Patterns of Data Modeling

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Section 1: Introduction

Pattern Definitions From the Literature

- [Alexander-1979]. A solution to a problem in context.
- [Buschmann-1996]. Describes a particular recurring design problem that arises in specific design contexts, and presents a well-proven generic scheme for its solution.
- [Erl-2009] A proven solution to a common problem individually documented in a consistent format and usually as part of a larger collection.
- [Fowler-1997]. An idea that has been useful in one practical context and will probably be useful in others.
- [Gamma-1995] Explains a general design that addresses a recurring design problem. Describes the problem, the solution, when to apply the solution, and its consequences.
- [Blaha-2010] A model fragment that is profound and recurring.

Why are Patterns Important?

- **Enriched modeling language**. Patterns provide a higher level of building blocks than modeling primitives. Patterns are prototypical modeling fragments that distill the knowledge of experts.
- **Improved documentation**. Patterns offer standard forms that improve modeling uniformity.
- **Reduced modeling difficulty**. Many developers find modeling difficult because of the intrinsic abstraction. Patterns are all about abstraction and give developers a better place to start.
- **Faster modeling**. Developers do not have to create everything from scratch and can build on the accomplishments of others.
- **Better models**. Patterns reduce mistakes and rework. Carefully considered patterns are more likely to be correct and robust than an untested, custom solution.

Drawbacks of Patterns

- **Sporadic coverage**. You cannot build a model by just combining patterns. Typically you will use only a few patterns, but they often embody key insights.
- **Pattern discovery**. It can be difficult to find a pattern, especially if your idea is ill-formed.
- **Complexity**. Patterns are an advanced topic and can be difficult to understand.
- **Inconsistencies**. There has been a real effort in the literature to cross reference other work and build on it. However, inconsistencies still happen.
- **Immature technology**. The patterns literature is active but the field is still evolving.

Pattern vs. Seed Model

Most of the database literature confuses patterns with seed models.

- ***Seed model***: a model that is specific to a problem domain.
  – Provides a starting point for applications from its problem domain.

	Pattern	**Seed model**
Applicability	Application independent	Application dependent
Scope	An excerpt of a model	Intended to be the starting point for an application
Model size	Typically <10 classes	Typically 10-50 classes
Abstraction	More abstract	Less abstract
Model type	Can be described with a data model	Can be described with a data model

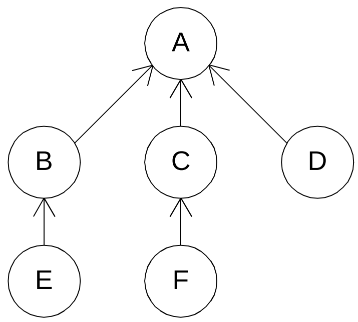
Section 2: Aspects of Pattern Technology

- ***Mathematical template***: an abstract model fragment that is devoid of application content.
  – Driven by deep data structures that often arise in database models.
  – Notation: Angle brackets denote parameters that are placeholders.
- ***Antipattern***: a characterization of a common software flaw.
  – Shows what not to do and how to fix it
- ***Archetype***: a deep concept that is prominent and cuts across problem domains.
- ***Identity***: the means for denoting individual objects, so that they can be found.
- ***Canonical model***: a submodel that provides a useful service for many applications

The remaining lecture will focus on the first two topics.

Section 3: Mathematical Template — Tree

- ***Tree***: a term from graph theory.
  - A tree is a set of nodes that connect from child to parent. Each node has one parent node except for the node at the tree's top.
  - A node can have many (zero or more) child nodes.
  - There are no cycles — at most one path connects any two nodes.
- An example of a tree...

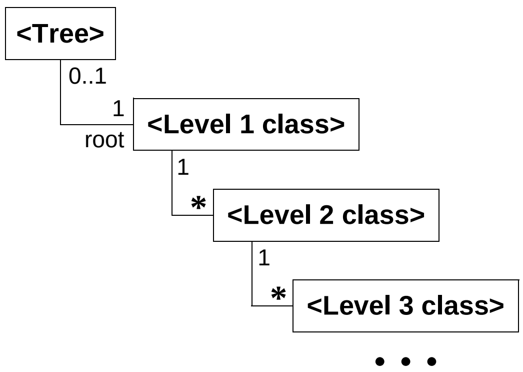


Six Tree Templates

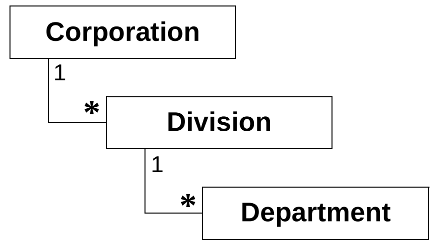
- **Hardcoded tree**. Hardcodes types, one for each level of the tree.
- **Simple tree**. Restricts nodes to a single tree. Treats nodes the same.
- **Structured tree**. Restricts nodes to a single tree. Differentiates leaf nodes from branch nodes.
- **Overlapping trees**. Permits a node to belong to multiple trees. Treats nodes the same.
- **Tree changing over time**. Stores multiple variants of a tree. A particular tree can be extracted by specifying a time. Restricts nodes to a single tree. Treats nodes the same.
- **Degenerate node and edge**. Groups a parent with its children. The grouping itself can be described with attributes and relationships. Restricts nodes to a single tree. Treats nodes the same.

Hardcoded Tree

Hardcoded tree template



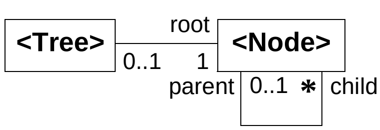
Example: Organizational chart



- Use when:
  - The structure of a tree is well known and it is important to enforce the sequence of types in the levels of the hierarchy.
  - In practice, used for examples, but seldom for code.

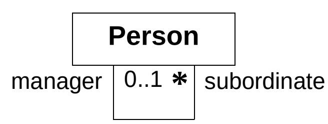
Simple Tree

Simple tree template



{All nodes have a parent except the root node.}
{There cannot be any cycles.}

Example: Management hierarchy

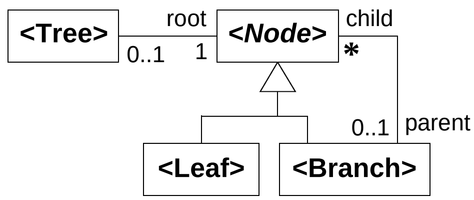


{Every person has a manager, except the CEO.}
{The management hierarchy must be acyclic.}

- Use when:
  - Tree decomposition is merely a matter of data structure.
- Node names can be globally unique or unique within the context of a parent.

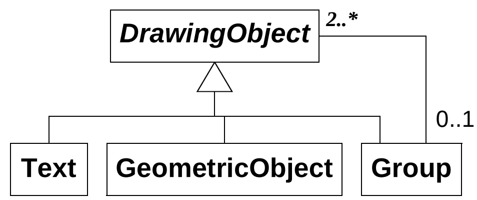
Structured Tree

Structured tree template



{All nodes have a parent except the root node.}
{There cannot be any cycles.}

Example: Graphical editor

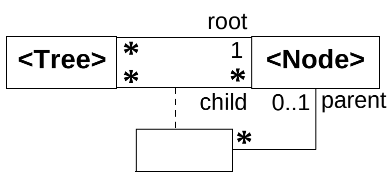


{The group hierarchy must be acyclic.}

- Use when:
  - Branch nodes and leaf nodes have different attributes, relationships, and/or behavior.
- Node names can be globally unique or unique within the context of a parent.

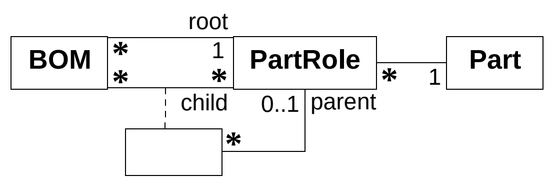
Overlapping Trees

Overlapping trees template



{All nodes have a parent except the root node.}
{There cannot be any cycles.}
{A parent must only have children for trees to which the parent belongs.}

Example: Mechanical parts

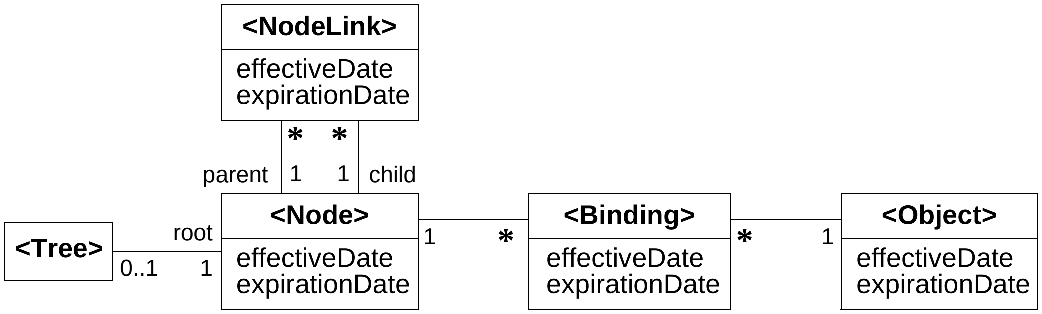


{Each BOM must be acyclic.}

- Use when:
  - A node can belong to multiple trees.
  - Example: A part can have several bill-of-materials, such as one for manufacturing, another for engineering, and another for service.
- Motivated by [Fowler, page 21] but a more powerful template capturing the constraint that a child has at most one parent for a tree.

Tree Changing Over Time

Tree changing over time template

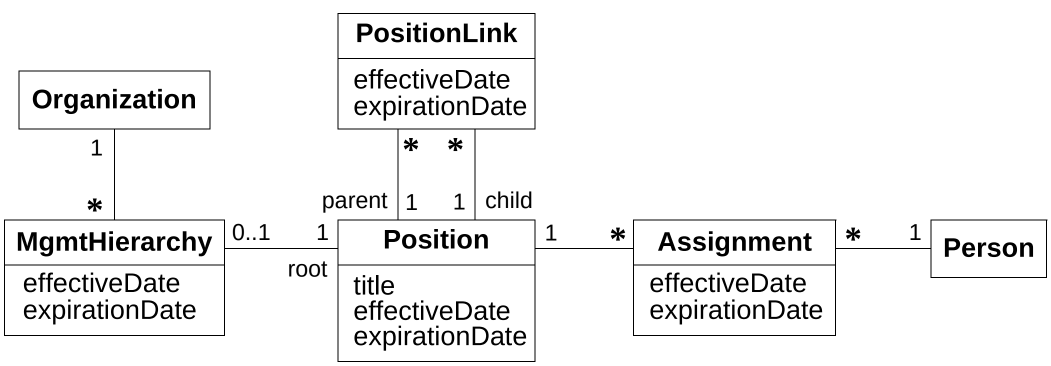


{All nodes have a parent except the root node. There cannot be any cycles.}
{A child has at most one parent at a time.}

- Note that the data structure does not enforce that a *Node* has at most one parent at any time. Application code would need to enforce this constraint.

Tree Changing Over Time (continued)

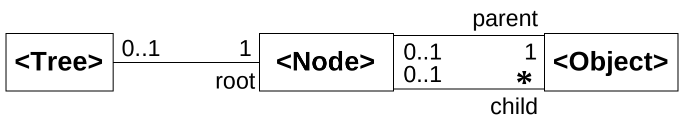
Example: management hierarchy



- Use when:
  - The history of a tree must be recorded.

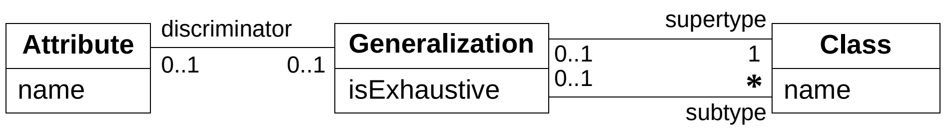
Degenerate Node and Edge

Degenerate node and edge template



{There cannot be any cycles.}

Example: Single inheritance



{There cannot be any cycles.}

- Use when:
  - The grouping of a parent and its children must be described.

Additional Templates

There are templates for additional data structures...

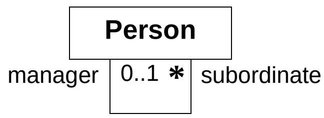
- Directed graph.
- Undirected graph.
- Item description.
- Star schema.

I welcome suggestions for other important data structures that can be characterized with templates.

Section 5: Mathematical Template — Example

Here are alternative patterns for expressing the data structure of a corporate management hierarchy.

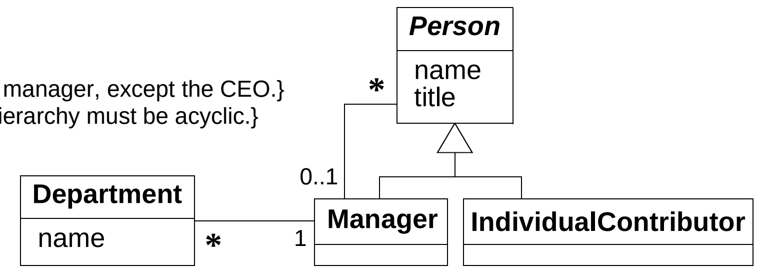
Management Template — Simple Tree



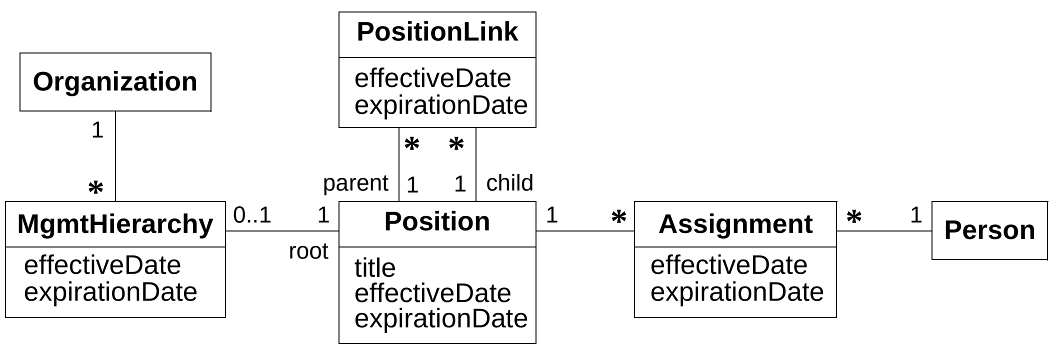
{Every person has a manager, except the CEO.}
{The management hierarchy must be acyclic.}

Management Template — Structured Tree

{Every person has a manager, except the CEO.}
{The management hierarchy must be acyclic.}



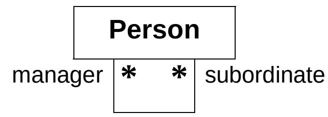
Mgmt Template — Tree Changing Over Time



The model provides matrix management. This is because the model does not enforce a tree—that a child can only have a single parent at a time.

Application code would need to provide such a constraint if it was desired.

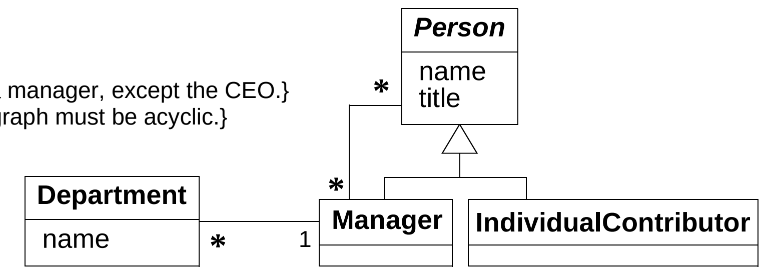
Management Template — Simple Directed Graph



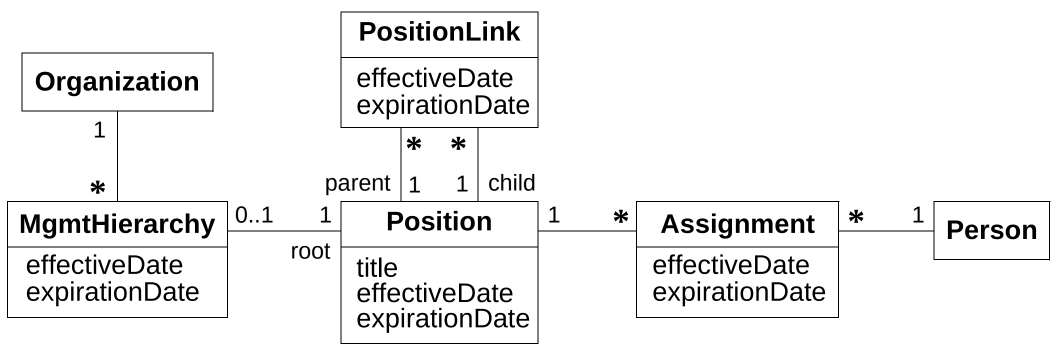
{Every person has a manager, except the CEO.}
{The management graph must be acyclic.}

Mgmt Template — Structured Directed Graph

{Every person has a manager, except the CEO.}
{The management graph must be acyclic.}



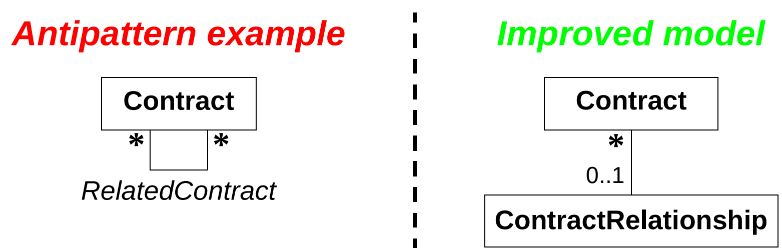
Mgmt Template — Simple DG Changing Over Time



Section 6: Antipatterns

- ***Antipattern***: a characterization of a software flaw. When you find an antipattern, substitute the correction.
  - ***Universal antipattern*** — avoid for all applications.
  - ***Non-data-warehouse antipattern*** — acceptable for data warehouses, but avoid them otherwise.
- Patterns are good ideas that can be reused.
  In contrast, antipatterns look at what can go wrong.
- The literature focuses on antipatterns for programming code, but antipatterns also apply to data models.
- [Brown-98]. An antipattern is some repeated practice that initially appears to be beneficial, but ultimately produces more bad consequences than beneficial results.

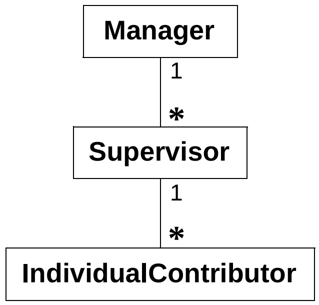
Universal Antipattern: Symmetric Relationship



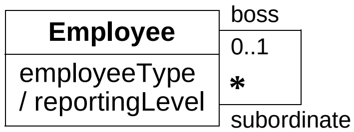
- ***Observation***: There is a self relationship with the same multiplicity and role names on each end.
  - Symmetric relationships are always troublesome for relational databases.
    - Which column is first? Which column is second?
    - Double entry or double searching of data.
- ***Improved model***: Promote the relationship to a class in its own right. The improved model is often more expressive.

Universal Antipattern: Artificial Hardcoded Levels

Antipattern example



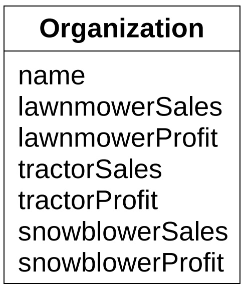
Improved model



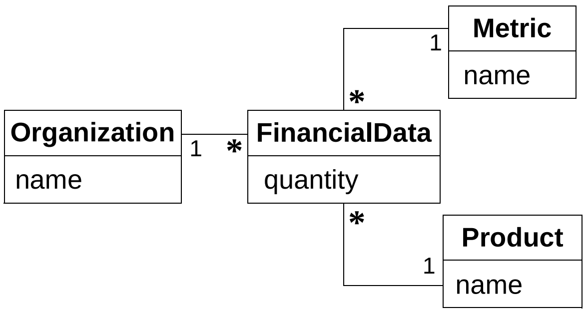
- ***Observation***: There is a fixed hierarchy with little difference between the levels.
  - Contrast with the hardcoded tree template where there is a material difference between the levels.
- ***Improved model***: Abstract and consolidate the levels. Use one of the tree patterns to relate the levels.

Non-DW Antipattern: Parallel Attributes

Antipattern example



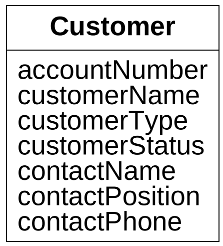
Improved model



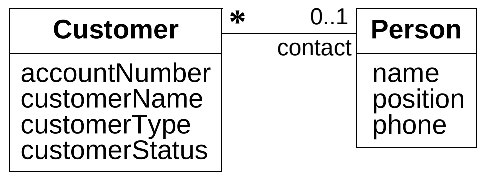
- ***Observation***: A class has groups of similar attributes. Such a model can be brittle, verbose, and awkward to extend.
- ***Exceptions***: OK for data warehouses.
- ***Improved model***: Abstract and factor out commonality.
  - The improved model can handle new products and financial metrics.

Non-DW Antipattern: Combined Classes

Antipattern example



Improved model



- ***Observation***: A class has disparate attributes and lacks cohesion.
  - The contact position and contact phone depend on the contact name which in turn depends on the customer.
  - Several customer records could have the same contact name with inconsistent positions and phones.
- ***Exceptions***: OK for data warehouses.
- ***Improved model***: Make each concept its own class.

Section 7: Antipattern Example

Reverse Engineering the LDAP Standard

- LDAP = Lightweight Directory Access Protocol
  - LDAP is a public standard that has two primary purposes: user authentication and sharing basic data across applications.
  - LDAP was originally implemented with files, but we will study a product with a database implementation.
  - The LDAP schema is by intent a meta-schema that stores both a model and the model's data.
- My motive was to reverse engineer the database so that my client could better understand the product.
- Available inputs.
  - Schema: tables, attributes, data types, nullability, and primary keys.
  - Data.
  - A book explaining LDAP concepts.

LDAP Reverse Engineering: Original Schema

I was given a printout of a SQL server schema.

DsTimestamp

Column Name	Datatype	Length	Precision	Scale	Allow Nulls	Identity
i_Replication_Key	int	4	10	0		✓
dt_SchemaTimestamp	datetime	8	0	0	✓	
dt_DitTimestamp	datetime	8	0	0	✓	
dt_ReplicationTimestamp	datetime	8	0	0	✓	
dt_GroupTimestamp	datetime	8	0	0	✓	

There were a total of 11 tables. *DsTimestamp* is one of the tables.

LDAP Reverse Engineering: Original Schema

First, I typed the schema into a modeling tool (three slides).

Configuration

replicationKey[1..1]:int(4) {pk}
id[1..1]:int(4)
containerPartitionID:int(4)
containerDbID:int(4)
peKey:varchar(255)

AttributeContainers

replicationKey[1..1]:int(4) {pk}
aid[1..1]:int(4)
containerClsID[1..1]:int(4)
required[1..1]:bit

ObjectAttributes

dsID[1..1]:int(4) {pk}
sequence[1..1]:int(4) {pk}
aid[1..1]:int(4) {pk}
vcVal:varchar(255)
iVal:int(4)
vbVal:varbinary(255)
imgVal:image
dtVal:datetime
expiresTime:datetime

DsTimestamp

replicationKey[1..1]:int(4) {pk}
schemaTimestamp:datetime
ditTimestamp:datetime
replicationTimestamp:datetime
groupTimestamp:datetime

ObjectLookup

dsID[1..1]:int(4) {pk}
entryName[1..1]:varchar(255)
objectClass[1..1]:int(4)
containerDsID:int(4)
dseType[1..1]:int(4)
creatorsName:varchar(255)
createTimestamp:datetime
modifiersName:varchar(255)
modifyTimestamp:datetime
acl:image
expiresTime:datetime

Attributes have a name, nullability, datatype, and primary key flag.

LDAP Rev Engr: Original Schema (continued)

ClassContainers
replicationKey[1..1]:int(4) {pk}
clsID[1..1]:int(4)
containerClsID[1..1]:int(4)

Classes
clsID[1..1]:int(4) {pk}
name[1..1]:varchar(255)
oid:varchar(255)
description:varchar(255)
rdnAid[1..1]:int(4)
guid[..1]:char(39)
dseDitType[1..1]:int(4)
displayName:varchar(255)
isSecurityPrincipal[1..1]:bit
containerType[1..1]:int(4)
defaultSecurityDecriptor:image
acl:image

DsConfiguration
serverID[1..1]:int(4) {pk}
instanceID[1..1]:int(4)
serverName[1..1]:varchar(255)
dynamicDbFlags[1..1]:int(4)
replicationFlags[1..1]:int(4)
replicationProto[1..1]:varchar(255)
replicationEndP[1..1]:varchar(255)
replicationQSize[1..1]:int(4)
replicationLagTime[1..1]:int(4)
replicationBuffSize[1..1]:int(4)
replicationSyncTime[1..1]:int(4)
replicationInfo[1..1]:varchar(255)

Subrefs
namespacePartitionID[1..1]:int(4) {pk}
subrefEntry:varchar(255)
subrefPrentID:int(4)
valuePartitionCount[1..1]:int(4)

LDAP Rev Engr: Original Schema (continued)

DsoGrid
serverID[1..1]:int(4) {pk}
namespacePartitionID[1..1]:int(4)
valuePartitionID[1..1]:int(4)
dsoType[1..1]:int(4)
datasource[1..1]:varchar(255)
database[1..1]:varchar(255)
login:varchar(255)
password:varchar(255)
maxCnx:int(4)
timeout:int(4)
replicationType:int(4)

Attributes
aid[1..1]:int(4) {pk}
name[1..1]:varchar(255)
oid:varchar(255)
description:varchar(255)
dataType[1..1]:int(4)
multiValued[1..1]:bit
searchble[1..1]:bit
guid[1..1]:char(39)
syntax[1..1]:int(4)
displayName:varchar(255)
constraints:varchar(255)
acl:image

LDAP Reverse Engineering: Observations

- The schema has a strong and uniform style.
  - Primary key fields are IDs, *replicationKey*, and *sequence*.
  - All primary key fields are int(4).
- ***Antipattern***: Parallel attributes.
  - *ObjectAttributes* has parallel attributes: *vcVal*, *iVal*, *vbVal*, *imgVal*, and *dtVal*. Apparently, each record fills in the one field with the appropriate data type.
  - The usage is very limited and seems OK here.
- ***Antipattern***: Disguised (overloaded) fields.
  - *ObjectAttributes.iVal* is used to store both integers and IDs (essentially pointers to objects). I determined this by inspecting data.
  - Thus the LDAP standard subverts referential integrity. This is largely a consequence of LDAP's heritage of being designed for files.

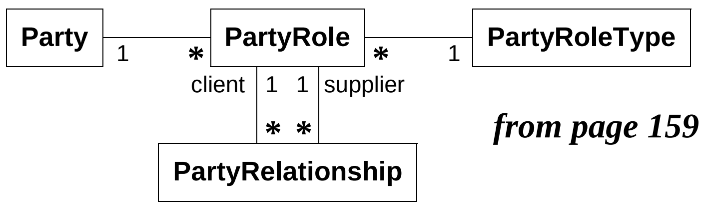
LDAP Reverse Engineering: Observations (cont.)

- ***Antipattern***: Modeling error,
  - There can be many *ClassContainers* for the same contained *Classes* and container *Classes*.
  - This lets a class contain multiple copies of a class.
  - Apparently, the multiple copies do not have different roles. This is odd. There is no way to distinguish the multiple copies.
- ***Antipattern***: Paradigm degradation.
  - The LDAP standard forces data into a hierarchical structure. A hierarchy is adequate for simple data. It distorts a complex data structure (unlike the neutral structure of relational databases).
  - LDAP degrades use of a relational database. It foregoes referential integrity and uses pointers that programming code must handle.

Section 8: Pattern Literature

Jim Arlow and Ila Neustadt. *Enterprise Patterns and MDA: Building Better Software with Archetype Patterns and UML*. Boston: Addison-Wesley, 2004.

- Their archetype models are large and more like seed models.
  - Small archetype models are more likely to be application independent and reusable.
- They distinguish between client and supplier. This is a modeling error. This is completely unnecessary, given that they have roles.



from page 159

- The book focuses on design and programming.
- Data modeling notation: UML class model.

Pattern Literature (continued)

Martin Fowler. *Analysis Patterns: Reusable Object Models*. Boston, Massachusetts: Addison-Wesley, 1997.

- Fowler discusses different application domains and gradually elaborates the seed models, explaining important abstractions along the way.
  - Most of his examples are from health care, finance, accounting, and the stock market.
- Data modeling notation: IE-like notation with object-oriented jargon.
- This is an excellent book.

Pattern Literature (continued)

Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides. *Design Patterns: Elements of Reusable Object-Oriented Software*. Reading, Massachusetts: Addison-Wesley, 1995.

- Focuses on issues of programming design.
  - They don't cover databases.
- Discusses abstract patterns that transcend individual programs.
  - This stands in contrast to most of the database pattern books.
- Data modeling notation: OMT class model notation (a precursor to the UML).
- This is a seminal work.

Pattern Literature (continued)

David C. Hay. *Data Model Patterns: Conventions of Thought*. New York, New York: Dorset House, 1996.

- Presents seed models for a wide variety of applications areas.
  - Person and Organization
  - Product
  - Procedure
  - Contract
  - Laboratory
  - Material planning
  - Process manufacturing
  - Document
- Data modeling notation: Richard Barker et al's (Oracle notation).
- This is an excellent book. (Hays has just come out with a new book.)

Pattern Literature (continued)

Len Silverston. *The Data Model Resource Book, Volume 1*. New York, New York: Wiley, 2001.

Len Silverston. *The Data Model Resource Book, Volume 2*. New York, New York: Wiley, 2001.

- Vol 1 presents seed models for a wide variety of applications areas.
  - Person and Organization
  - Product, Order, Shipment
  - Work effort
  - Invoice, Accounting, Budgeting
  - Human Resources
- Vol 2 presents seed models for a variety of industries.
- Data modeling notation: Richard Barker et al's (Oracle notation).

Pattern Literature (continued)

Len Silverston and Paul Agnew. *The Data Model Resource Book, Volume 3*. New York, New York: Wiley, 2009.

- Chapters 2 and 3 have an excellent discussion of *party* (comparable to *actor* in this book). They distinguish between a declarative role (a role that a person or organization plays within an entire enterprise) and a contextual role (a role in a specific relationship).
- Volume 3 is an excellent book. The scope is limited, but the book is abstract and incisive.
- Data modeling notation: Richard Barker et al's (Oracle notation).
  - Uses this notation for consistency with earlier books, even though the notation is dated.