

Multidimensional Design

Knowledge Objectives

1. Justify the usefulness of multidimensional analysis against operational databases and spreadsheets
2. Define OLAP (On-Line Analytical Processing)
3. Describe a data cube
4. Describe the most typical multidimensional operations over the cube
5. Distinguish the main kinds of multidimensional tools (ROLAP, MOLAP and HOLAP)

Understanding Objectives

1. Explain the meaning of a star (or its variants snowflake and galaxy) shape multidimensional schema
2. Translate a multidimensional UML diagram into a relational star-join schema
3. Elaborate on the advantages and disadvantages of ROLAP in front of MOLAP

MOTIVATION AND DEFINITION

Spreadsheets

- Absence of metadata
 - Rows and columns without associated meaning
 - Difficult query and interpretations
- Limited amount of data
 - M\$Excel ($65,000 \times 256 = 16,000,000$ cells)
- The position limits operations 
- Aggregation hierarchies are not managed

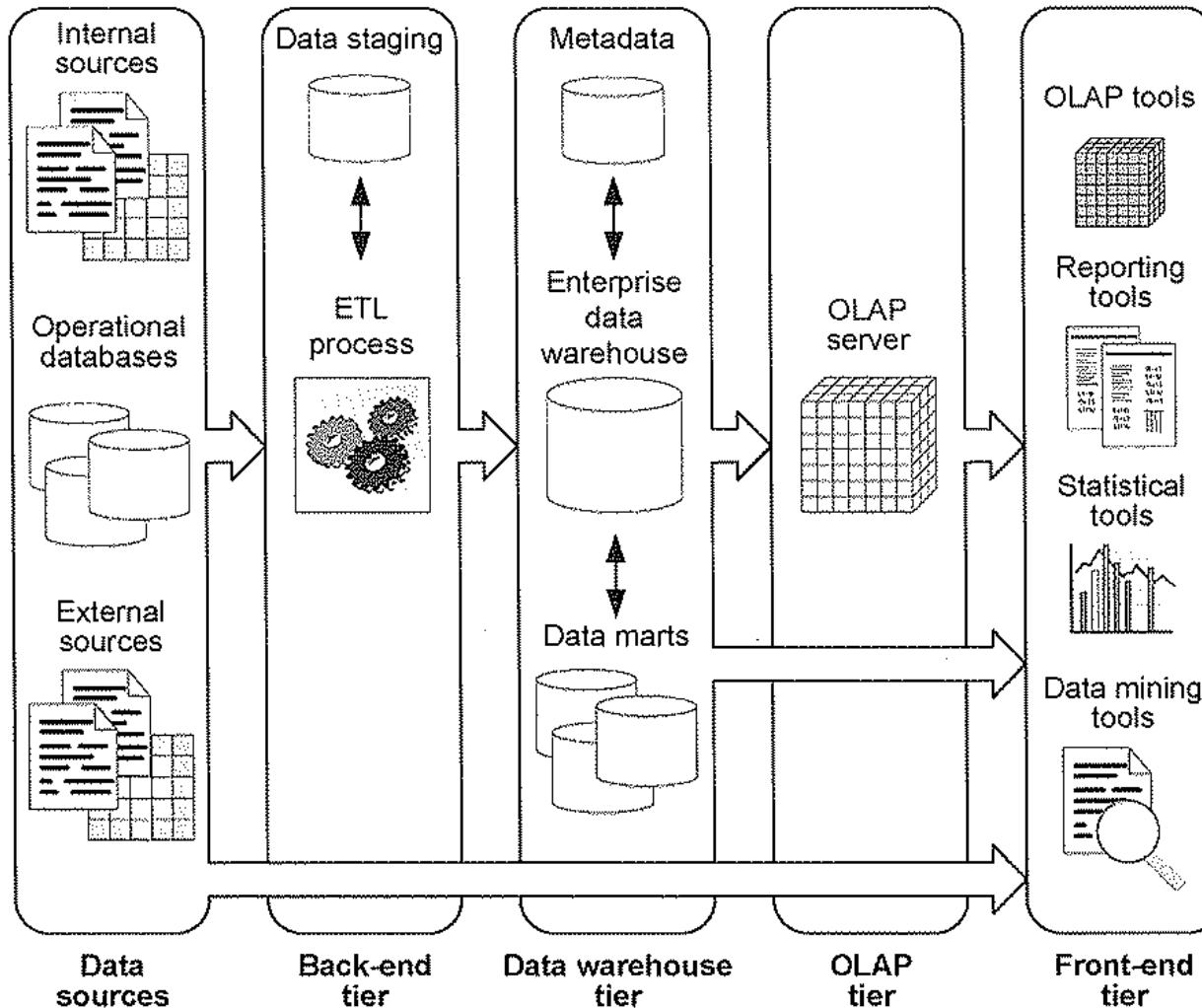
FASMI test

- F
- A
- of S
- M
- I

Nigel Pendse, 1995

Spreadsheet → **FAMSI**
Operational DB → **SIFAM**

Reference architecture



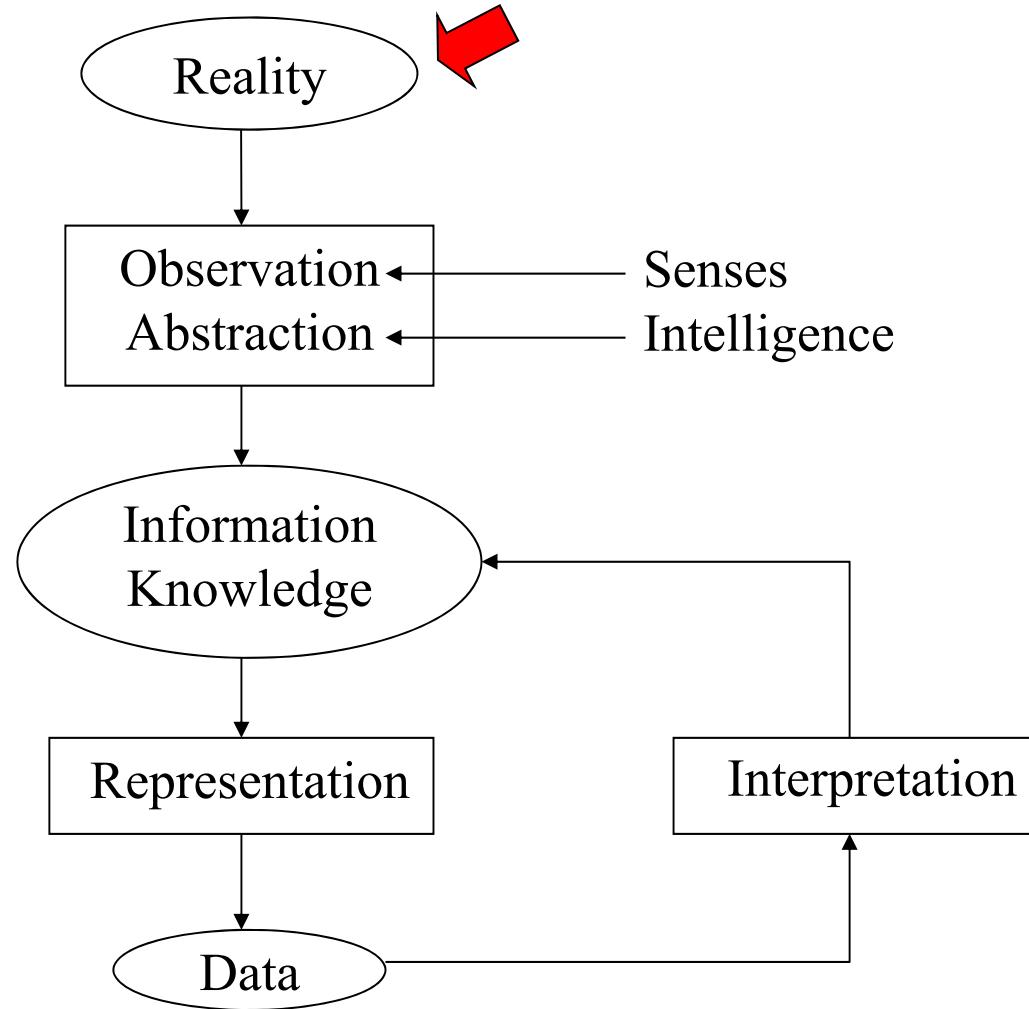
REAL WORLD VIEW

Three worlds

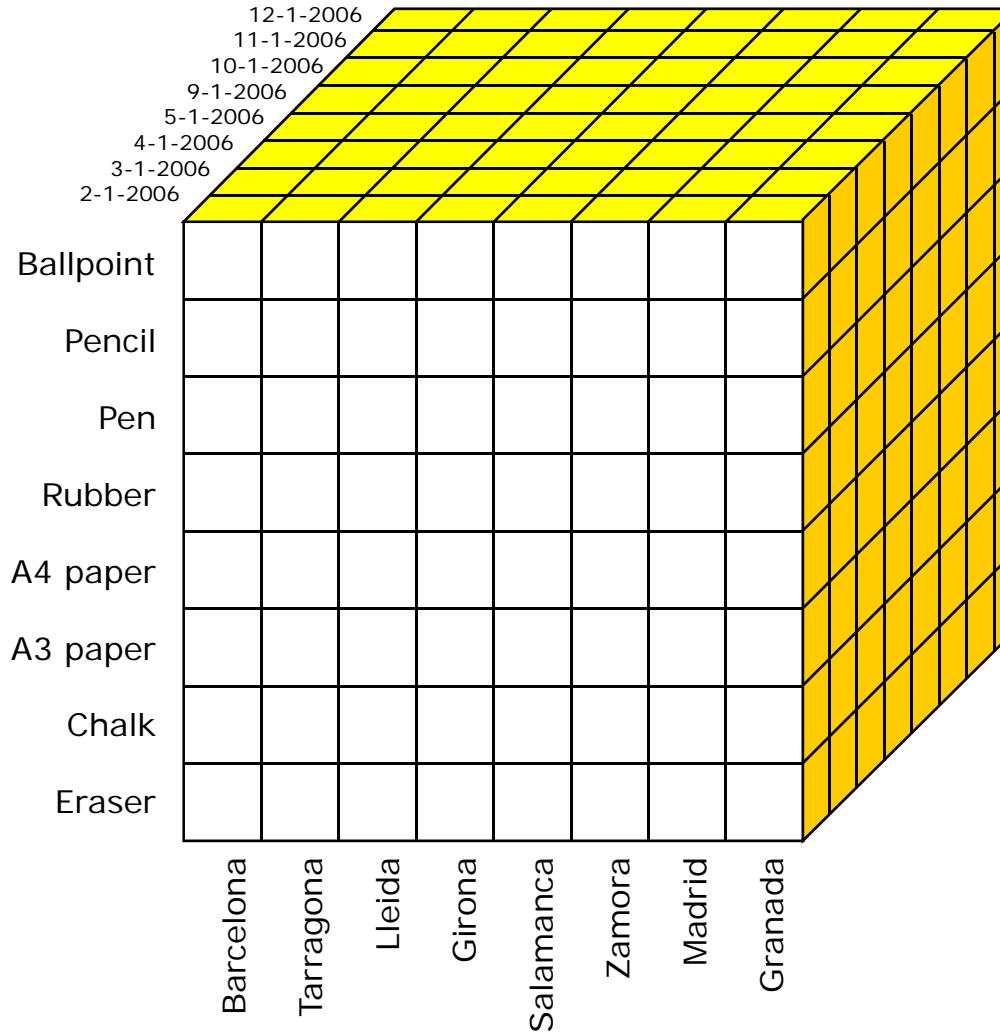
Real world
(unique)

Conceptual world
(multiple)

Representation world
(multiple)



Cube (Hyperprism)



Cross-tab view

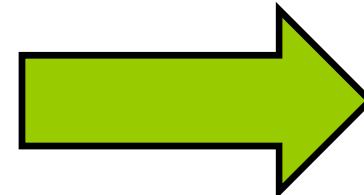
Time (Quarter)	Customer (City)	Köln				Berlin				Lyon				Paris					
		24	18	28	14	33	25	23	25	12	20	24	33	25	14	21	10	18	35
	Beverages	21	10	18	35	35	14	23	25	33	35	10	18	21	12	10	18	35	
	Produce	27	14	11	30	30	12	20	17	32	30	10	18	27	14	11	30	32	
	Condiments	26	10	18	35	35	14	23	25	33	35	10	18	26	12	35	32	31	
	Seafood	14	20	47	31	31	10	33	17	31	30	12	20	14	20	47	31	33	
Q1	21	10	18	35	35	14	23	25	33	35	10	18	21	12	10	18	35	35	
Q2	27	14	11	30	30	12	20	17	32	30	10	18	27	14	11	30	32	31	
Q3	26	12	35	32	32	10	33	17	31	30	12	20	14	20	47	31	33		
Q4	14	20	47	31	31	10	33	17	31	30	12	20	14	20	47	31	33		
	Product (Category)	Produce	Seafood	Beverages	Condiments	Produce	Seafood												



		Q1	Q2	Q3	Q4
Paris	Beverages	21	10	18	35
	Produce	27	14	11	30
	Condiments	26	12	35	32
	Seafood	14	20	47	31
Lyon	Beverages	12	20	24	33
	Produce				
	Condiments				
	Seafood				
Berlin	Beverages	33	25	23	25
	Produce				
	Condiments				
	Seafood				
Köln	Beverages	24	18	28	14
	Produce				
	Condiments				
	Seafood				

Slice

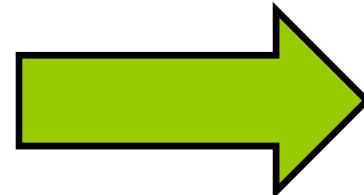
Time (Quarter)	Customer (City)	Köln				Berlin				Lyon				Paris			
		24	18	28	14	33	25	23	25	12	20	24	33	21	10	18	35
	Beverages	Produce	Condiments		Beverages	Produce	Condiments		Beverages	Produce	Condiments		Beverages	Produce	Condiments		
Q1	21	10	18	35	35	14	23	17	27	14	11	30	30	12	20	18	
Q2	27	14	11	30	30	12	20	17	26	12	35	32	10	33	18	26	
Q3	26	12	35	32	32	10	33	18	14	20	47	31	31	14	20	47	
Q4	14	20	47	31	31	14	20	47	21	10	18	35	27	14	11	30	



Time (Quarter)	Product (Category)			
	Produce	Seafood	Beverages	Condiments
Q1	21	10	18	35
Q2	27	14	11	30
Q3	26	12	35	32
Q4	14	20	47	31

Dice

		Customer (City)		Köln				Berlin				Lyon				Paris				
		Beverages	Condiments	24	18	28	14	33	25	23	25	14	12	20	24	33	21	10	18	35
		Product (Category)		21	10	18	35	35	33	25	23	14	30	12	20	17	26	12	35	32
		Q1	21	10	18	35	35	33	25	23	14	14	30	12	20	17	27	14	11	30
		Q2	27	14	11	30	30	12	20	17							26	12	35	32
		Q3	26	12	35	32	32	10	33	18							14	20	47	31
		Q4	14	20	47	31	31													



		Customer (City)		Time (Quarter)				Product (Category)				Time (Quarter)				Customer (City)			
		Lyon	Paris	12	20	24	33	12	20	24	33	12	20	24	33	21	10	18	35
		Product (Category)		21	10	18	35	35	33	25	23	14	30	30	33	21	10	18	35
		Q1	21	10	18	35	35	33	25	23	14	14	30	30	33	27	14	11	30
		Q2	27	14	11	30	30	12	20	17						26	12	35	32
		Q3	26	12	35	32	32	10	33	18						14	20	47	31
		Q4	14	20	47	31	31												

Sort

Time (Quarter)	Customer (City)	Köln				Berlin				Lyon				Paris			
		24	18	28	14	33	25	23	25	12	20	24	33	21	10	18	35
	Produce	Seafood	Beverages	Condiments	Produce	Seafood	Beverages	Condiments	Produce	Seafood	Beverages	Condiments	Produce	Seafood	Beverages	Condiments	
Q1	21	10	18	35	35	14	23	17	12	20	24	33	21	10	18	35	
Q2	27	14	11	30	30	12	20	18	21	18	10	35	27	11	14	30	
Q3	26	12	35	32	32	10	33	17	35	33	32	31	26	35	12	32	
Q4	14	20	47	31	31	31	31	31	31	31	31	31	14	47	20	31	



Time (Quarter)	Customer (City)	Köln				Berlin				Lyon				Paris			
		24	28	18	14	33	23	25	25	12	24	20	33	21	18	10	35
	Condiments	Seafood	Beverages	Produce	Condiments	Seafood	Beverages	Produce	Condiments	Seafood	Beverages	Produce	Condiments	Seafood	Beverages	Produce	
Q1	21	18	10	35	35	14	23	17	12	24	20	33	21	18	10	35	
Q2	27	11	14	30	30	12	20	18	21	18	10	35	27	11	14	30	
Q3	26	35	12	32	32	10	33	17	35	33	32	31	26	35	12	32	
Q4	14	47	20	31	31	31	31	31	31	31	31	31	14	47	20	31	

Pivot

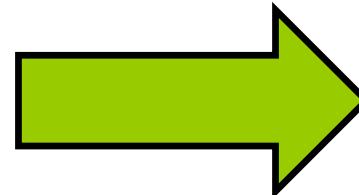
Time (Quarter)	Customer (City)	Köln				Berlin				Lyon				Paris			
		24	18	28	14	33	25	23	25	12	20	24	33	21	10	18	35
	Product (Category)	Produce	Seafood	Beverages	Condiments												
Q1	21	10	18	35	35	14	23	23	25	12	20	24	33	21	10	18	35
Q2	27	14	11	30	30	12	20	20	25	13	28	32	47	27	14	11	30
Q3	26	12	35	32	32	10	33	33	31	10	33	35	47	26	12	35	32
Q4	14	20	47	31	31	31	18	17	14	31	31	31	31	14	20	47	31



Customer (City)	Product (Category)	Seafood				Condiments				Produce				Beverages			
		35	30	32	31	18	11	35	47	10	14	12	20	21	27	26	14
	Time (Quarter)	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Paris	21	27	26	14	14	20	21	10	21	27	26	14	14	20	21	10	21
Lyon	12	14	11	13	13	28	20	33	13	14	11	13	13	28	20	33	13
Berlin	33	28	35	32	32	19	47	32	33	28	35	32	32	19	47	32	33
Köln	24	23	25	18	18	18	18	18	18	24	23	25	18	18	18	18	18

Roll-up (I)

Customer (City)	Köln	Sales Data (Units)			
		24	18	28	14
Berlin	33	25	23	25	
Lyon	12	20	24	33	14
Paris	21	10	18	35	25
Q1	21	10	18	35	33
Q2	27	14	11	30	23
Q3	26	12	35	32	17
Q4	14	20	47	31	18
	Produce		Seafood		
	Beverages		Condiments		
	Product (Category)				

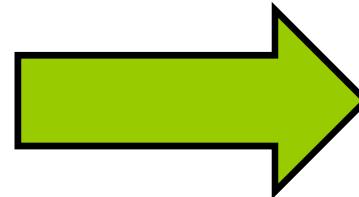


*Customer
(Country)*

Time (Quarter)	Germany		France			
	Q1	Q2	Q3	Q4	Q1	Q2
	Produce	Seafood	Beverages	Condiments		
Q1	33	30	42	68	68	41
Q2	39	26	41	44	44	37
Q3	30	22	46	44	44	51
Q4	25	29	49	41	41	

Roll-up (II)

Time (Quarter)	Customer (City)		Product (Category)					
	Köln	Berlin	Paris	Lyon	Beverages	Condiments	Seafood	
Q1	21	10	18	35	24	18	28	14
Q2	27	14	11	30	33	25	14	18
Q3	26	12	35	32	35	23	20	17
Q4	14	20	47	31	31	10	33	18



Time (Quarter)	Customer (City)			
	Köln	Berlin	Paris	Lyon
Q1	84	89	106	84
Q2	82	77	93	79
Q3	105	72	65	88
Q4	112	61	96	102

Roll-up (III)

Time (Quarter)	Customer (City)		Product (Category)					
	Köln	Berlin	Paris	Lyon	Beverages	Condiments	Seafood	Produce
Q1	24	18	28	14	33	25	23	25
Q2	33	25	23	14	12	20	24	33
Q3	23	25	21	18	10	18	35	35
Q4	14	18	21	10	35	33	35	31

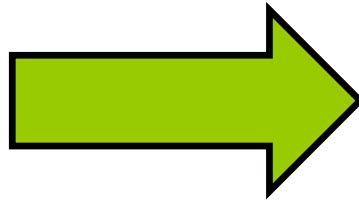


Time (Quarter)	Customer (City)			
	Köln	Berlin	Paris	Lyon
Q1	84	89	106	84
Q2	82	77	93	79
Q3	105	72	65	88
Q4	112	61	96	102

Drill-down



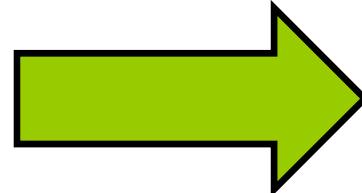
Time (Quarter)	Customer (City)	Köln				Berlin				Lyon				Paris			
		24	18	28	14	33	25	23	25	12	20	24	33	21	10	18	35
	Q1	21	10	18	35	35	14	23	25	12	20	24	33	21	10	18	35
	Q2	27	14	11	30	30	12	20	17	10	18	24	33	26	12	35	32
	Q3	26	12	35	32	32	10	33	18	10	18	24	33	26	12	35	32
	Q4	14	20	47	31	31	10	33	18	10	18	24	33	14	20	47	31
		Produce	Seafood	Beverages	Condiments												
		Product (Category)															



Time (Quarter)	Customer (City)	Köln				Berlin				Lyon				Paris			
		8	6	9	5	10	8	11	8	4	7	8	14	7	2	6	20
	Jan	7	2	6	20	20	10	14	8	7	2	6	20	7	2	6	20
	Feb	8	4	8	8	8	9	7	8	4	8	8
	Mar	6	4	4	7	7	6	4	4	7
	5	14	8	...
	Dec	4	4	16	7	7	5	14	8	1	4	4	16
		Produce	Seafood	Beverages	Condiments	Product (Category)											

Drill-across

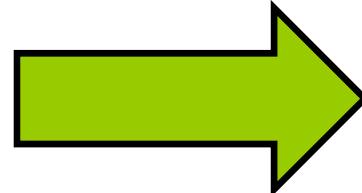
Time (Quarter)	Customer (City)	Köln		Berlin		Lyon		Paris									
		24	18	28	14	33	25	23	25	12	20	24	33	21	10	18	35
	Q1	21	10	18	35	35	14	23	25	33	33	25	14	Produce	Seafood		
	Q2	27	14	11	30	30	12	20	17	19	16	22	33	27	12	18	30
	Q3	26	12	35	32	32	10	33	18	21	16	31	35	28	16	21	23
	Q4	14	20	47	31	31	31	31	17	19	16	26	14	29	14	20	16
		Beverages	Condiments														
		Product (Category)															



Time (Quarter)	Customer (City)	Köln		Berlin		Lyon		Paris									
		29	25	22	24	14	20	23	26	28	25	26	16	19	16	14	18
	Q1	19	12	31	28	35	29	21	23	33	33	21	19	Produce	Seafood		
	Q2	30	12	10	29	30	30	14	20	28	32	32	17	20	14	20	19
	Q3	28	11	31	28	32	29	12	20	28	32	32	18	21	12	31	18
	Q4	12	22	45	29	31	29	10	18	29	31	31	19	23	10	33	17
		Beverages	Condiments														
		Product (Category)															

Union

Time (Quarter)	Customer (City)	Köln				Berlin				Lyon				Paris				
		24	18	28	14	33	25	23	25	12	20	24	33	21	10	18	35	
	Produce	Seafood	Beverages	Condiments		Produce	Seafood	Beverages	Condiments		Produce	Seafood	Beverages		Produce	Seafood	Beverages	Condiments
Q1	21	10	18	35	35	14	23	23	14	12	20	24	33	21	10	18	35	
Q2	27	14	11	30	30	12	20	17	18	21	10	18	35	27	14	11	30	
Q3	26	12	35	32	32	10	33	17	17	26	12	35	32	26	12	35	32	
Q4	14	20	47	31	31	31	31	31	31	14	20	47	31	14	20	47	31	

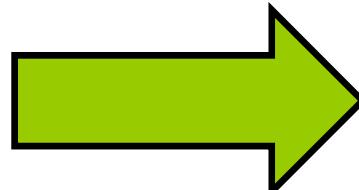


Time (Quarter)	Customer (City)	Madrid				Bilbao				Köln				Berlin				
		22	27	23	15	24	18	28	14	24	18	28	14	33	25	23	25	
	Produce	Seafood	Beverages	Condiments		Produce	Seafood	Beverages	Condiments		Produce	Seafood	Beverages		Produce	Seafood	Beverages	Condiments
Q1	21	10	18	35	35	14	23	23	14	21	10	18	35	21	10	18	35	
Q2	27	14	11	30	30	12	20	17	18	27	14	11	30	30	12	20	17	17
Q3	26	12	35	32	32	10	33	17	17	26	12	35	32	32	10	33	18	17
Q4	14	20	47	31	31	31	31	31	31	14	20	47	31	31	10	33	18	17

Difference

		Customer (City)				
		Köln	18	28	14	
		Berlin	33	25	23	25
		Lyon	12	20	24	33
		Paris	21	10	18	35
Time (Quarter)			21	35	33	14
Q1		21	10	18	35	35
Q2		27	14	11	30	30
Q3		26	12	35	32	32
Q4		14	20	47	31	31
		Product (Category)	Produce	Seafood	Beverages	Condiments

		Customer (City)				
		Köln	18	28	14	
		Berlin	33	25	23	25
		Lyon	20	33	25	
		Paris	21	35	33	23
Time (Quarter)			21	35	33	23
Q1		21		35	35	23
Q2		27		30	30	20
Q3			35	32	32	33
Q4			47	31	31	
		Product (Category)	Produce	Seafood	Beverages	Condiments



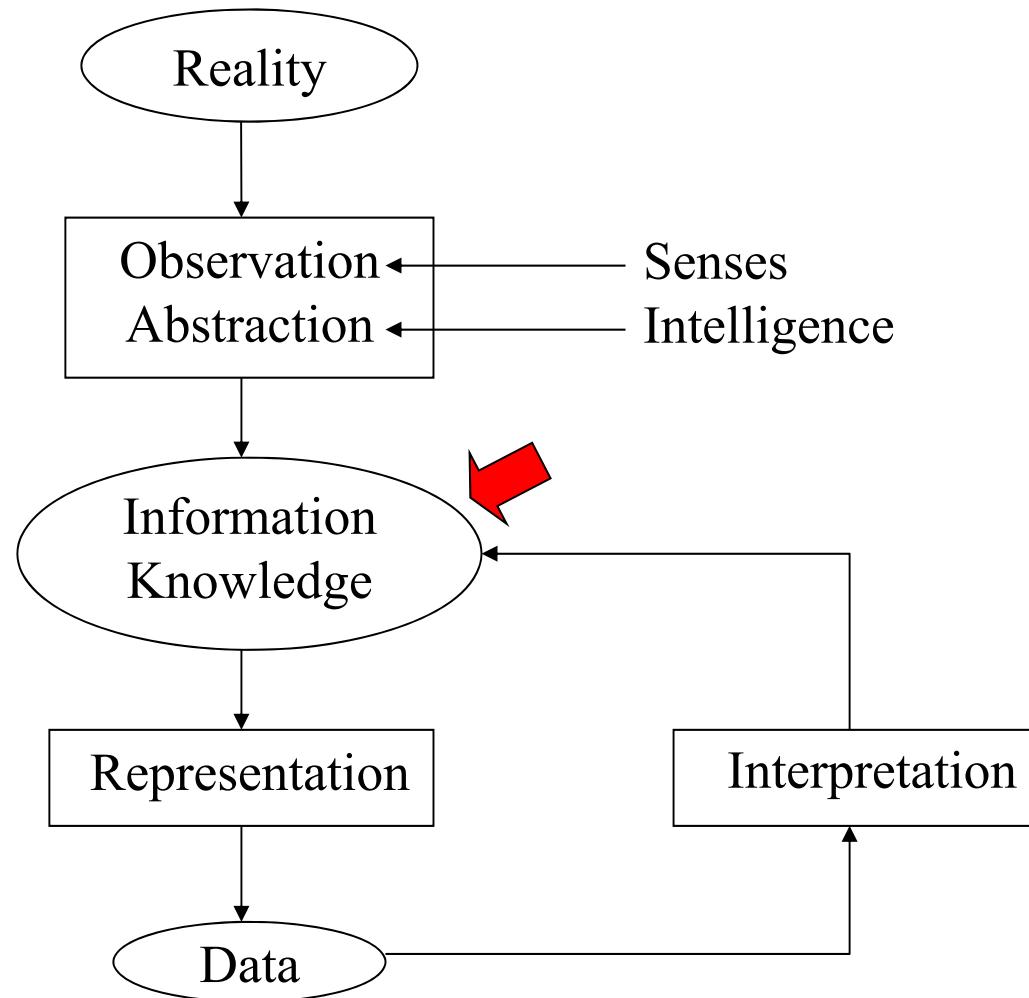
		Customer (City)				
		Köln	18	23	14	
		Berlin	12	24	23	14
		Lyon	10	18	18	
		Paris	10	18	18	
Time (Quarter)			10	18	18	
Q1		10	18	18	14	17
Q2		14	11	12	18	
Q3		26	12	10		
Q4		14	20			
		Product (Category)	Produce	Seafood	Beverages	Condiments

A. Vaisman & E.Zimanyi

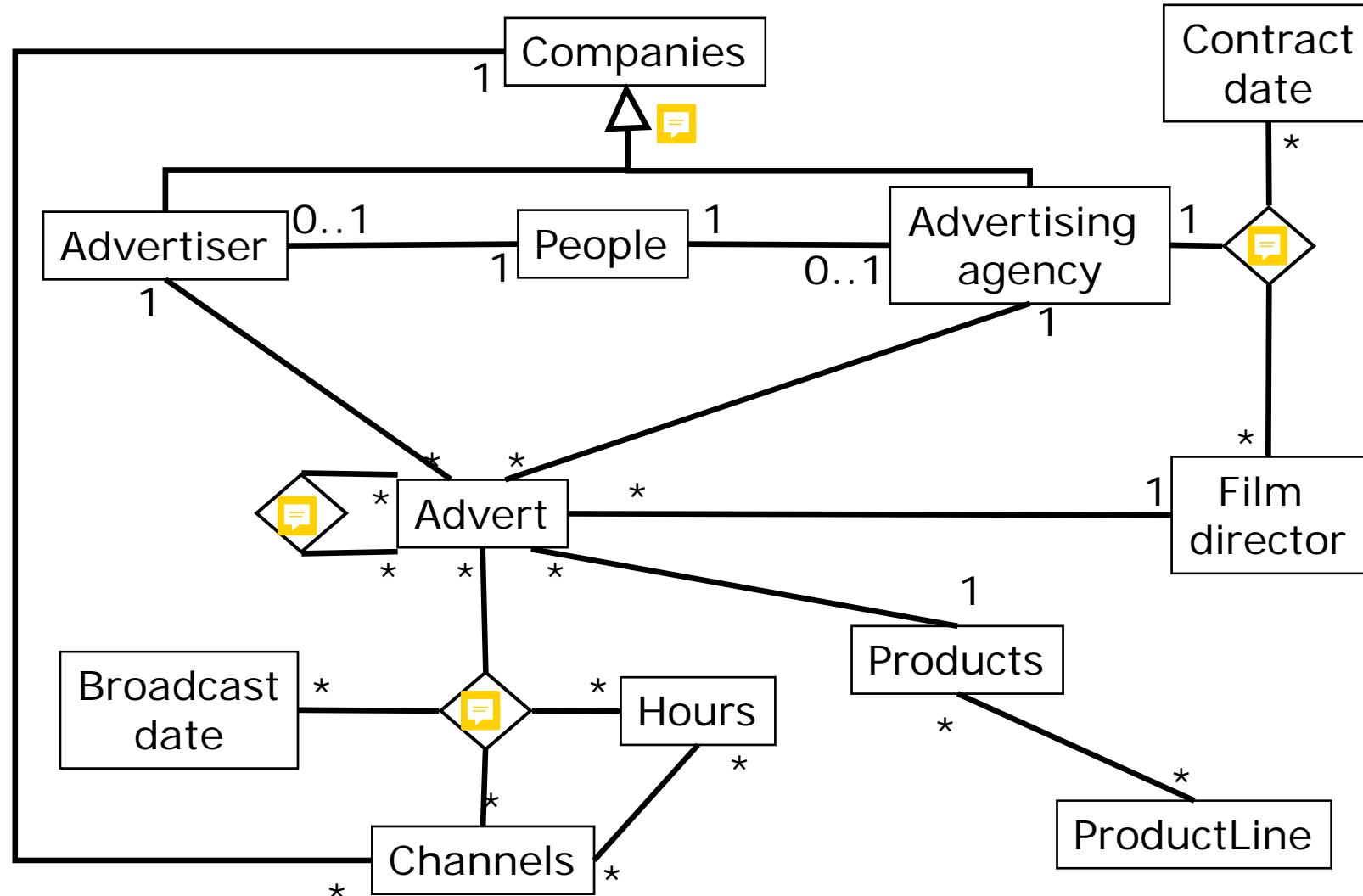
CONCEPTUAL WORLD VIEW

Three worlds

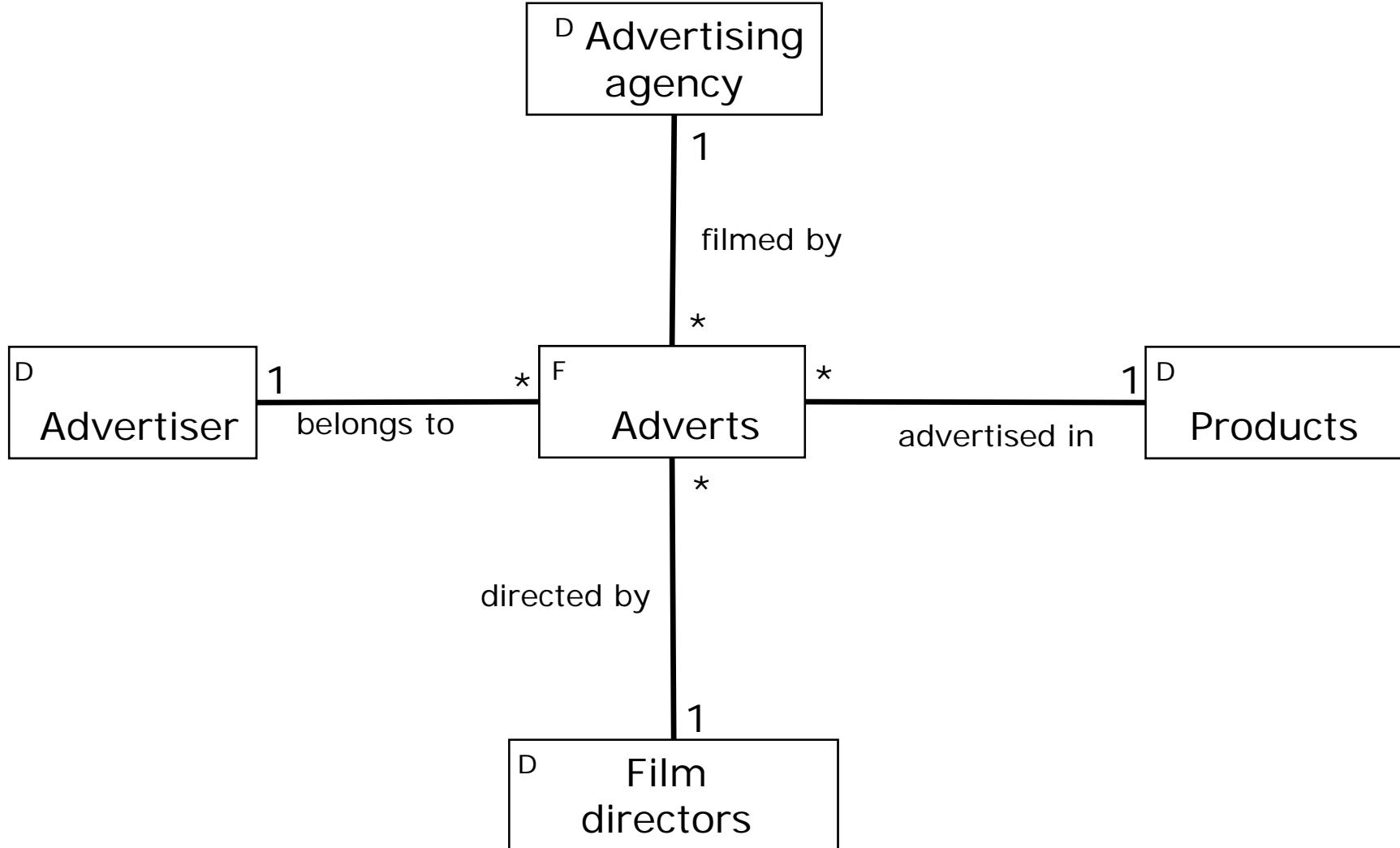
- Real world
(unique)
- Conceptual world
(multiple)
- Representation world
(multiple)



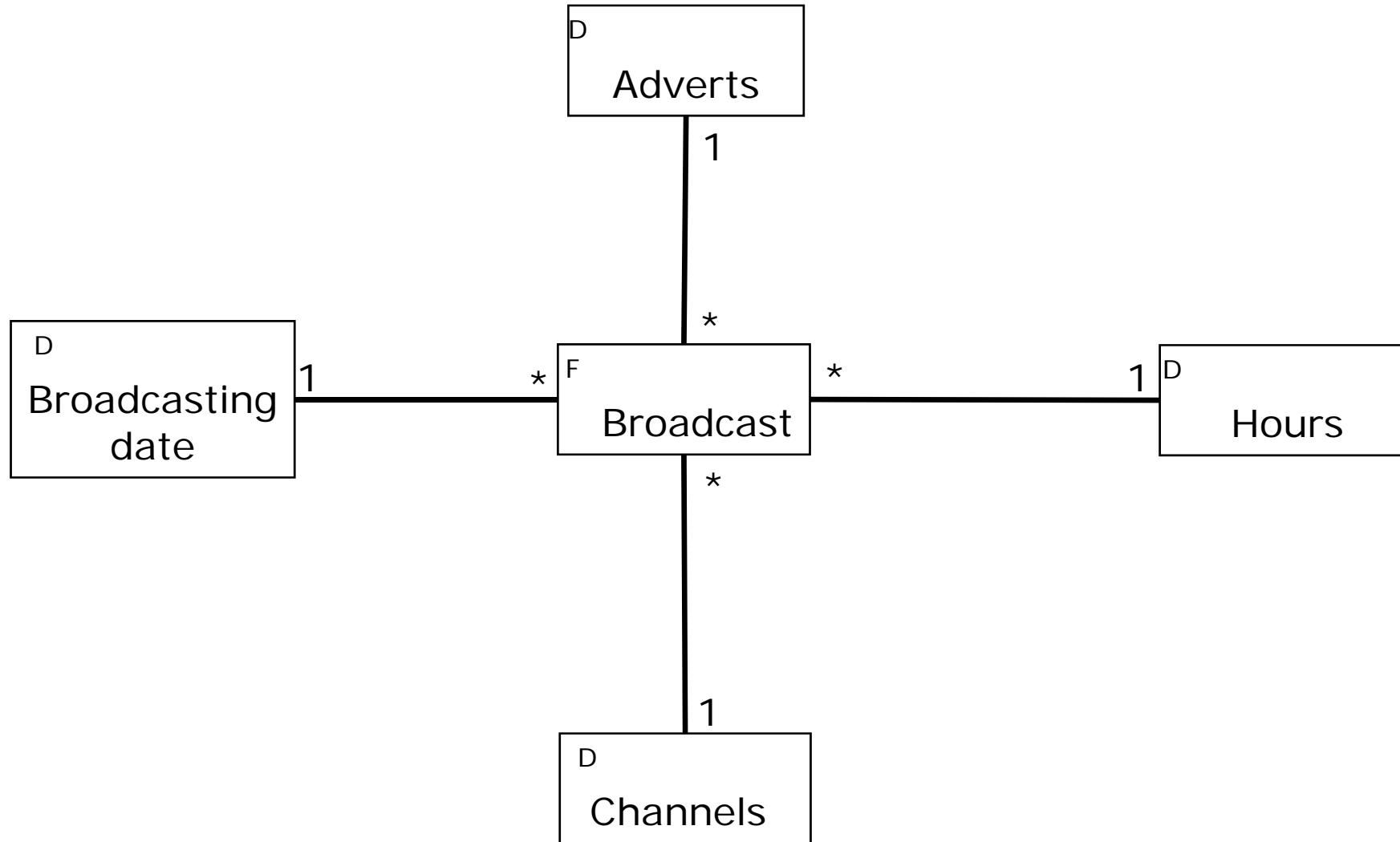
Example of transactional modeling



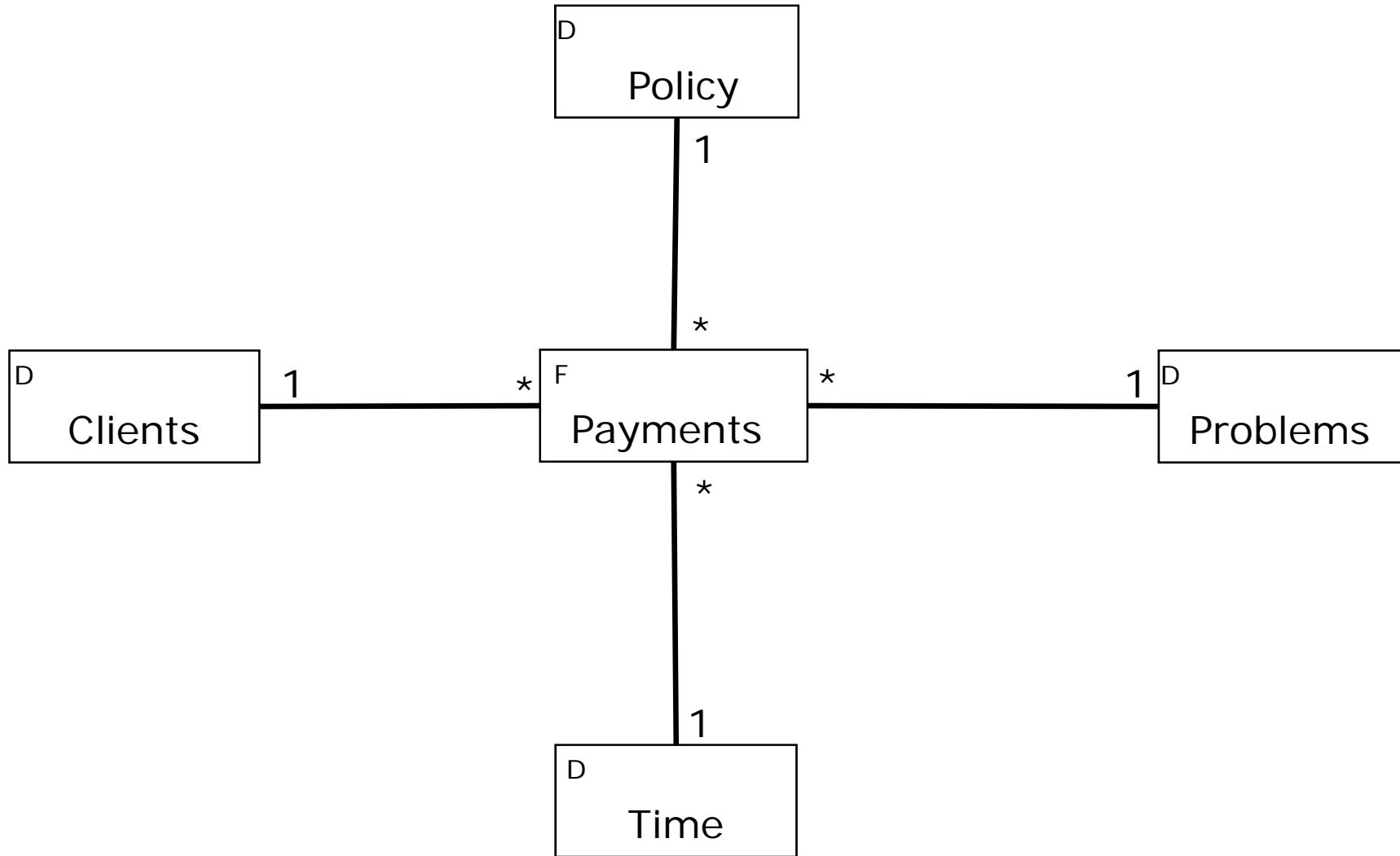
Star schema (I)



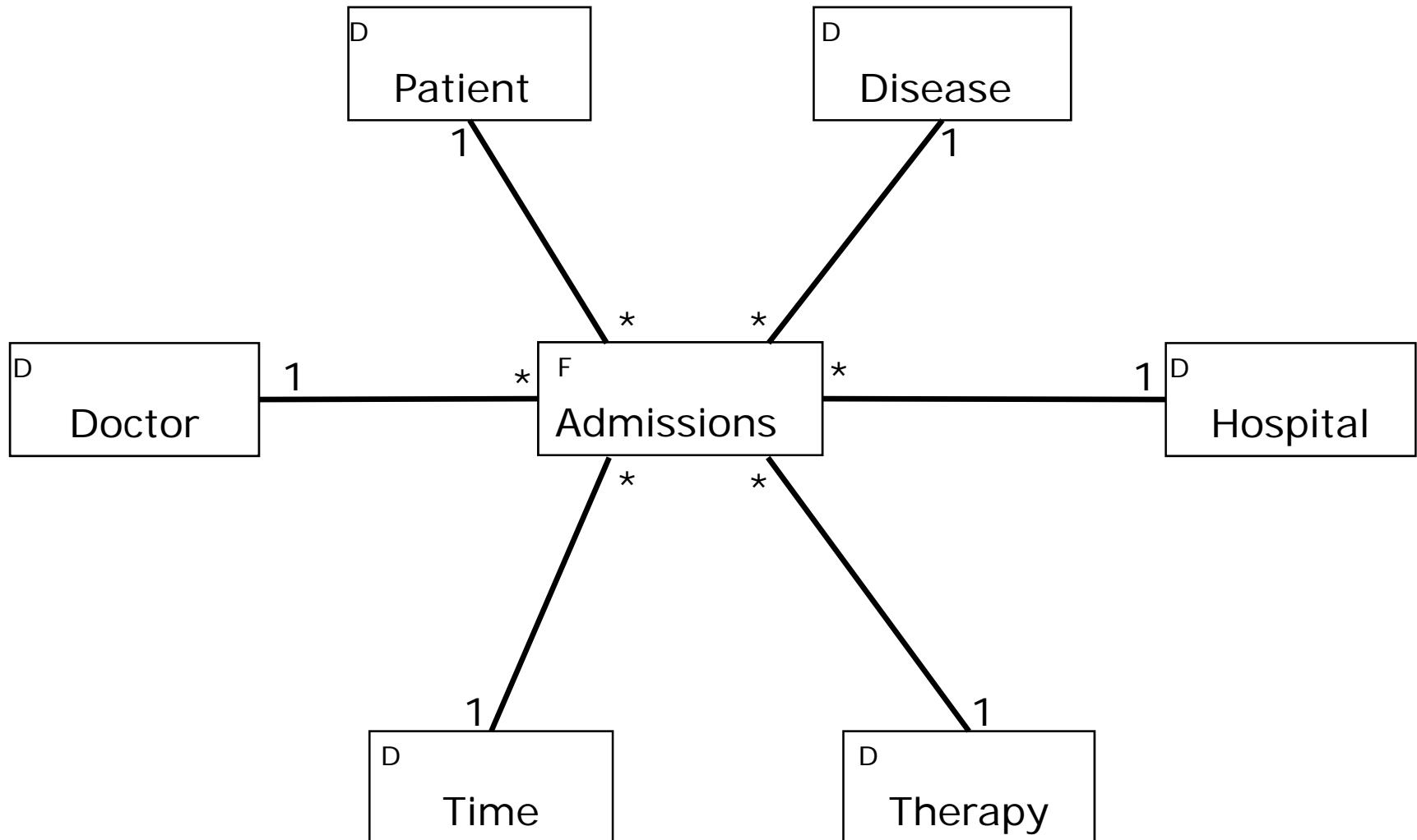
Star schema (II)



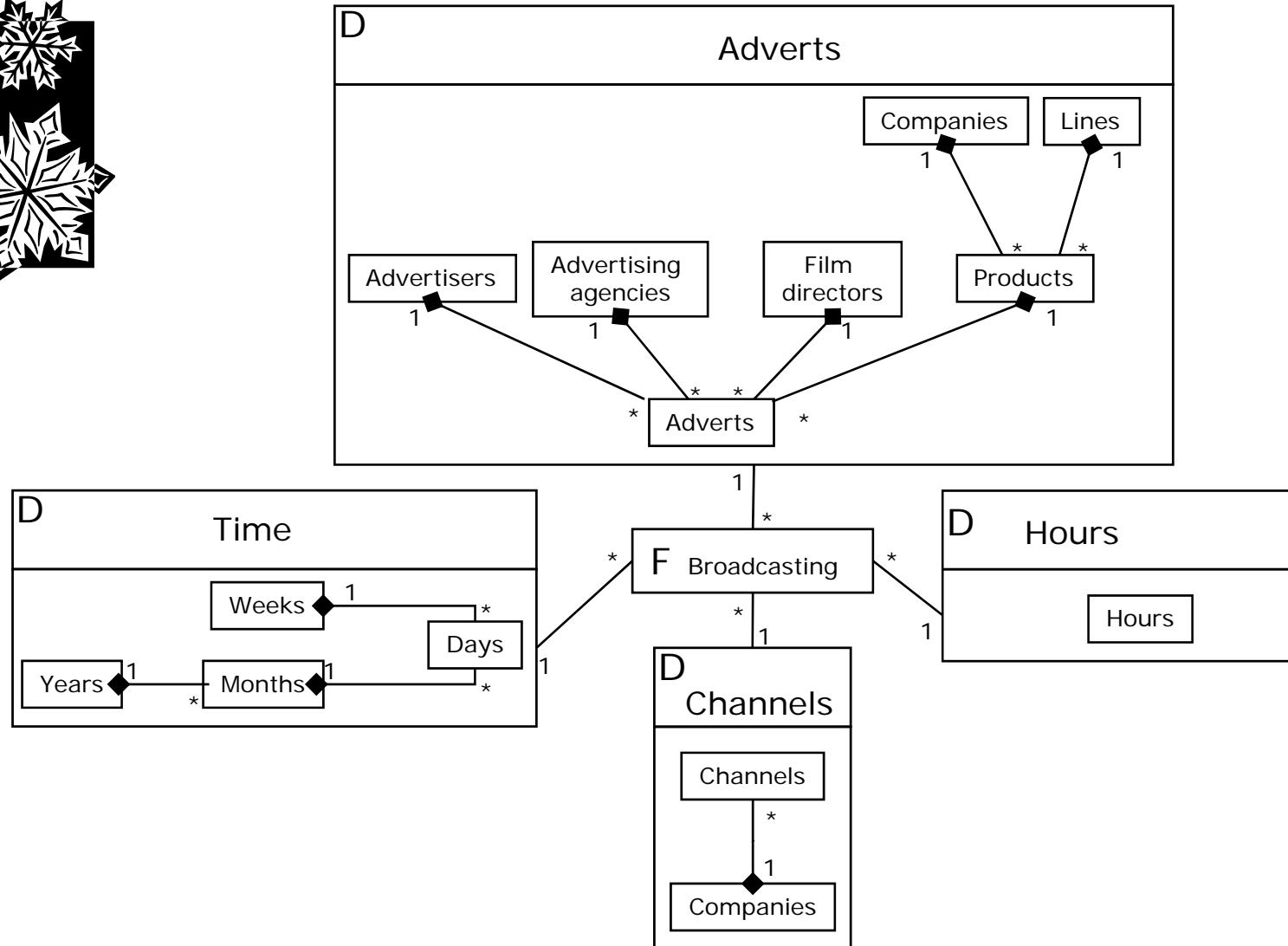
Star schema (III)



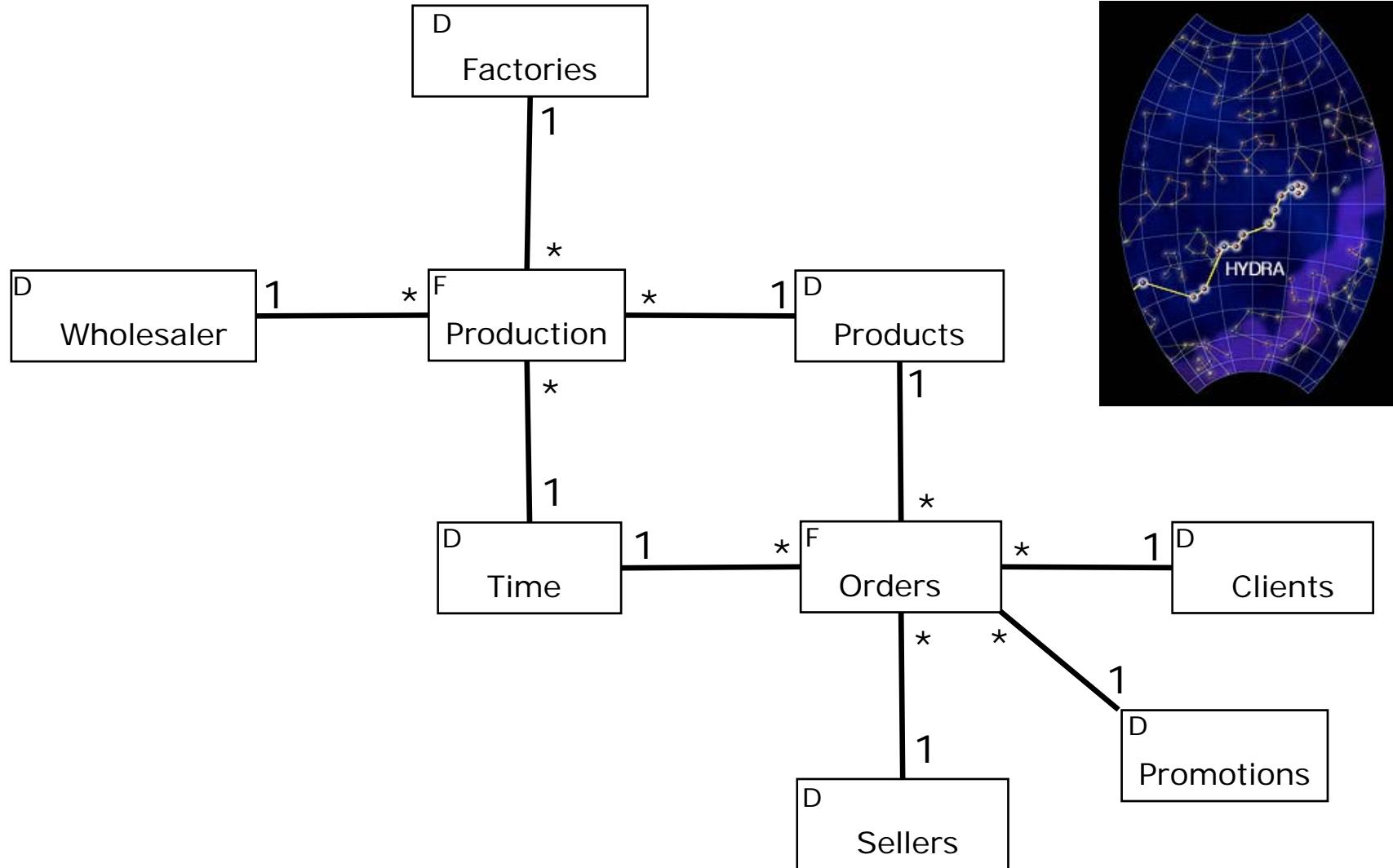
Star schema (IV)



Snowflake



Galaxy or Constellation



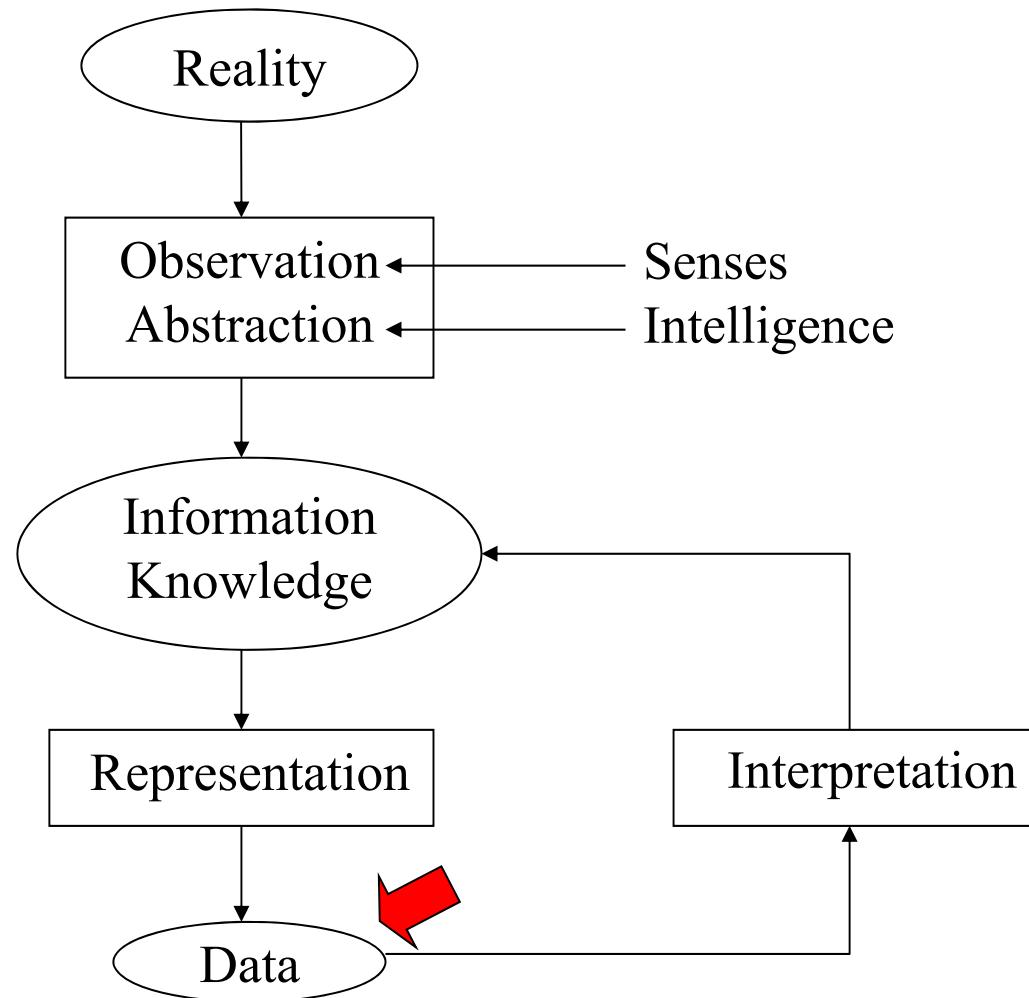
REPRESENTATION WORLD VIEW

Three worlds

Real world
(unique)

Conceptual world
(multiple)

Representation world
(multiple)



MOLAP: Multidimensional matrix



Ballpoint
Pencil
Pen
Rubber
A4 paper
A3 paper
Dash
Eraser

Barcelona

Tarragona
Lleida
Girona
Salamanca
Zamora
Madrid
Granada

3-1-2006

Barcelona
Tarragona
Lleida
Girona
Salamanca
Zamora
Madrid
Granada

4-1-2006

⋮

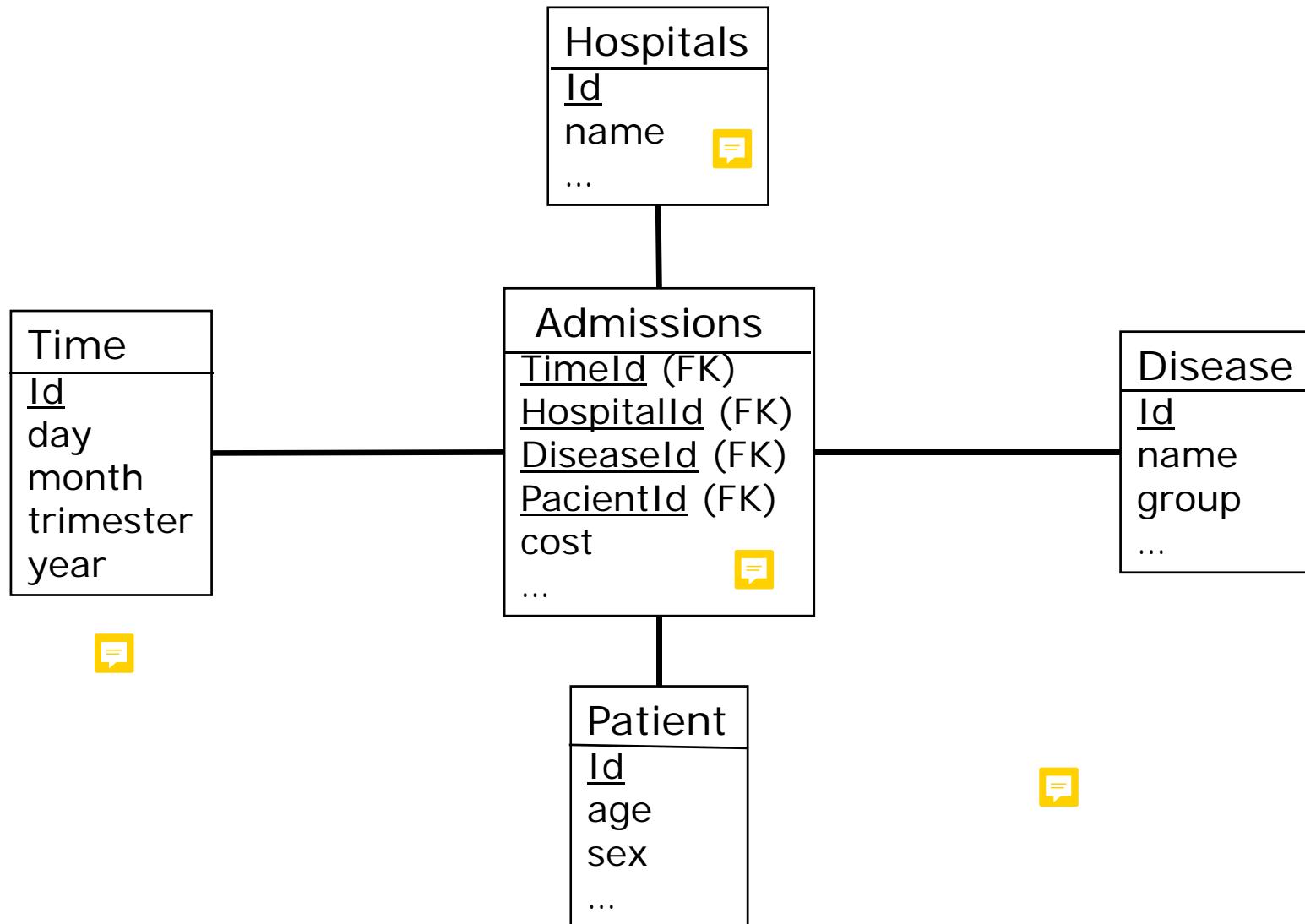
Barcelona
Tarragona
Lleida
Girona
Salamanca
Zamora
Madrid
Granada

11-1-2006

ROLAP: Characteristics

- Relational DBMS with multidimensional views
 - Two levels: Storage and Translation
- Use standard SQL
 - Easy to obtain
 - Independent of the DBMS
- Performance problems
 - Relational DBMS conceived for OLTP
 - OLAP operations are missing
 - Generate too many joins
- Used in huge Data Marts

ROLAP: Star-join schema



ROLAP: Cube-Query

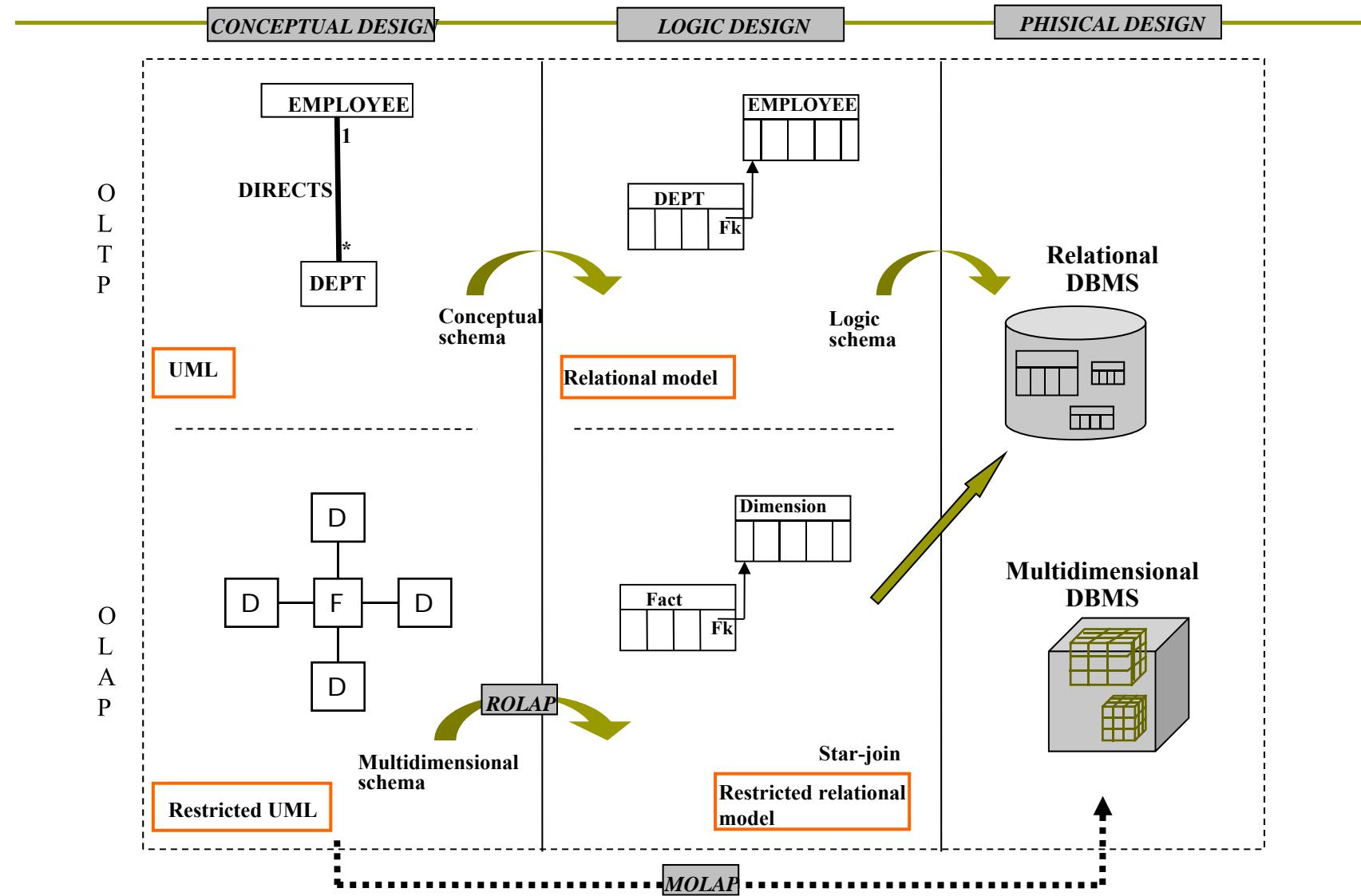
```
SELECT d1.attr, ..., dn.attr, F(f.Measure1), ...  
FROM Fact f, Dimension1 d1, ..., Dimensionn dn  
WHERE f.key1 = d1.ID AND ... AND f.keyn = dn.ID  
GROUP BY d1.attr, ..., dn.attr  
ORDER BY d1.attr, ..., dn.attr
```

ROLAP: Results table

Hospital	Month	Average Cost
Duran i Reinals	January'06	3300
Duran i Reinals	February'06	4500
Duran i Reinals
Duran i Reinals	All	4300
Bellvitge	January'06	180
Bellvitge	February'06	300
Bellvitge
Bellvitge	All	200



Comparison of design steps



Reasons for ROLAP

- Integrates existing technology
- Does not show scalability problems
- Query tools are independent from the DBMS
- Improves efficiency by codifying and compressing
- Allows using parallelism
- MOLAP does not allow ad-hoc queries
- MOLAP makes data actualization difficult

Reasons for MOLAP

- Matrixes are really efficient
- Relational tables are unnatural
- Multidimensionality and SQL do not fit each other
- ROLAP gains efficiency with MOLAP techniques

HOLAP

- a) Store dense chunks in MOLAP and sparse chunks in ROLAP
- b) Store atomic data in ROLAP and aggregates in MOLAP 
- c) Store frequently accessed data in MOLAP and the remaining data in ROLAP

CLOSING

Summary

- OLAP definition
- Cube
- Multidimensional schemas
 - Star
 - Snowflake
 - Galaxy or Constellation
- Kinds of multidimensional tools
 - ROLAP
 - MOLAP
 - HOLAP
- Star-join schema
- Cube-Query

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