weltanschauung: Monitoring spending on drugs is possible and is an adequate basis for joint control action
Owner: Hospital
Environment: Hospital mechanisms, roles of administrators and doctors, defined budgets



*i**

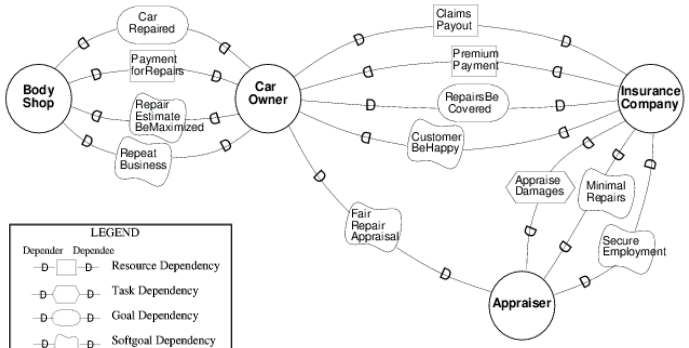
→ Background

- Developed in the early 90's
  - provides a structure for asking 'why' questions in RE
  - models the organisational context for information systems
  - based on the notion of an "intentional actor"
- Two parts to the model
  - Strategic dependency model - models relationships between the actors
  - Strategic rationale model - models concerns and interests of the actors

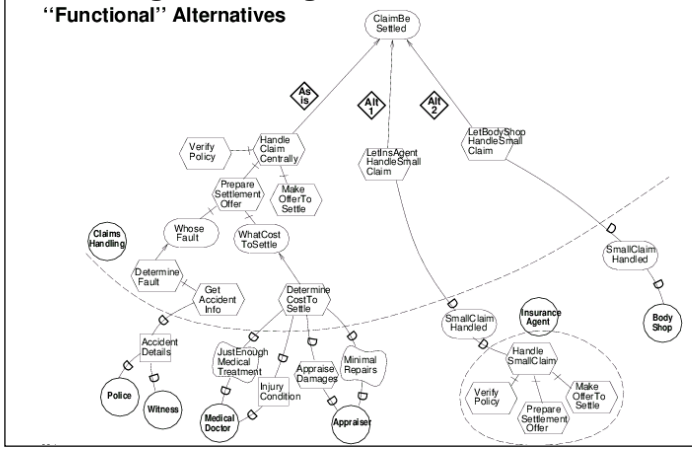
→ Approach

- SD model shows dependencies between actors:
  - goal/softgoal dependency - an actor depends on another actor to attain a goal
  - resource dependency - an actor needs a resource from another actor
  - task dependency - an actor needs another actor to carry out a task
- SR model shows interactions between goals within each actor
  - Shows task decompositions
  - Shows means-ends links between tasks and goals

E.g. Strategic Dependency Model



E.g. Strategic Rationale Model



KAOS

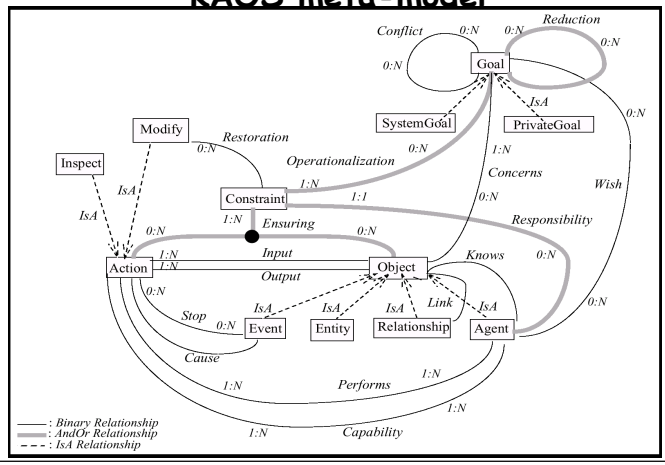
→ Background

- Developed in the early 90's
  - first major teleological requirements modeling language
  - full tool support available
  - has been applied to a number of industrial case studies
- Two parts:
  - Informal goal structuring model
  - Formal definitions for each entity in temporal logic

→ Approach

- Method focuses on goal elaboration:
  - define initial set of high level goals & objects they refer to
  - define initial set of agents and actions they are capable of
- Then iteratively:
  - refine goals using AND/OR decomposition
  - identify obstacles to goals, and goal conflicts
  - operationalize goals into constraints that can be assigned to individual agents
  - refine & formalize definitions of objects & actions

KAOS meta-model



Business Processes

→ Business Process Automation

- Leave existing business processes as they are
  - Look for opportunities to automate parts of the process
- Can make an organisation more efficient; has least impact on the business

→ Business Process Improvement

- Make moderate changes to the way the organisation operates
- E.g. improve efficiency and/or effectiveness of existing process
  - Techniques: Duration analysis; activity-based costing; benchmarking

→ Business Process Reengineering

- Fundamental change to the way the organisation operates
- Techniques:
  - Outcome analysis - focus on the real outcome from the customer's perspective
  - Technology analysis - look for opportunities to expoit new technology
  - Activity elimination - consider each activity in turn as a candidate for elimination

Modelling Business Processes

→ Business processes involve:

- Multiple actors (people, business units,…)
- Concurrent activities
- Explicit synchronization points
  - E.g. some task cannot start until several other concurrent tasks are complete
- End-to-end flow of activities

→ Choice of modelling language:

- UML Activity diagrams
  - …based on flowcharts and petri nets
  - Not really object oriented (poor fit with the rest of UML)
- Business Process Modelling Notation (BPMN)
  - New (emerging) standard, loosely based on pi calculus

Using UML for enterprise modelling

→ Use Cases
- Already assume the basic functions of the machine have been decided
- Hence, it's premature to look for Use Cases yet…

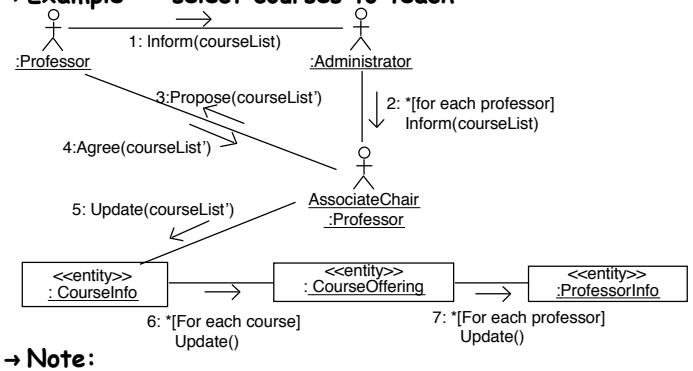
→ Collaboration/Activity Diagrams
- Show how classes (actors?) collaborate to perform tasks
  - Represent "message" flows between objects
  - Offer a simple way of diagramming scenarios
- But do not show:
  - Intentionality, task dependency, task decomposition

→ Class diagrams
- Show the actors/roles and entities in the domain
  - Concentrate on static structure
  - Can implicitly capture business rules through multiplicity constraints
- Must remember to model *domain entities* rather than *implementation classes*

→ Conclusion
- UML offers only very crude tools for enterprise modeling

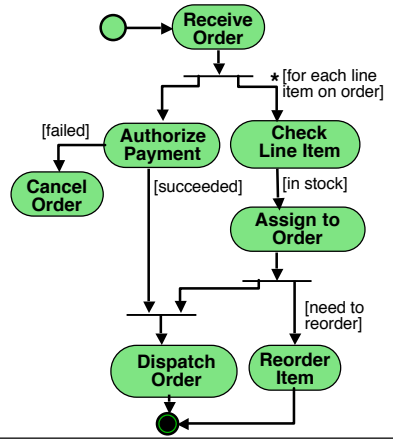
Collaboration Diagrams

→ Example - "select courses to teach"

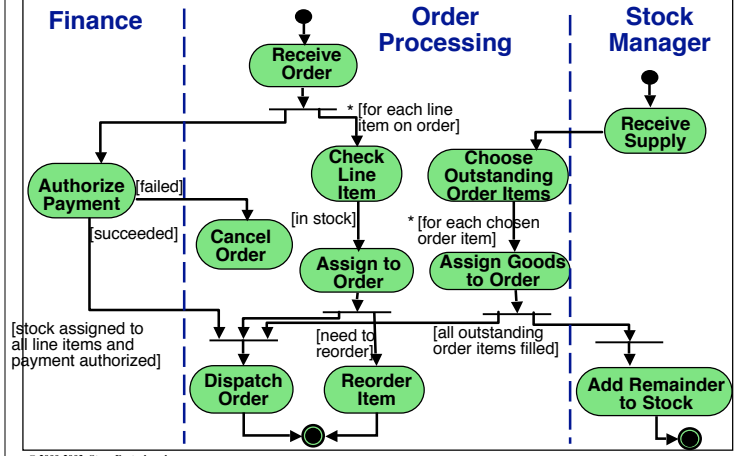


→ Note:
- Impossible to tell whether this is an indicative or optative description

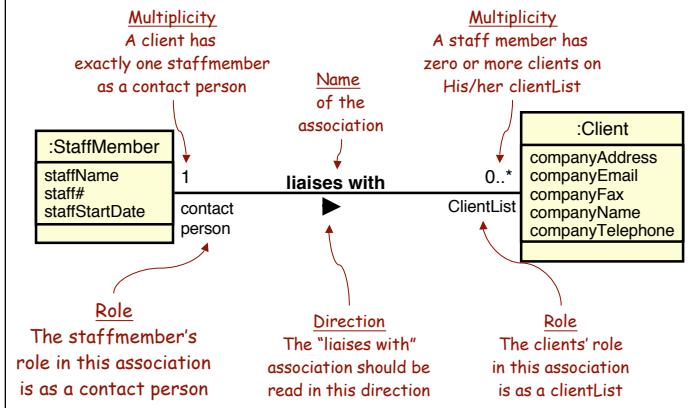
Example Activity Diagram



Activity Diagram with Swimlanes



Class Associations



Capturing Business Rules

→ Why do we care about business rules?
- They help us to understand the business context
- They could be important constraints for the design of the new system
  - E.g. constraints on when and how operations can happen
  - E.g. constraints on the state space of objects
- They help us write "operation specifications" for class operations

→ How do we specify business rules?
- Natural Language
  - such descriptions can be highly ambiguous
- Structured English
  - use a subset of a natural language (limited syntax and vocabulary)
  - can be hard to write, hard to verify, and too close to program code
- Decision Tables
  - use a table representation of alternative outcomes (similar to truth tables)
- Decision Trees
  - use a tree representation of alternative outcomes
- Object Constraint Language
  - UML notation for adding extra constraints to models
  - Can also be used for specifying pre- and post-conditions on operations

Decision Tables

→ Inputs as columns, actions (outputs) as rows
- If there are n parameters (conditions) to a decision, each with k_1, k_2,…,k_n values, then table has:
  - $k_1 \times k_2 \times \ldots \times k_n$ columns
  - as many rows as there are possible actions
- For example:
  - "If the plane is more than half full and the flight costs more than $350 per seat, serve free cocktails, unless it is a domestic flight. Charge for cocktails in all domestic flights where cocktails are served, i.e., those that are more than half full"

conditions	Domestic?	Y	Y	Y	Y	N	N	N	N
	≥half full?	Y	Y	N	N	Y	Y	N	N
	≥$350/seat	Y	N	Y	N	Y	N	Y	N
outcomes	Serve cocktails?	X	X			X	?	?	?
	Free cocktails?					X			

Decision Trees

→ Represent the decision logic as a tree:
- Nodes of the tree represent input parameters (questions)
- Leafs of the tree represent outputs (actions)

→ Example: