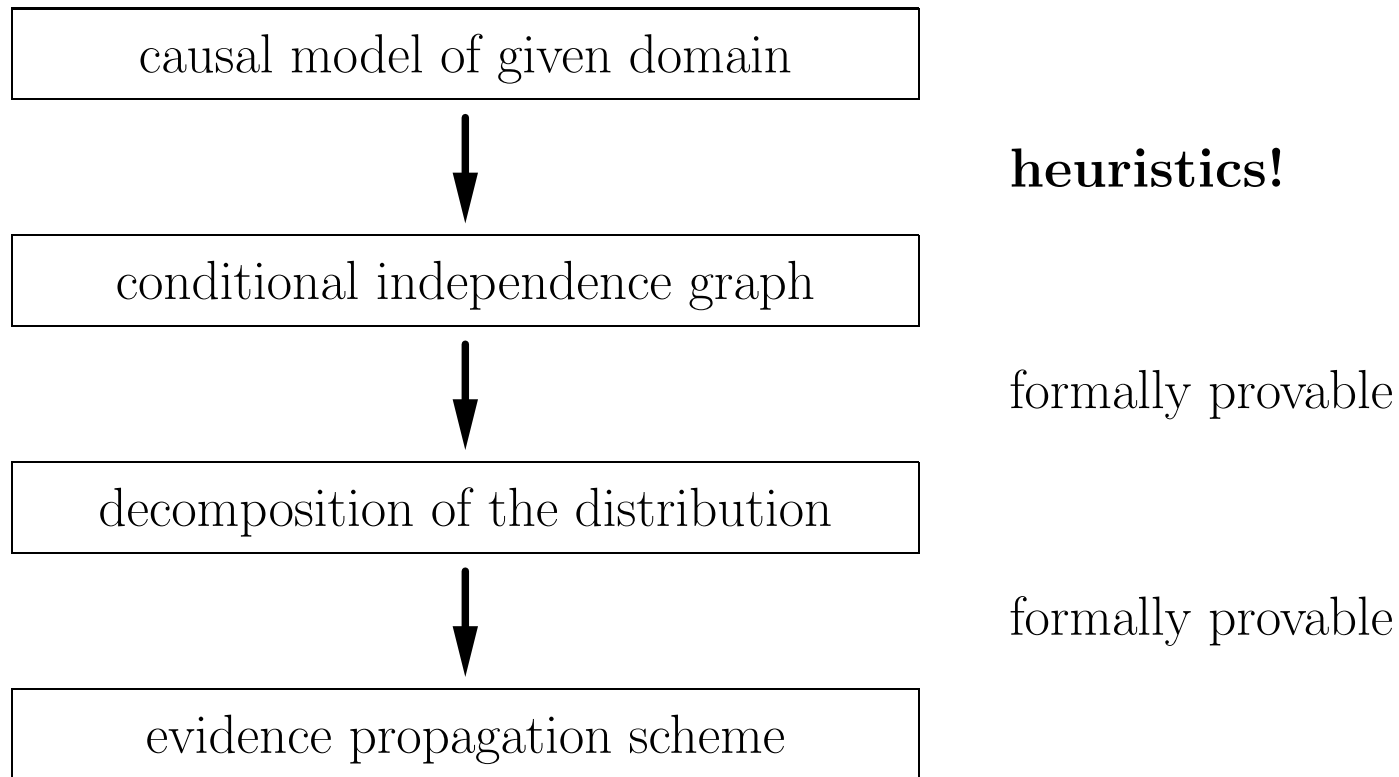


# Manual Building of Bayes Networks

# Building Graphical Models: Causal Modeling

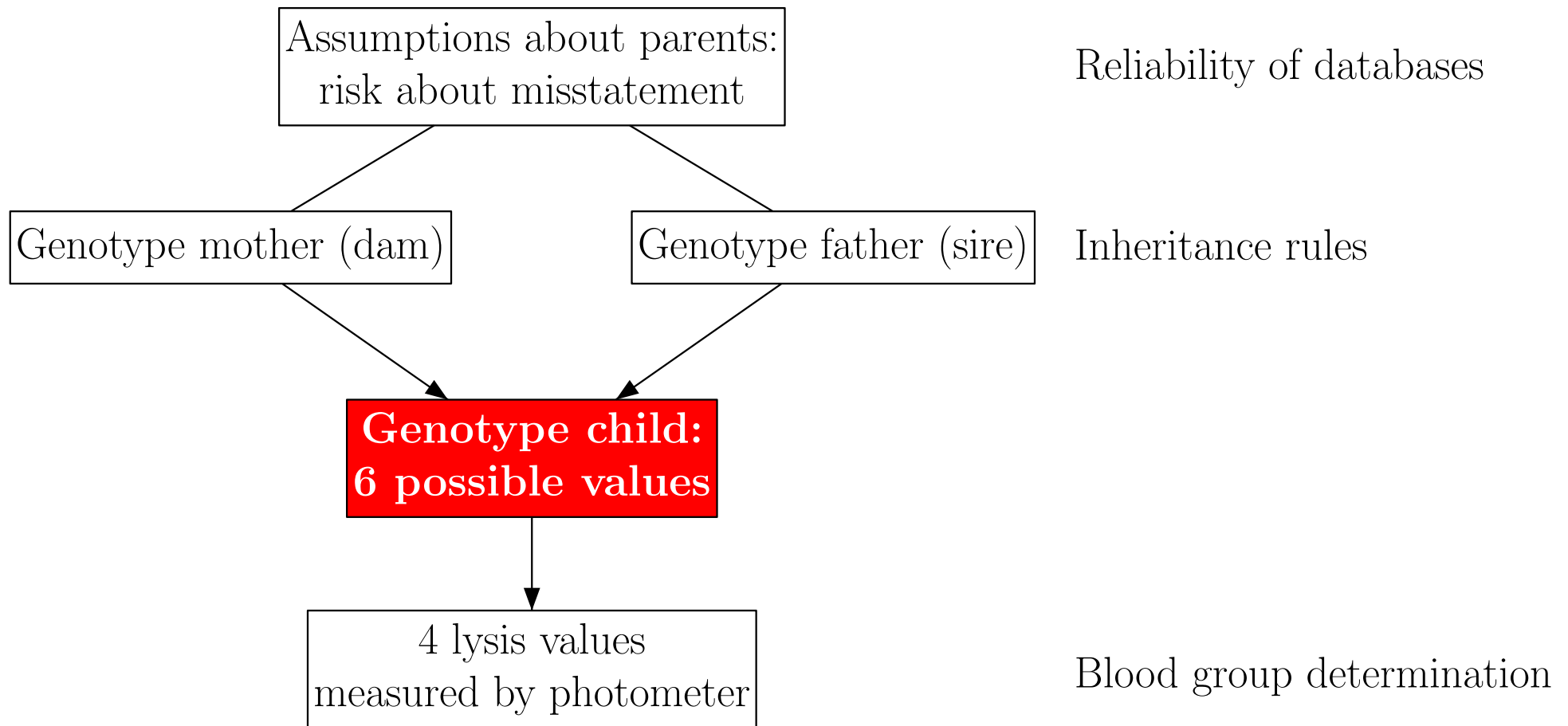
Manual creation of a reasoning system based on a graphical model:



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

Nevertheless this approach often yields usable graphical models.

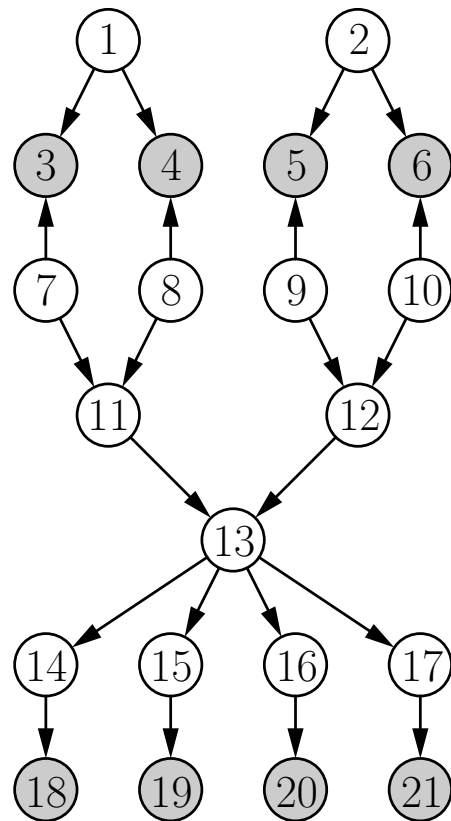
# Example 1: Genotype Determination of Danish Jersey Cattle



See paper on our website.

# Example 1: Genotype Determination of Danish Jersey Cattle

## Danish Jersey Cattle Blood Type Determination



21 attributes:

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

# Example 1: Genotype Determination of Danish Jersey Cattle

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

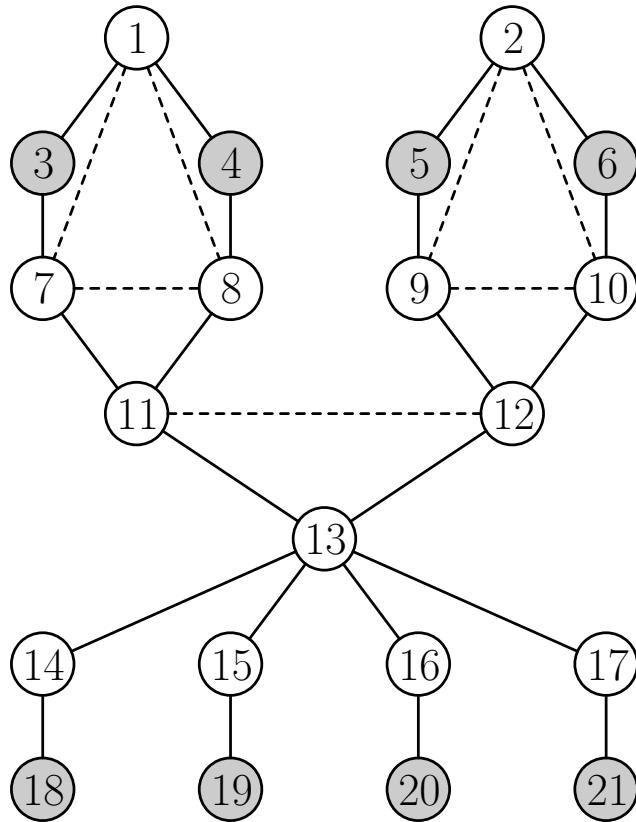
Bayesian network requires only 306 conditional probabilities.

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

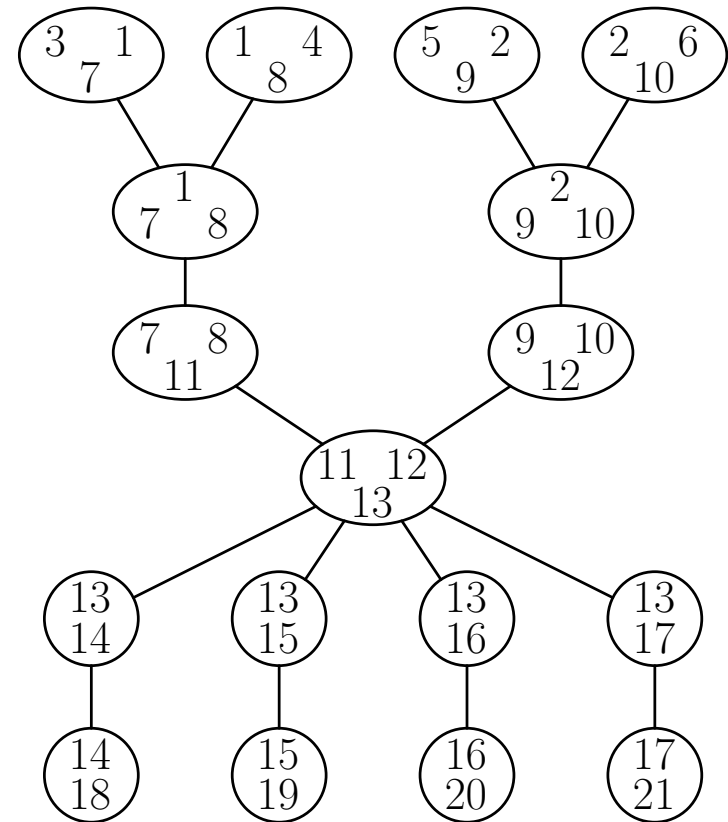
sire correct	true sire phenogroup 1	stated sire phenogroup 1		
		F1	V1	V2
yes	F1	1	0	0
yes	V1	0	1	0
yes	V2	0	0	1
no	F1	0.58	0.10	0.32
no	V1	0.58	0.10	0.32
no	V2	0.58	0.10	0.32

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

# Example 1: Genotype Determination of Danish Jersey Cattle



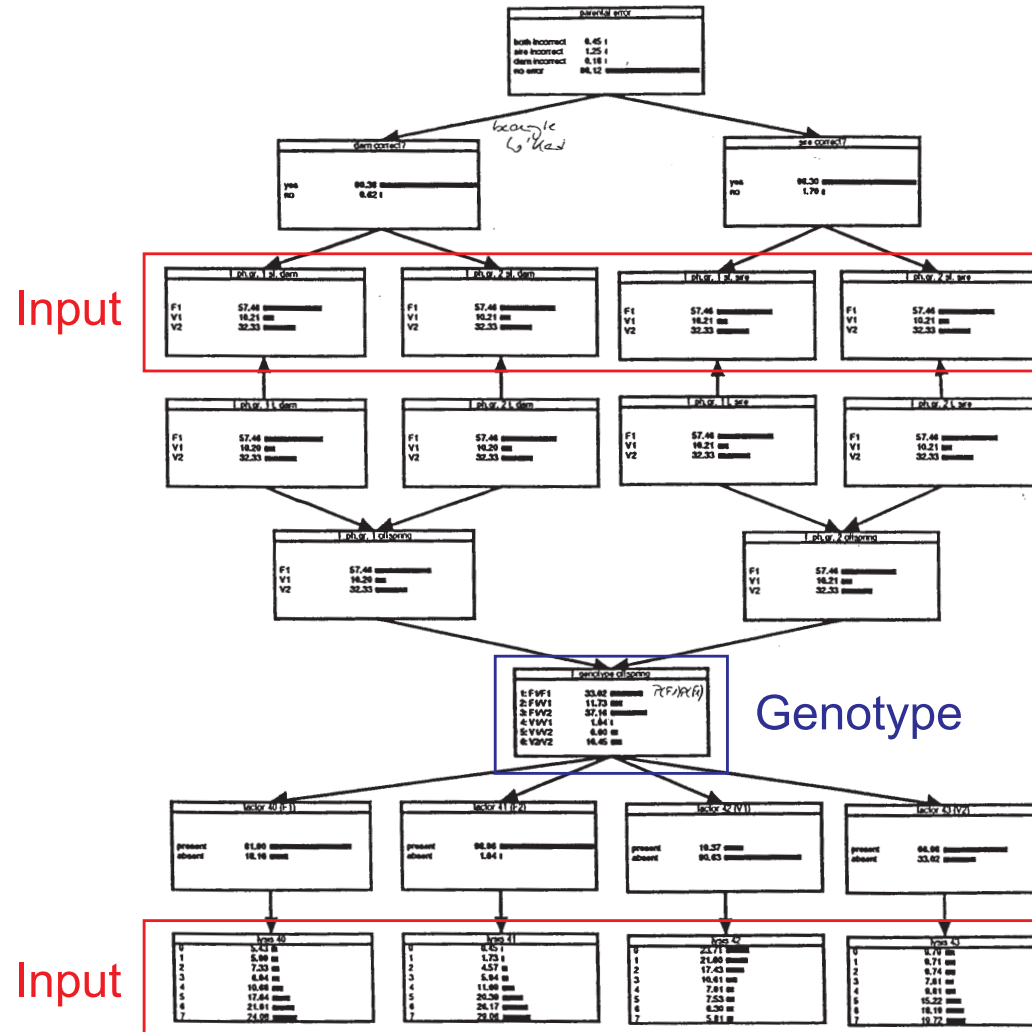
**moral graph**  
(already triangulated)



**join tree**

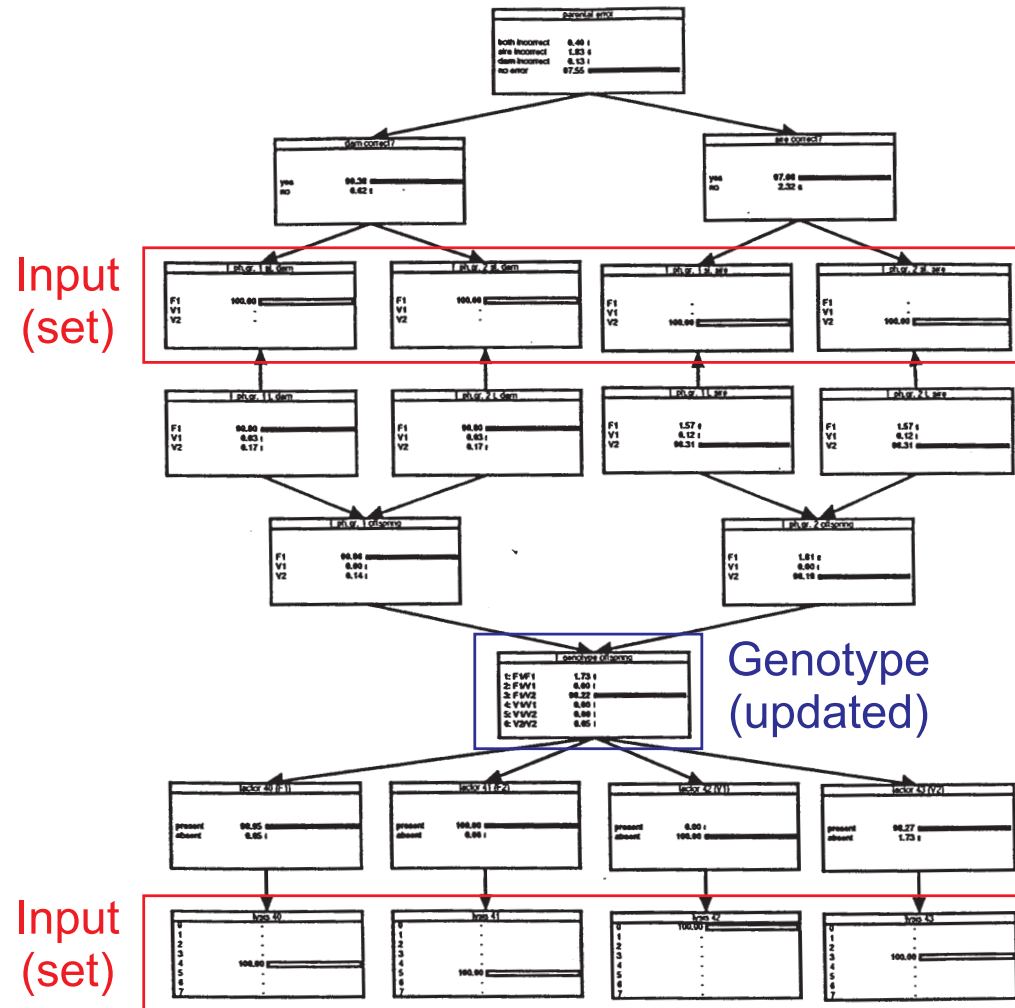
# Example 1: Genotype Determination of Danish Jersey Cattle

Marginal distributions before setting evidence:



# Example 1: Genotype Determination of Danish Jersey Cattle

Conditional distributions given evidence in the input variables:





# Example 2: Item Planning at Volkswagen

## Strategy of the VW Group

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



## Vehicle specification

Equipment	fastback	2,8l, 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

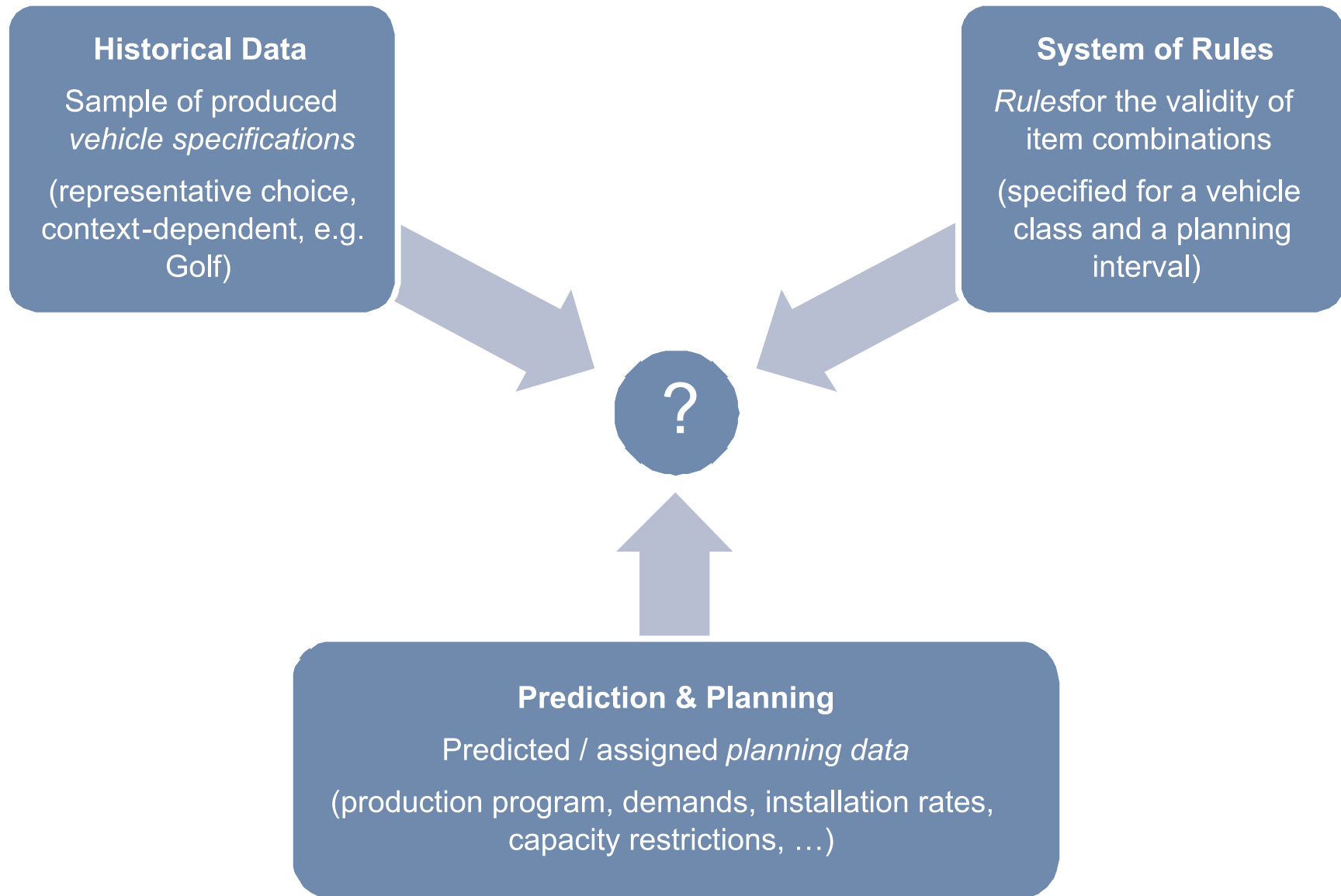
Choice of valid specifications is constrained by a rule system  
(10000 technical rules, plus marketing and production rules)

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



# 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
$e_1$	$t_1$	$h_1$	$g_1$	...	0.0000012
...	...	...	...	...	...

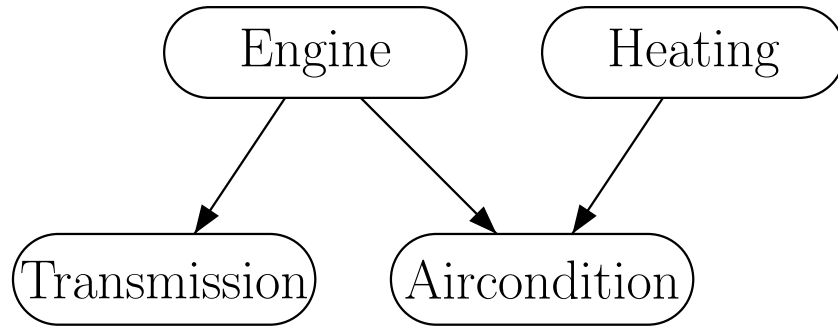
Result is a 200-dimensional, finite probability space

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

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

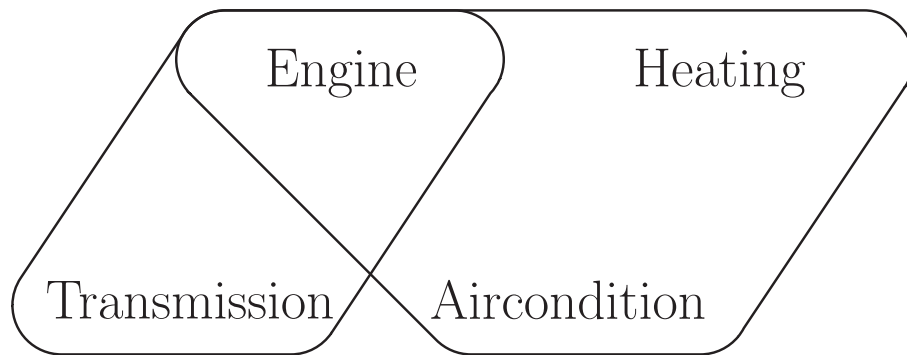
Problem of complexity!

# Solution: Decomposition into Subspaces



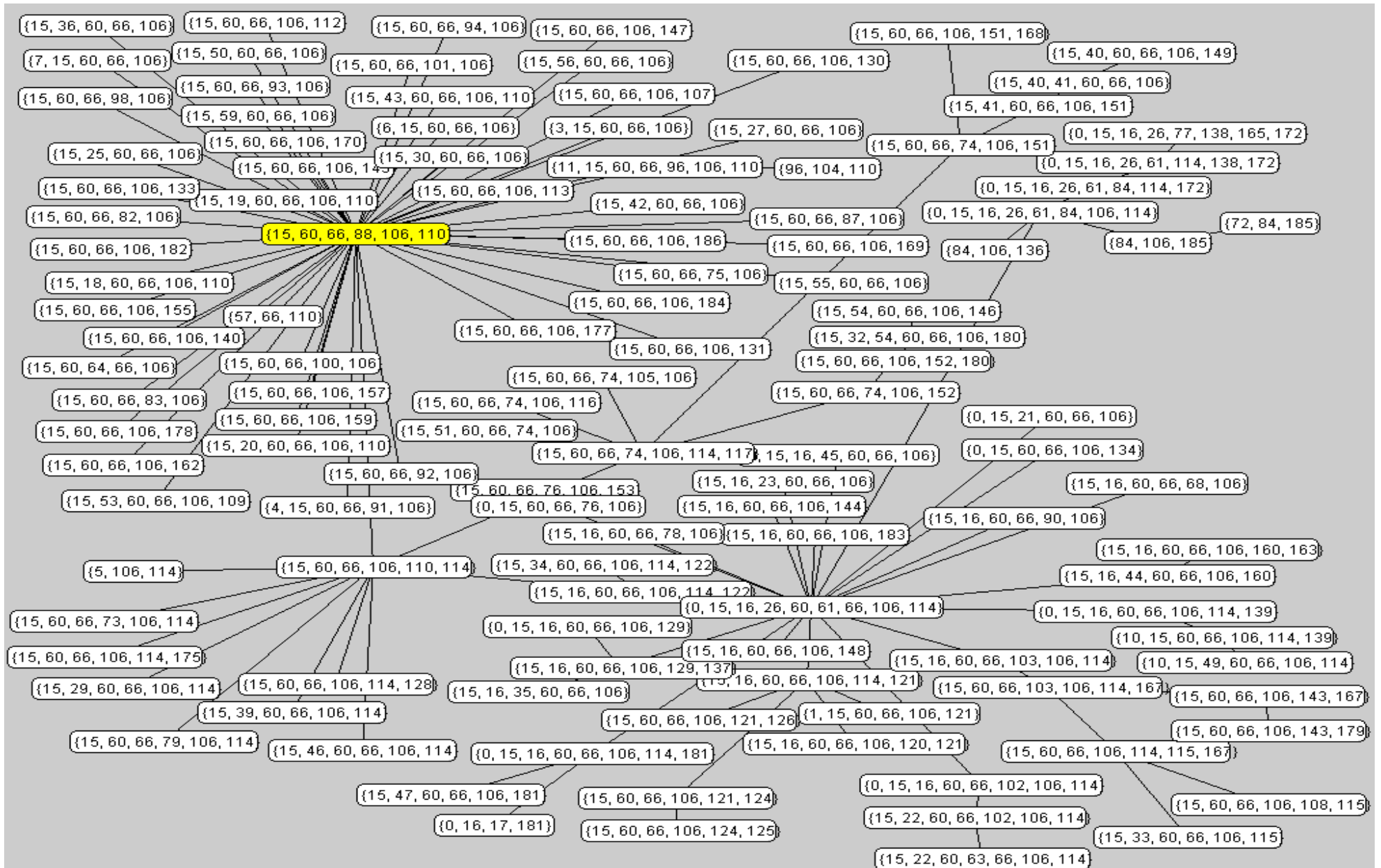
Bayesian Network

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



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 machines

Quadcore platform

Terabyte hard drive

Java, Linux, Oracle

WebSphere application server

Software used daily worldwide

20 developers

5000 Bayesian networks are currently used

