Lecture 5: Modeling Enterprises

Last Week:
Elicitation Techniques
Cognitive approaches
Contextual approaches
Ethnography

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 Hierachies
State machines

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.

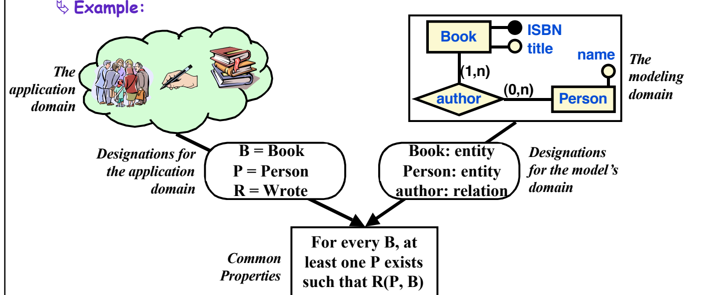
Catering Manager
The food loaded is dictated by the number of passengers travelling in a particular class.
A predicted number of passengers on a flight must be available 24 hours prior to departure.
Passengers requiring special meals must indicate their request 24 hours prior to departure.

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?

RE involves a lot of modelling

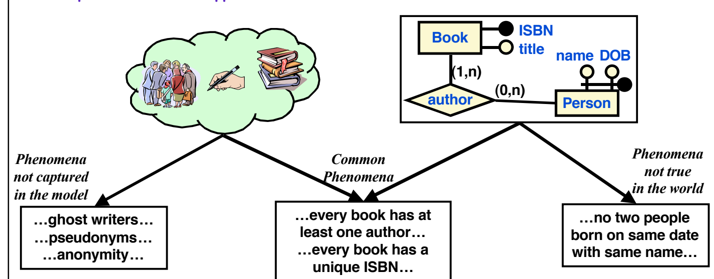
- A model is more than just a description
  - it has its own phenomena, and its own relationships among those phenomena.
    - The model is only useful if the model's phenomena correspond in a systematic way to the phenomena of the domain being modelled.
  - Example:



Source: *Adapted from Jackson, 1995, p120-122*

Remember: "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*

Modeling…

- **Modeling can guide elicitation:**
  - Does the modeling process help you figure out what questions to ask?
  - Does the modeling process help to surface hidden requirements?
    - i.e. does it help you ask the right questions?
- **Modeling can provide a measure of progress:**
  - Does completeness of the model imply completeness of the elicitation?
    - i.e. if we've filled in all the pieces of the model, are we done?
- **Modeling can help to uncover problems**
  - Does inconsistency in the model reveal interesting things…?
    - e.g. inconsistency could correspond to conflicting or infeasible requirements
    - e.g. inconsistency could mean confusion over terminology, scope, etc
    - e.g. inconsistency could reveal disagreements between stakeholders
- **Modeling can help us check our understanding**
  - Can we test that the model has the properties we expect?
  - Can we reason over the model to understand its consequences?
  - Can we animate the model to help us visualize/validate the requirements?

Type of Model

Can choose a variety of conceptual schema:

- **natural language**
  - extremely expressive and flexible
  - very poor at capturing the semantics of the model
  - better used for elicitation, and to annotate models for communication
- **semi-formal notation**
  - captures structure and some semantics
  - can perform (some) reasoning, consistency checking, animation, etc.
    - E.g.s: diagrams, tables, structured English, etc.
  - mostly visual - for rapid communication with a variety of stakeholders
- **formal notation**
  - very precise semantics, extensive reasoning possible
  - long way removed from the application domain
    - note: requirements formalisms are geared towards cognitive considerations, hence differ from most computer science formalisms

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

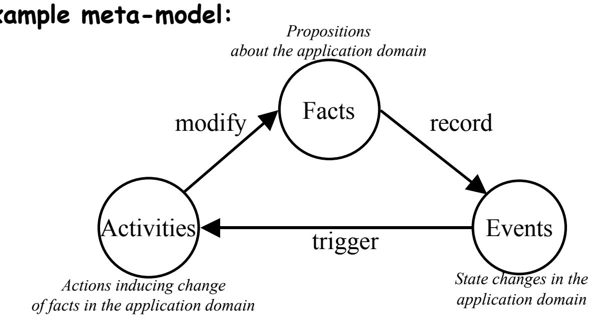
Desiderata for Conceptual Schema

- **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 modeling 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:**



Modeling 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

Modeling 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:		based on symptoms:
instrumentation fault,	OR	no response from device;
communication fault,		incorrect response;
processor fault,		self-test failure;
etc		etc...

Modeling 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 communication between spacecraft and ground system
  - Model separately:
    - sequencing of messages;
    - format of data packets;
    - error correction behavior;
    - 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

Survey of Modeling Techniques

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

> **Organization modeling:** i*, SSM, ISAC
> **Goal modeling:** KAOS, CREWS

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

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

- Modeling System Qualities (NFRs)
  - Product requirements
  - Process requirements
  - External requirements

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

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

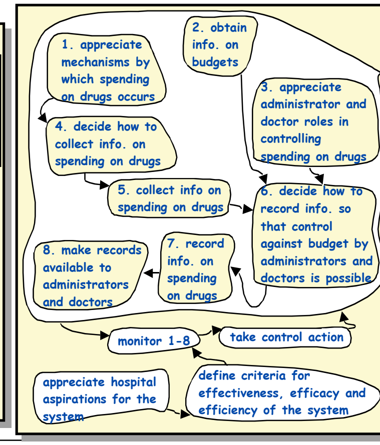
7 Implement changes

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

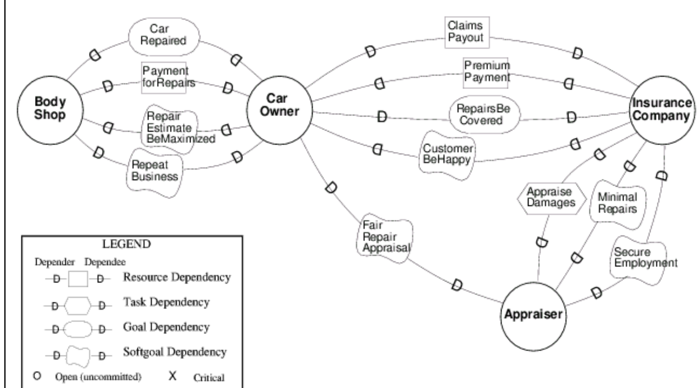


*i**

→ 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

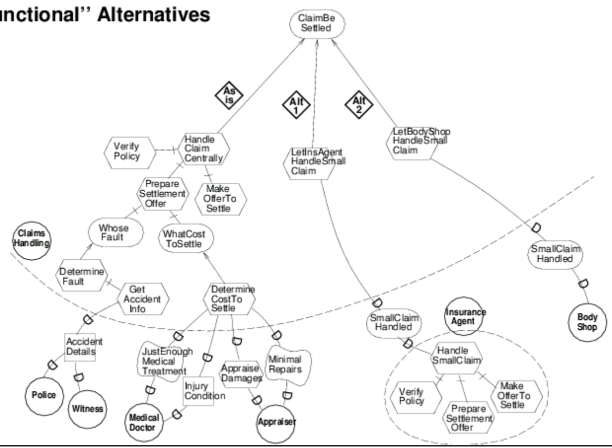
E.g. Strategic Dependency Model



This diagram ©2001, Eric Yu

E.g. Strategic Rationale Model

"Functional" Alternatives



This diagram ©2001, Eric Yu

KAOS

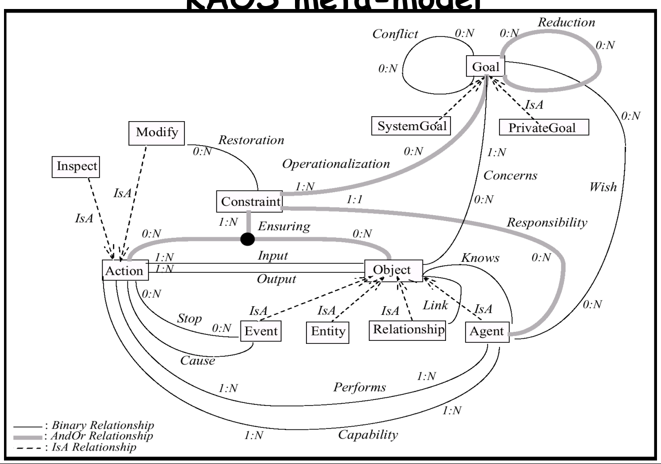
→ Background

- 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



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

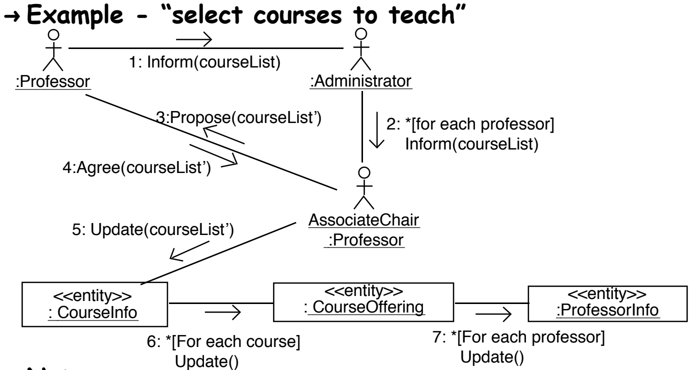
- Show the actors/roles and entities in the domain
  - Concentrate on static structure
  - Can implicitly capture business rules through multiplicity constraints
- Must remember to model *domain entities* rather than *implementation classes*

→ Conclusion

- UML offers only very crude tools for enterprise modeling

Collaboration Diagrams

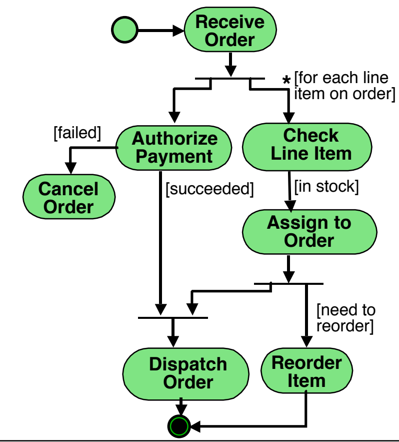
→ Example - "select courses to teach"



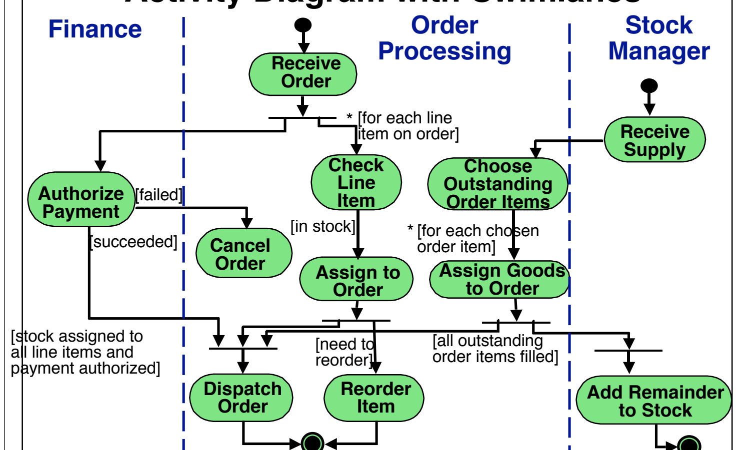
→ Note:

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

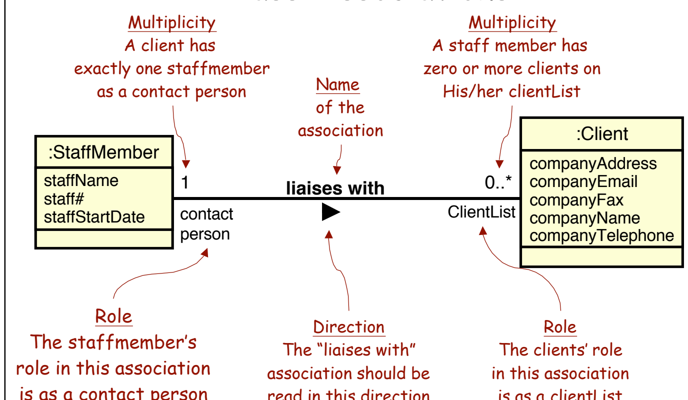
Example Activity Diagram



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: