Presentation in Lleida, 2000

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Modeling with LIMIDs —

Exemplified by Disease Treatment in Slaughter Pigs

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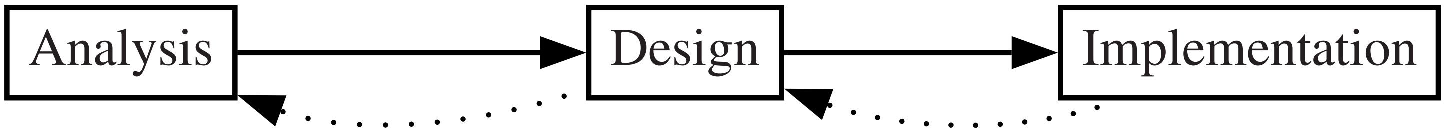
The Development of a Decision Support System

Software Development Process:



Advantages of the Object Oriented Paradigm:

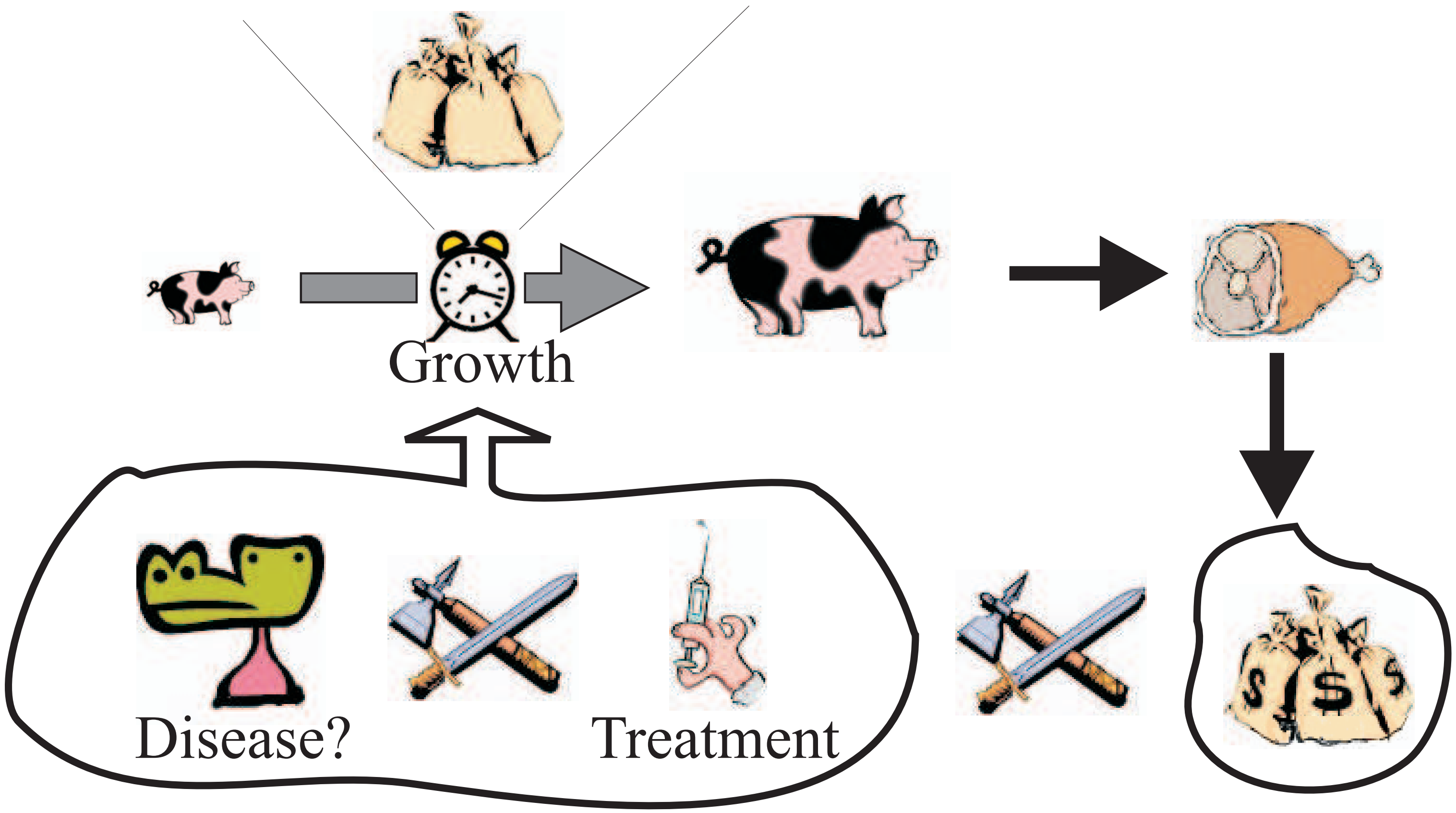
- Component based development.
- Encapsulation, Inheritance, etc.
- Existing methods exist for A, D, and I-phases.

Challenge: Bayesian Networks, Influence Diagrams, or LIMIDs as implementation language.

Disease Treatment in Slaughter Pigs - Analysis

Example: Development of non-infectious disease in the individual.

Overview: Illustration by a “rich picture”.



Analysis — cnt'ed

Dynamic decision scenario with partially observable state, observations, and decisions.

- **State:** Health status of the Slaughter Pig.
- **Observation:** An insecure test reflecting the state.
- **Decision:** Treat or do nothing.

Stepwise modeling:

- State model $\rightarrow$ Observation model $\rightarrow$ Decision model.

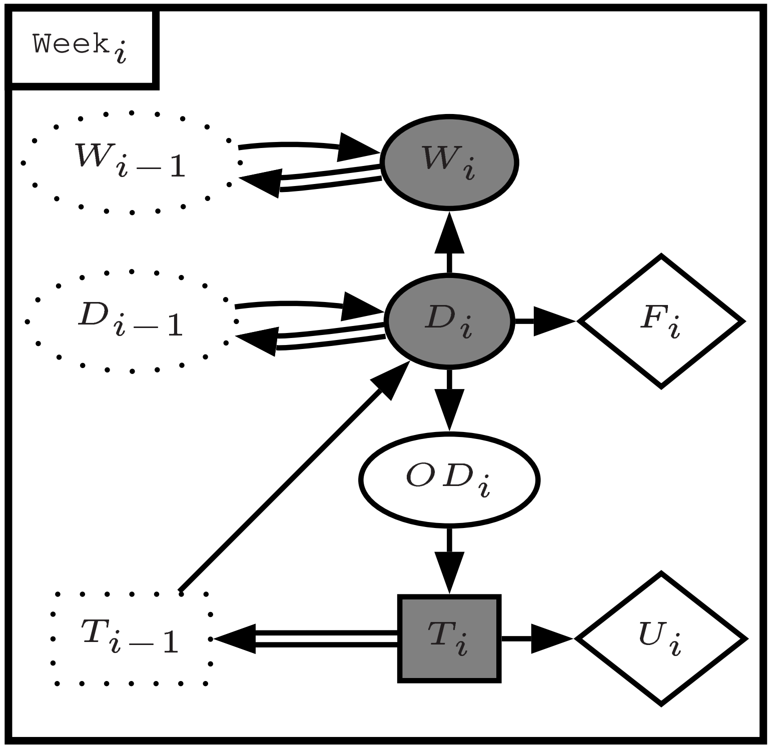
Design Phase — Tasks

- Determine nodes and states.

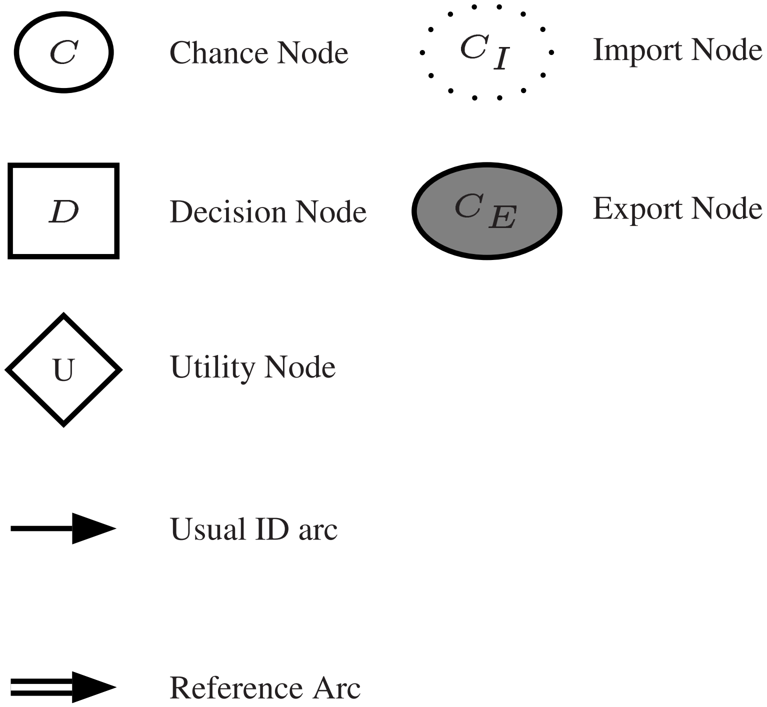
Name	Description	States
W_i	A counter, summing the weeks spent sick.	$\{0, \ldots, 16\}$
D_i	Disease stage	$\{H, I, R, D\}$
OD_i	Observed disease state through test	{healthy,diseased,dead}
T_i	Apply treatment?	{yes,no}

- Fix temporal characteristics.
- Establish graphical structure of the network using an Object Oriented specification language.

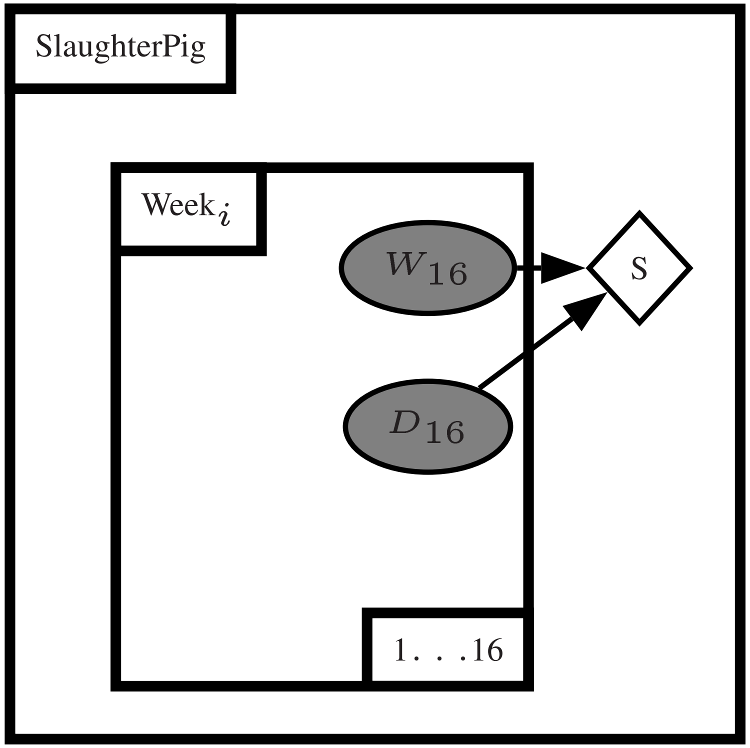
Object Oriented Specification of the Slice-Network



The Week$_i$ class.



The SlaughterPig-Network

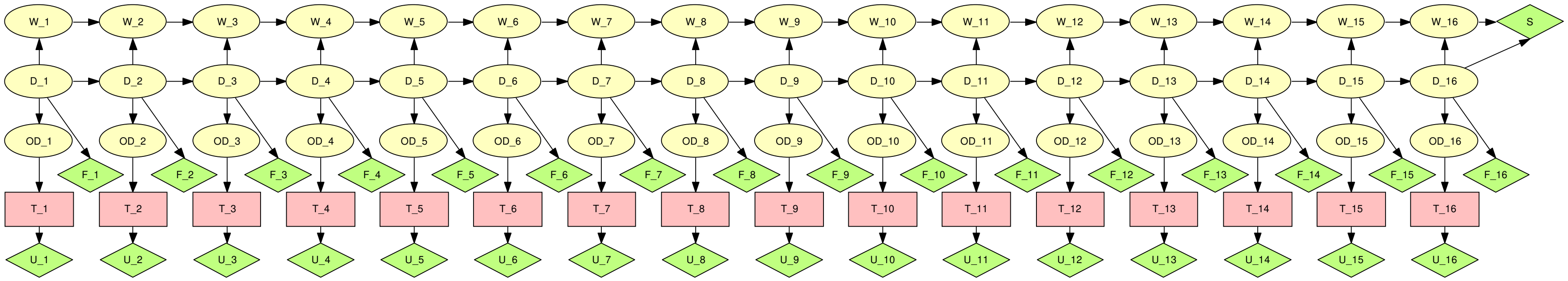


The SlaughterPig class.

Comments:

- Class contains (a number of) instances of other classes.
- Only used export nodes need to be drawn.
- Information-hiding keeps things clear.
- An equivalent ordinary network can be obtained by unfolding.

The Underlying Network

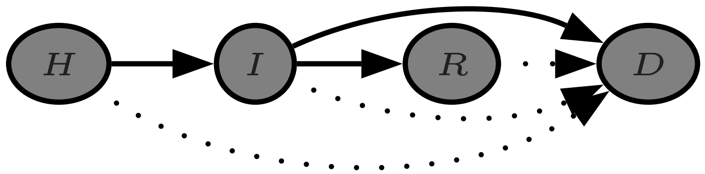


Conclusion:

- Development and maintenance should happen in OO-notation.
- So far only graphical notation $\rightarrow$ Inference?

Implementation Phase

- Specification of the quantitative side
  - Deterministic Time Markov Chain for disease evolution.



  - Sensitivity & Specificity of the test.
  - Reward received for slaughtering.
- Which solution technique to find maximum expected utility?
  - Influence Diagrams
  - Limited Memory Influence Diagrams

Relevant History in Dynamic Decision Scenarios

$H_R(T_i)$: relevant history for decision T_i. In our example:

$$H_R(T_i) = \{OD_1, T_1, \ldots, OD_{i-1}, T_{i-1}, OD_i\}$$

Goal: Find pure policy for T_i:

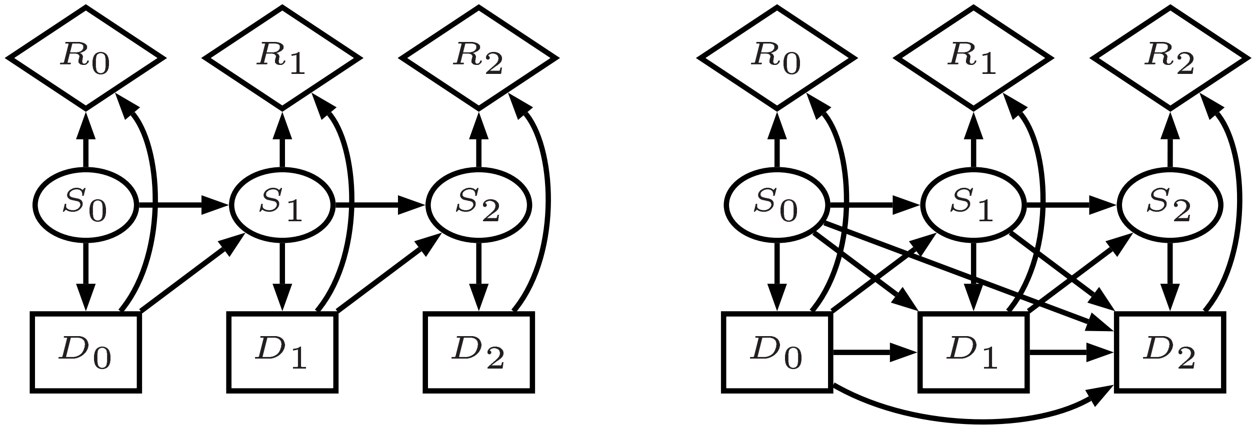
$$\delta_{T_i} : \mathcal{X}_{H_R(T_i)} \times \mathcal{X}_{T_i} \to \{0, 1\}.$$

Problems:

- δ_{T_i} quickly intractably large as i increases $\to$ IDs fail.
- Domain constraints $\to$ relevant past is unavailable $\to$ IDs fail.

Limited Memory Influence Diagrams

- Explicit specification of memory, i.e. information arcs. $\rightarrow$ tractable policies.



(a) 3-slice MDP as ID/LIMID (b) ID from (a) as LIMID

- Procedure to determine all graph deducible non-requisite information links.

LIMIDs - cnt'ed

Iterative Solution Algorithm: Single Policy Updating

- Finds a *local maximum strategy*.
  - No EU improvement can be obtained by changing the policy for at most one decision.
  - How good is the local maximum??
- Finding a *global maximum strategy* is in general NP-complete. Although, for *Soluble LIMIDs*: lms $\equiv$ gms.

Results for our Model

- Local maximum for our memoryless strategy:
  - $T_1, \ldots, T_{12}$ — apply treatment if test positive.
  - $T_{13}, \ldots, T_{16}$ — do not treat no matter what
- Treating of a disease with low mortality rate is not beneficial close to slaughter time.
- Memoryless policies are not that bad?

memory	EU [DKK]
0	284.959
1	285.847

Conclusions

- OO-specification practical when dealing with large networks.
- One step closer to interleaving OOA, OOD, and OOI-phases for BNs, IDs, or LIMIDs.
- LIMIDs allow a more flexible treatment of relevant history, necessary in dynamic decision scenarios.
- Memoryless strategies are not that bad — quality of the found local maximum?