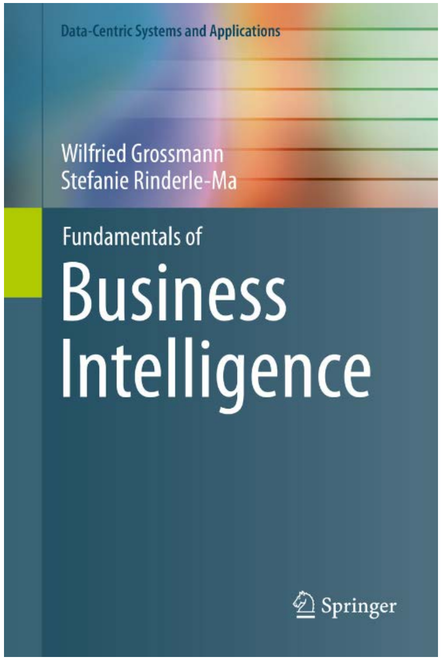


Chapter 2:
Modeling in
Business Intelligence

Contents

There are many different models used in BI

– Examples you know:

- *Model Definition*: Models represent some part of the business process and allow precise formulation of interesting questions (Analytical Goals)
- How can we realize the representation? (***representation function***)
- How should we formulate the representation? ("***model language"***)

Representation function of models

- Models of phenomena
- *Phenomena*: Features of the business process interesting from an analytical point of view
- *Models* define a picture of the phenomena (caricatures)
  - *Idealized models*, e.g., control flow of the business process, a treatment process, a course design
  - *Analogical models*: Overtake ideas from other sciences, e.g., gravity model for relations between persons in dependence of distance
  - *Phenomenological models*: Statistics, e.g. regression

Representation function of models (ctd.)

– Models of data

- We have no precise idea about the models, but only a number of candidate models for the empirical data
- The task is to learn the most appropriate model (Machine Learning, Data Mining)
- Simple example: Churn management:
  - ➢ Which variables influence the churn behavior of a customer , e.g., age, sex, marital status, income?
  - ➢ How should we define the relation between churn behavior and theses variables?

Representation function of models (ctd.)

– Models of Theories

- Each application domain of BI has specific domain knowledge, usually defined by concepts and relation (logical relations) between the concepts
- Concepts and logical relations define a formal system (ontology)
- Understanding this formal system as a theory data instances are models of this theory

→ Database models

Languages for Models

– Corresponding to the multitude of models there are different formulations (languages) used, for example:
  - UML or ER-modeling for data
  - BPMN for modeling the control flow
  - Statistics in case of modeling customer behavior
  - Connectedness (reachability) in a graph

Formulation of models

– Each language has its own semantic allowing definition of certain model elements an formulation of generic questions
  - Queries in a database
  - Simultaneous occurrence of two events in a business process
  - Strength of association between two variables
  - Graph models for social networks

Formulation of models (ctd.)

– Generic questions can be formulated in different languages

- Example: Relations between attributes
  - ➢ Formulate a query in a data model and represent the result as a table
  - ➢ Define a regression model and formulate the relation as an equation
  - ➢ Use a graphical language and visualize the relation in a scatterplot

Model Structures

- Putting all these things together leads to the concept of a ***model structure*** composed of:
  - Model Language:
    - Syntax defines basic elements and the rules how to compose model elements
    - Semantic defines the meaning of the elements in the language, independent from any domain
    - Notation for communication of the expressions in the language
- Model Elements: Certain expressions in the model language, useful for describing facts about the business process
- Generic questions: Questions formulated in the semantic of the model language about properties of model elements
  - Generic questions can be answered by specific analysis techniques

Modeling

- A mapping of some part of the domain semantic of a business process into a certain model structure ("***Conceptual Modeling***")
  - Examples for domain concepts and relations:
    - Health Care Use Case:
    - Higher Education Use Case:
    - CRM Use Case:
- Definition of a model configuration: admissible expression in a model structure which allows formulation of the analytical goal in questions about the model configuration
- Connection of model configuration with observations: data about the instances of the business process have to fit to the model configuration, i.e., views and perspectives
- Definition of model variability: Usually data are blurred due to noise or statistical variability

Model Assessment and Quality

- Quality criteria for business process models
  - *Correctness*: model is syntactical correct and mapping of domain semantic and model semantic is appropriate
  - *Relevance*: model complies with intended function, i.e., explain past observations and predict future observations
  - *Economic efficiency*: trade-off between complexity and costs (Occams razor)
  - *Clarity*: model can be understood by users
  - *Comparability*: model fits in the overall analysis framework of the business process

Model Assessment and Quality (ctd.)

– Quality criteria for empirical models

- *Objectivity*: Results are independent of the person using the model
- *Reliability*: results of the model can be reproduced
- *Validity*: model is useful from a practical point of view
  - Content validity: model represents phenomenon under consideration
  - Criterion validity: high correlation between model results and other external properties
  - Construct validity: new results can be derived from model

Models and Patterns

- Patterns describe local behavior whereas models describe global behavior
- Examples:
  - Medical treatment process: a pattern of co-occurrence of certain medications
  - Customer relationship: A pattern of occurrence of certain combination of variables like outliers

Contents

2 Logical and Algebraic Structures

Language: Propositional logic and predicate logic

- Individual constants (names), e.g., "`John Dee`"
- Variables: placeholders for constants, e.g., "`Student`", "`Course`"
- Functions: operating on constants or variables, e.g., "`grade(Student) = passed`"
- Predicates: define properties for the individual constants, e.g., "`Attends BI`"
- Quantifiers ("`for all (∀)`", "`exists (∃)`")
- Definition of terms by individual constants, individual variables, and functions
- Generate atomic formulas by a predicate symbol followed by a number of terms for which the predicate is applicable, e.g., "`AttendsBI[John Dee]`"
- Build well formed formulas using propositional calculus and quantifiers, e.g., `∃(Student)(∀(Course) grade(Student, Course) = passed`

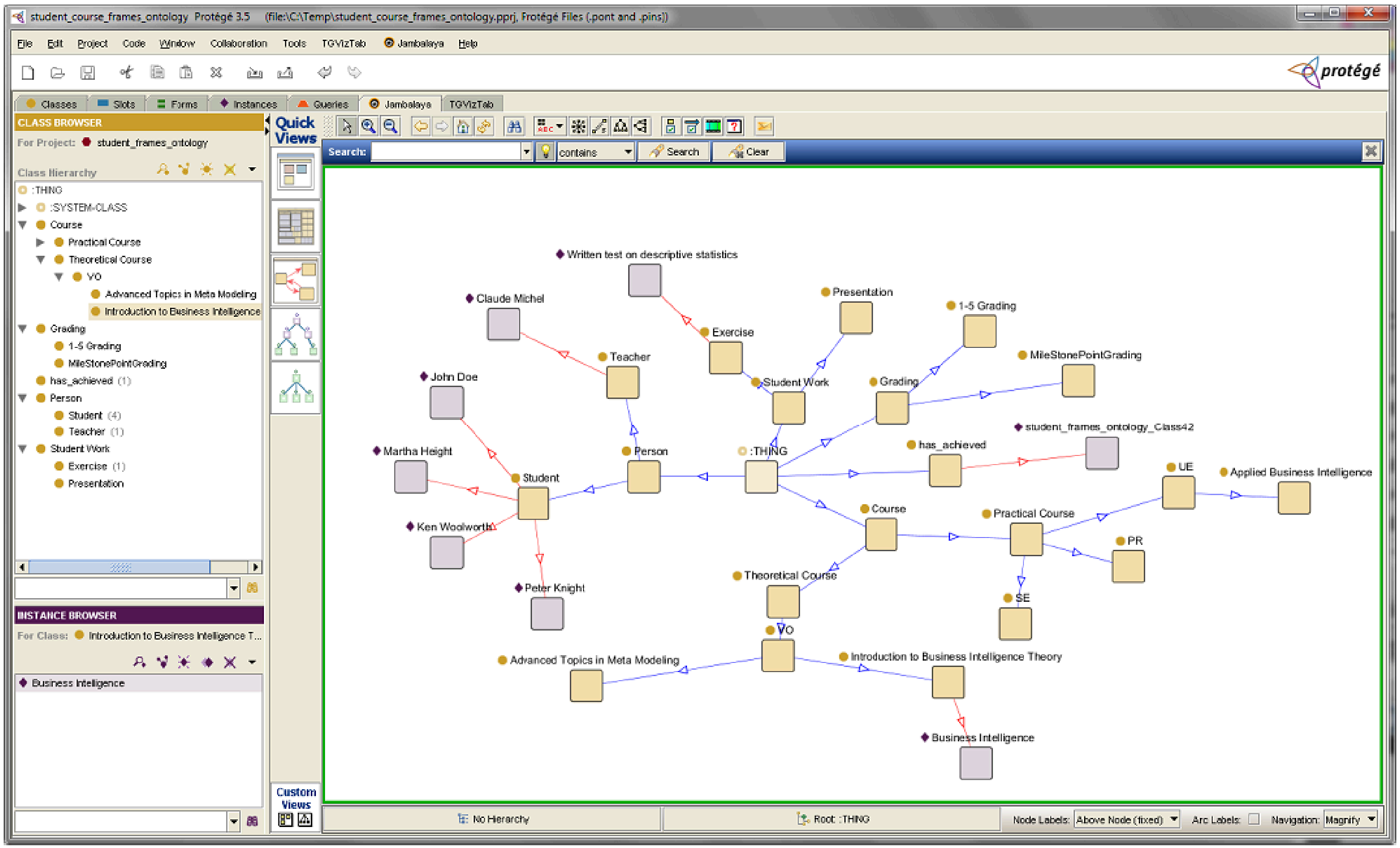
Model elements and generic questions

- Building expressions according to predicate logic
- Assign truth values to the expressions (interpretation)
- If the interpretation results in truth values TRUE for all possible assignments of the free variables we call the interpretation a model
- Generic questions are whether a well formed formula is true
- Modeling using logical structures tries to capture domain knowledge in a logical form
- The simplest form are terminology systems like taxonomies

Ontologies: “*A specification of a conceptualization*”

– OWL:
  - T-Box: Vocabulary of a domain as a logical theory
  - A-Box: Assertion about the domain, which has to be checked
  - Uses the open world assumption, i.e., anything can be entered in the T-Box unless it violates constraints

2 Logical and Algebraic Structures



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Frames

- Representation in an object-oriented style
- For each object a number of slots are defined for attributes of the objects
- Frames use the closed world assumption, i.e., a statement is true if its negation cannot be proven within the system
- Example:
  - “All birds can fly” (closed world)
  - “There exist non flying birds” (open world)

Contents

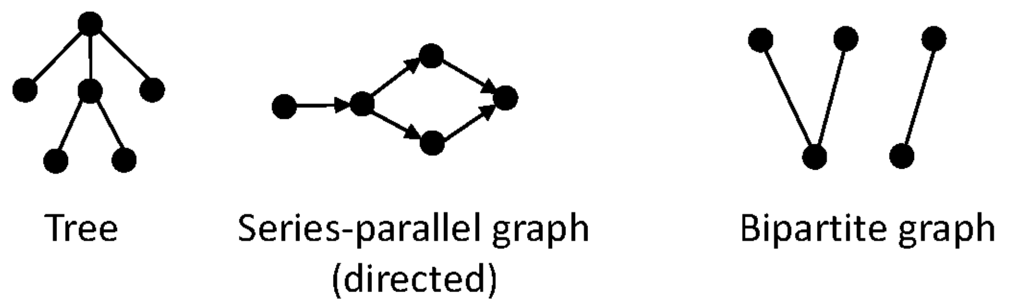
Model Structure - Language:

- Syntactic elements:
  - Nodes (vertices)
  - Edges (directed, undirected)
  - Labels for edges (e.g., “distance”) or nodes (e.g., “degree”)
- Notation:
  - Numeric representation (adjacency matrix)
  - Visual representation

Model Structure

– Model elements

- Special kinds of graphs, e.g., trees, series parallel networks, bipartite graphs
- Connected graphs (path)



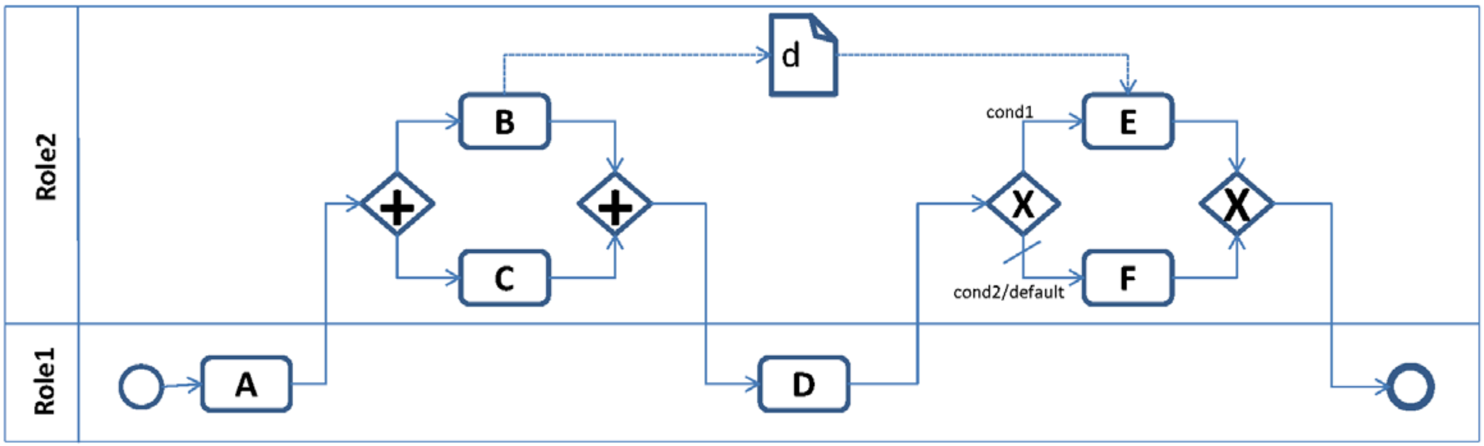
– Generic questions

- Generic questions refer to properties of the graph and can be answered by well known algorithms like spanning tree, shortest path, best matching of nodes

3 Graph Structures

Modeling using graph structures, e.g.,

– Business process modeling and notation (BPMN)

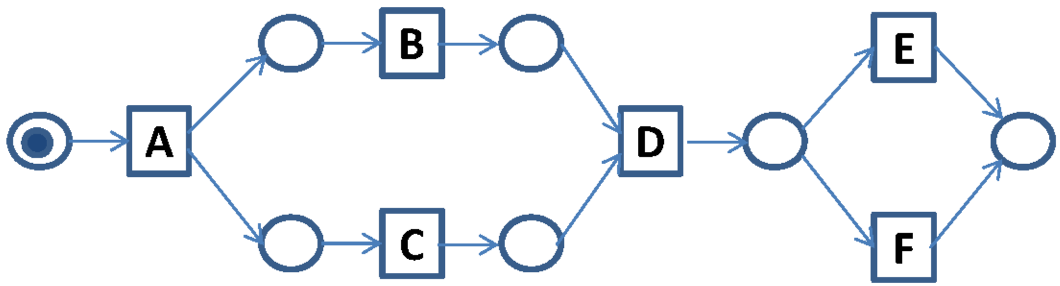


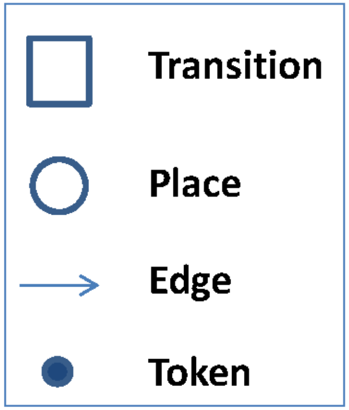
Control Flow	Data Flow	Events	Gateways	Organization
Task Sequence Flow cond Transition condition	Data Object Data Association	Start Event End Event	Parallel Exclusive	

3 Graph Structures

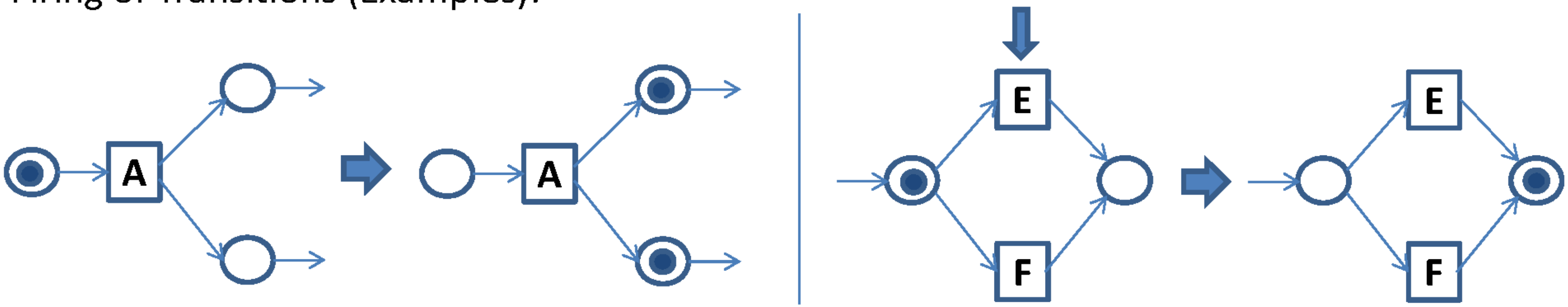
– Modeling using graph structures, e.g., Petri Nets

Process Model Represented as Petri Net:





Firing of Transitions (Examples):



Contents

Calculus

- Language:
  - Variables in one or more dimensions
  - Mathematical functions $f: X \rightarrow Y, y = f(\boldsymbol{x}) = f(x_1, \ldots x_p)$
- Model elements:
  - Classical functions (linear functions, logarithm, exponential functions,...)
  - Norm of a vector: $\|x\| = \sqrt{\sum_{i=1}^{p} x_i^2}$
  - Distance between two vectors x and z:

$$d(x, z) = \sqrt{\sum_{i=1}^{p} (x_i - z_i)^2} = \|\boldsymbol{x} - \boldsymbol{z}\|$$

Calculus (ctd.)

- Model elements (ctd.)
- Inner product, given a vector w of coefficients:

$$f(x) = w^T x = \mathrm{w}_1 \mathrm{x}_1 + \cdots + \mathrm{w}_\mathrm{p} \mathrm{x}_\mathrm{p}$$

- Linear functions in more than one variable (matrices): $f(\boldsymbol{x}) = B\boldsymbol{x}$ where B is a $k \times p$ matrix
- Projections: The orthogonal projection of a vector x onto another vector w is defined by $p_{w(x)} = x' * \frac{w}{\|w\|}$

Calculus (ctd.)

- Generic questions:
  - Properties of functions
  - Minimization and maximization of a function
    - Value of the minimum: $z = \min f(x)$
    - Argument of the minimum: $x_m = \arg\min f(x) \big(f(x_m)\big) = z$
- Matrix factorization: If C is a symmetric positive definite matrix (covariance matrix) then we can represent this matrix in the form: $C = P * D * P^t$
  - Here D is a Diagonal matrix and P is a matrix with orthogonal columns
  - This is frequently used for dimensionality reduction

Probability – Language

- Events, Calculus of events: E
- Probability of events $P(E), odds(E) = \frac{P(E)}{1-P(E)}$
- Random variables as model for measurement: X
- Probability Distribution:
  - Distribution function: $F(x) = P(X \leq x)$
  - Density function and probability function: $p(x)$
  - We interpret the density as likelihood of an observation

Probability – Language (ctd.)

- Conditional probability and independence: $p(x|y) = p(x,y)/p(y)$
- Two variables are independent if $p(x,y) = p(x) * p(y)$
- Bayes Theorem: $p(x|y) = p(y|x)/p(y)$
- Interpretation of Bayes Theorem in the discrete case: Compute column percentages from row percentages

Probability – Example

Joint Probabilities

Usage Pattern	Age Group		marginal
	young	old	
high	0.2	0.1	0.3
moderate	0.3	0.2	0.5
inactive	0.1	0.1	0.2
marginal	0.6	0.4	1.0

Conditional Probabilities given Usage

Usage Pattern	Age Group		marginal
	young	old	
high	0.67	0.33	1
moderate	0.6	0.4	1
inactive	0.5	0.5	1
marginal	0.6	0.4	1.0

Conditional Probabilities given Age

Usage Pattern	Age Group		marginal
	young	old	
high	0.33	0.25	0.3
moderate	0.50	0.50	0.5
inactive	0.17	0.25	0.2
marginal	1.00	1.00	1.0

4 Analytical structures

Statistics – Language

- Statistical units (observation units)
- Population
- Observable variable
- Transfer the concepts of probability to observations, e.g., “distribution” to “sample distribution” (“empirical distribution”)
- Model elements and generic questions:
  - Descriptive methods
  - Inferential methods
    - Estimation
    - Testing
    - Confidence regions
- Modeling methods
  - Regression

Contents

Data Generation

- In BI we have usually secondary data, i.e., data which have been collected for other purposes, e.g.,
  - Transactional data
  - Administrative data
  - Web data
- An important question for interpretation of results is defining the population which is represented by the data (e.g., tweets or evaluations on portals)
- Measurement of the data

Elements of the knowledge based temporal abstraction method

- Time stamps T_i are the basic primitives with a predefined granularity and a well defined zero.
- Time intervals $T = [T_{start}, T_{end}]$ are defined as pairs of time stamps for start and end. Time points are zero length intervals.
- An interpretation context ξ is a proposition that can change the interpretation of parameters within the scope of a time interval. Interpretation contexts can be nested.
- A context interval $\langle \xi, I \rangle$ defines time intervals for which the interpretation context holds.
- An event proposition e represents the occurrence of an external volitional action or process and has to be distinguished from a measurable datum.
- An event interval $\langle e, I \rangle$ represents the temporal duration of an event e.

5 Models and data

Elements of the knowledge based temporal abstraction method (ctd.)

– A parameter schema π is a measurable aspect of the state of the world (states of a process) with values in some domain $v \epsilon V_\pi$. Parameter schemas may be of different type: primitive parameters (measurable data), abstract parameters (concepts), constant parameters (instant specific or instant independent).
– A parameter proposition $\langle \pi, v, \xi \rangle$ defines the values of parameters in a context.
– An abstraction function $\theta \epsilon \Theta$ maps parameters into abstract parameters.
– A parameter interval $\langle \pi, v, \xi, I \rangle$ denotes the value v of the parameter π in the context ξ during time interval I.
– An abstraction is a parameter or a parameter interval.
– An abstraction goal $\psi \epsilon \Psi$ represent a specific intention or goal.
– An abstraction goal interval $\langle \psi, I \rangle$ represents the idea that abstraction goal ψ holds in interval I.
– Induction of context intervals allows the induction of events, parameters, or abstraction goal propositions for some context interval.

5 Models and data

Quality Dimensions for Data

- Relevance measures in how far the data are useful in the intended context.
- Accuracy is the degree of conformity of a measure to a standard or a true value.
- Completeness is a characteristic measuring the degree to which all required data is known, with respect to depth, breath, and scope.
- Timeliness: Data coming early or at the right time, appropriate or adapted to the times or the occasion.
- Consistency is expressed as the degree to which a set of data is equivalent in redundant or distributed databases.
- Coherence refers to the adequacy of the data to be reliable combined in different ways and for various uses.
- Reliability is a characteristic of an information infrastructure to store and retrieve information in an accessible, secure, maintainable, and fast manner.

Contents

- Modeling is a rather intricate activity in BI
- Different approaches for model representation and model presentation
- Key tasks:
  - Definition of a model configuration
  - Connection of the model configuration with the observations from business process instances.
  - Formulation of a model component for capturing the variability of the different process instances.

6 Summary & outlook