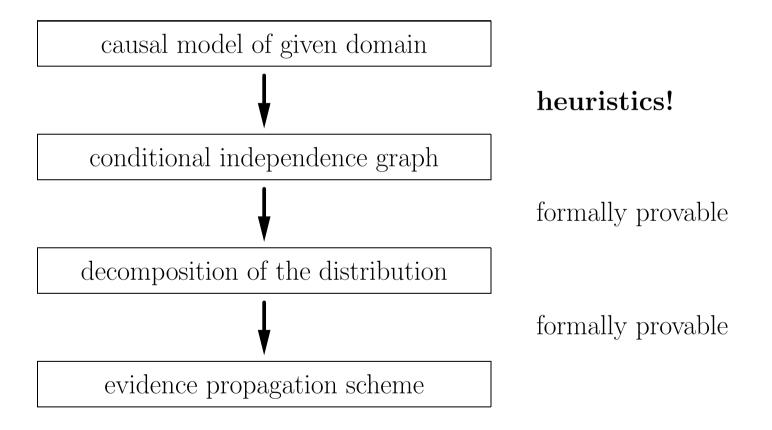
Manual Building of Bayes Networks

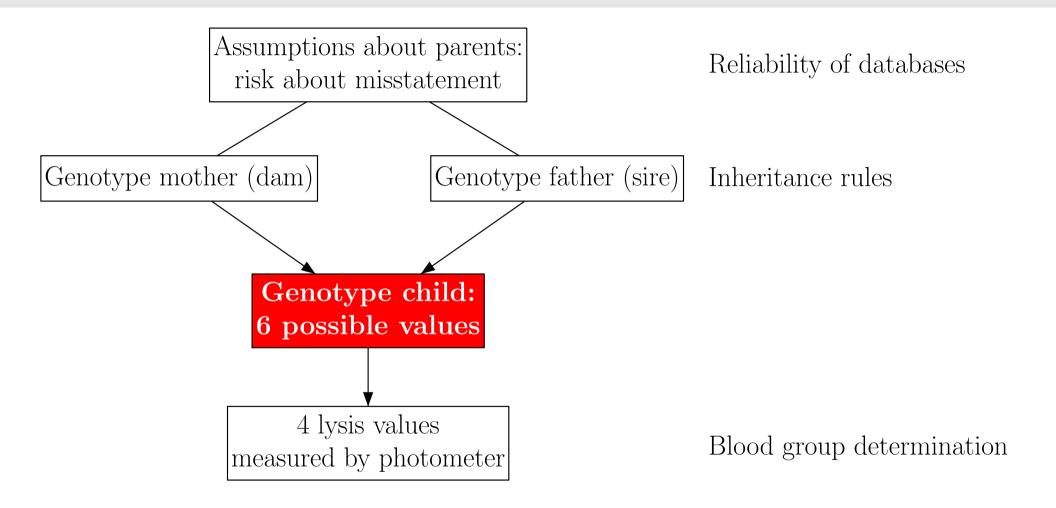
Building Graphical Models: Causal Modeling

Manual creation of a reasoning system based on a graphical model:



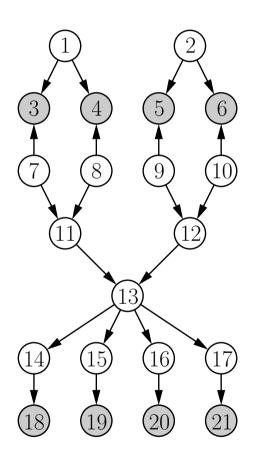
Problem: strong assumptions about the statistical effects of causal relations.

Nevertheless this approach often yields usable graphical models.



See paper on our website.

Danish Jersey Cattle Blood Type Determination



21 attributes:	11 – offspring ph.gr. 1
1 - dam correct?	12 – offspring ph.gr. 2
2 - sire correct?	13 – offspring genotype
3 – stated dam ph.gr. 1	14 - factor 40
4 – stated dam ph.gr. 2	15 - factor 41
5 – stated sire ph.gr. 1	16 - factor 42
6 – stated sire ph.gr. 2	17 - factor 43
7 – true dam ph.gr. 1	18 - lysis 40
8 – true dam ph.gr. 2	19 - lysis 41
9 – true sire ph.gr. 1	20 - lysis 42
10 – true sire ph.gr. 2	21 - lysis 43

The grey nodes correspond to observable attributes.

This graph was specified by human domain experts, based on knowledge about (causal) dependences of the variables.

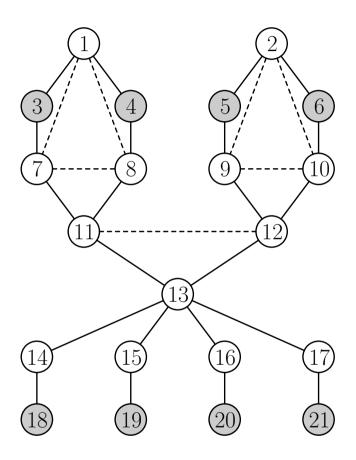
Full 21-dimensional domain has $2^6 \cdot 3^{10} \cdot 6 \cdot 8^4 = 92\,876\,046\,336$ possible states.

Bayesian network requires only 306 conditional probabilities.

Example of a conditional probability table (attributes 2, 9, and 5):

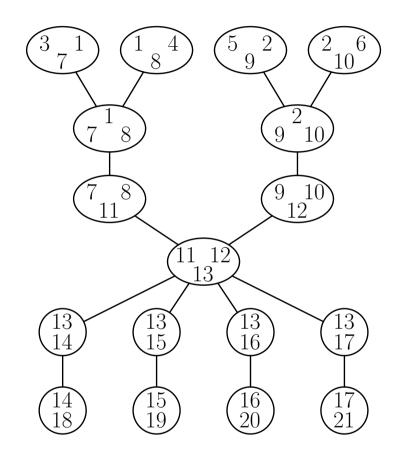
sire	true sire	stated sire phenogroup 1		
correct	phenogroup 1	F1	V1	V2
yes	F1	1	0	0
yes	V1	0	1	0
yes	V2	0	0	1
no	F1	0.58	0.10	0.32
no	V1	0.58	0.10	0.32
no	V2	0.58	0.10	0.32

The probabilities are acquired from human domain experts or estimated from historical data.



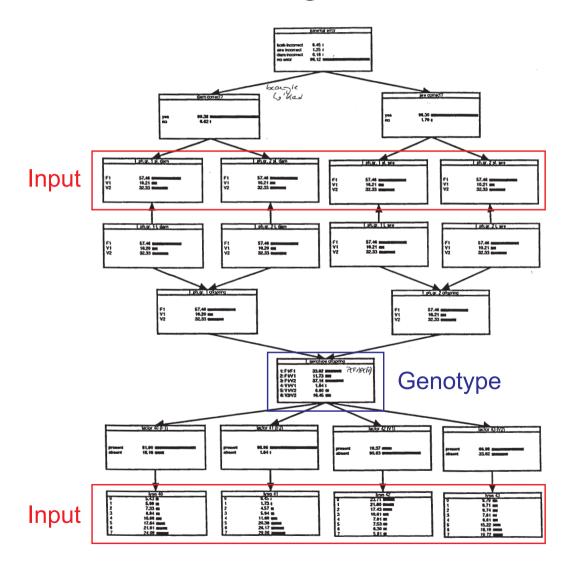
moral graph

(already triangulated)

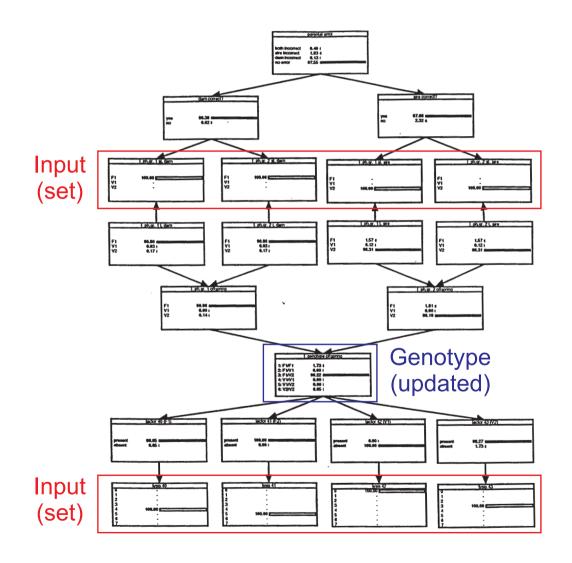


join tree

Marginal distributions before setting evidence:



Conditional distributions given evidence in the input variables:



Example 2: Item Planning at Volkswagen

Strategy of the VW Group

Marketing strategy	Vehicle specification by	Bestsellers defined by	
	clients	manufacturer	
Complexity	Huge number of variants	Small number of vari-	
		ants	



Vehicle specification

Equipment	fastback	2,8 l, 150 kW	Type Alpha	4	leather	
Group	car body type	engine	radio	doors	seat cover	

Example 2: Model "Golf"

Approx. 200 equipment groups

2 to 50 items per group

Therefore more than 2^{200} possible vehicle specifications

Choice of valid specifications is constrained by a rule system (10000 technical rules, plus marketing and production rules)

Example of technical rules:

If Engine= e_1 then Transmission= t_3

If Engine= e_4 and Heating= h_2 then Generator $\in \{g_3, g_4, g_5\}$

Problem Representation

Historical Data

Sample of produced *vehicle specifications*

(representative choice, context-dependent, e.g. Golf)

System of Rules

Rules for the validity of item combinations

(specified for a vehicle class and a planning interval)

Prediction & Planning

Predicted / assigned planning data

(production program, demands, installation rates, capacity restrictions, ...)

Complexity of the Planning Problem

Equipment table

	Engine	Transmission	Heating	Generator	•••
1	e_1	t_3	h_1	g_1	• • •
2	e_2	t_4	h_3	g_5	• • •
	• • •	• • •	• • •	• • •	
100000	e_7	t_1	h_3	g_2	• • •

Installation rates

Engine	Transmission	Heating	Generator	• • •	Rate
$\overline{e_1}$	t_1	h_1	g_1	• • •	0.0000012
• • •	• • •	• • •	• • •	• • •	• • •

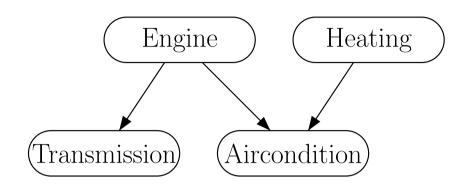
Result is a 200-dimensional, finite probability space

$$P(\text{Engine} = e_1, \text{Transmission} = t_3) = ?$$

$$P(\text{Heating} = h_1 \mid \text{Generator} = g_3) = ?$$

Problem of complexity!

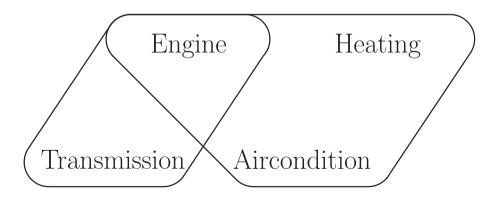
Solution: Decomposition into Subspaces



Bayesian Network

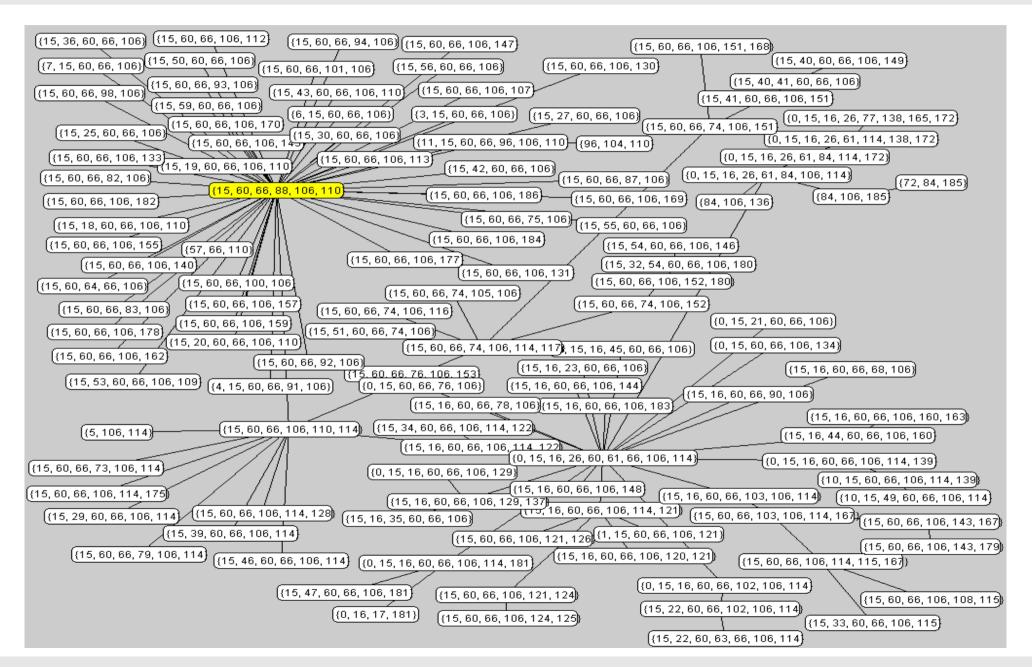
$$P(E, H, T, A) = P(A \mid E, H, T) \cdot P(T \mid E, H) \cdot P(E \mid H) \cdot P(H)$$

$$\stackrel{\text{here}}{=} P(A \mid E, H) \cdot P(T \mid E) \cdot P(E) \cdot P(H)$$



Hypergraph Decomposition

Clique Tree of the VW Bora



Typical Planning Operation: Focusing

Application:

Compute item demand

Calculation of installation rates of equipment combinations

• Simulation

Analyze customer requirements (e.g. of persons having ordered a navigation system for a VW Polo)

Input: Equipment combinations

Operation: Compute

- the conditional network distribution and
- the probabilities of the specified equipment combinations.

Implementation and Deployment

Project leader: Intelligent System Consulting (Gebhardt)

Client server system

Server on 6–8 maschines

Quadcore platform

Terabyte hard drive

Java, Linux, Oracle

WebSphere application server

Software used daily worldwide

20 developers

5000 Bayesian networks are currently used

