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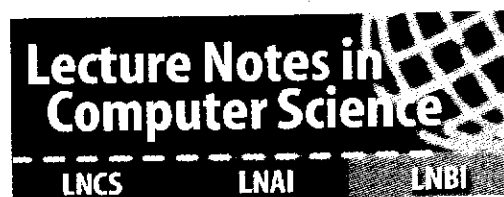
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3 Part III

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Computational Science and Its Applications – ICCSA 2006

International Conference
Glasgow, UK, May 8-11, 2006
Proceedings, Part III

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Preface

This five-volume set was compiled following the 2006 International Conference on Computational Science and its Applications, ICCSA 2006, held in Glasgow, UK, during May 8–11, 2006. It represents the outstanding collection of almost 664 refereed papers selected from over 2,450 submissions to ICCSA 2006.

Computational science has firmly established itself as a vital part of many scientific investigations, affecting researchers and practitioners in areas ranging from applications such as aerospace and automotive, to emerging technologies such as bioinformatics and nanotechnologies, to core disciplines such as mathematics, physics, and chemistry. Due to the sheer size of many challenges in computational science, the use of supercomputing, parallel processing, and sophisticated algorithms is inevitable and becomes a part of fundamental theoretical research as well as endeavors in emerging fields. Together, these far-reaching scientific areas contributed to shaping this conference in the realms of state-of-the-art computational science research and applications, encompassing the facilitating theoretical foundations and the innovative applications of such results in other areas.

The topics of the refereed papers span all the traditional as well as emerging computational science realms, and are structured according to the five major conference themes:

- Computational Methods, Algorithms and Applications
- High-Performance Technical Computing and Networks
- Advanced and Emerging Applications
- Geometric Modeling, Graphics and Visualization
- Information Systems and Information Technologies

Moreover, submissions from 31 workshops and technical sessions in areas such as information security, mobile communication, grid computing, modeling, optimization, computational geometry, virtual reality, symbolic computations, molecular structures, Web systems and intelligence, spatial analysis, bioinformatics and geocomputations, are included in this publication. The continuous support of computational science researchers has helped ICCSA to become a firmly established forum in the area of scientific computing.

We recognize the contribution of the International Steering Committee and sincerely thank the International Program Committee for their tremendous support in putting this conference together, the near 800 referees for their diligent work, and the IEE European Chapter for their generous assistance in hosting the event.

We also thank our sponsors for their continuous support without which this conference would not be possible.

Finally, we thank all authors for their submissions and all invited speakers and conference attendants for making the ICCSA Conference truly one of the premium events on the scientific community scene, facilitating exchange of ideas, fostering new collaborations, and shaping the future of computational science.

May 2006

Marina L. Gavrilova
Osvaldo Gervasi

on behalf of the co-editors

Vipin Kumar
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Using UML Packages for Designing Secure Data Warehouses

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Abstract. Due to the sensitive data contained in Data Warehouses (DWs), it is essential to specify security measures from the early stages of the DWs design and enforce them. In this paper, we will present a UML profile to represent multidimensional and security aspects of our conceptual modeling. Our approach proposes the use of UML packages in order to group classes together into higher level units creating different levels of abstraction, and therefore, simplifying the final model. Furthermore, we present an extension of the relational model to consider security and audit measures represented in the conceptual modeling. To accomplish this, we based on the Relational Package of the Common Warehouse Metamodel (CWM) and extend it to properly represent all security and audit rules defined in the conceptual modeling of DWs. Finally, we will show an example to illustrate the applicability of our proposal.

1 Introduction

Organizations depend increasingly on information systems, which rely upon databases and data warehouses (DWs), which need increasingly more quality and security. Indeed, the very survival of organizations depends on the correct management, security and confidentiality of information [2]. In fact, as some authors have remarked [1, 4], information security is a serious requirement which must be carefully considered, not as an isolated aspect, but as an element which turns up as an issue in all stages of the development lifecycle, from the requirement analysis to implementation and maintenance. As other authors point out [6, 9], even though most

DWs are implemented into relational DBMS, security measures and access control models specified for transactional (relational) databases are not appropriate for DWs. The main reason is that the security measures for DWs must be defined on a multidimensional basis, since DW users query the DW in terms of facts, dimensions, classification hierarchy levels and so on.

In MD modeling, information is structured into facts and dimensions. A fact represents interesting measures of a business process (sales, deliveries, etc.), whereas a dimension considers the context for analyzing a fact (product, customer, time, etc.). A high number of dimensions with their corresponding hierarchies, and a considerable number of facts sharing dimensions and classification hierarchies will lead to a very complex design, thereby increasing the difficulty in reading the modeled system. Therefore, a secure MD conceptual model should also provide techniques to avoid flat diagrams to simplify the final model.

In this paper, we present a UML profile to represent MD and security aspects of our conceptual modeling. We propose the use of UML packages in order to group classes together into higher level units creating different levels of abstraction. Furthermore, we present an extension of the relational model, aligned with OMG, to consider security and audit measures represented in the conceptual modeling.

The remainder of this paper is structured as follows. In Section 2 we summarize the main related work. In Section 3 we present the Common Warehouse Metamodel (CWM) and the four-layer architecture of OMG. In Section 4 we present the UML 2.0 profile for secure multidimensional modeling. In Section 5 we present an extension of the relational metamodel of CWM. In Section 6 we state an example to support the conceptual design of secure data warehouses using packages. Finally, in Section 7, we draw some conclusions and sketch our immediate future work.

2 Related Work

In the past few years, several approaches have been proposed for representing the main multidimensional (MD) properties at the conceptual level [5, 11-13]. Nevertheless, none of these approaches for MD modeling, considers security to be an important issue in their conceptual models, so they do not solve the problems arising from this question in these kinds of systems. It is true that, in the relevant literature, we can find several initiatives for the inclusion of security in data warehouses [6, 9, 10]. However, none of them considers security aspects which incorporate all stages of the system development cycle, nor the introduction of security into MD design.

The previous work presented in [8] introduced a Model Driven Architecture (MDA) oriented framework for the DW development, choosing the ROLAP (Relational On-Line Analytical Processing) like DBMS and the Platform Specific Model (PSM) is modeled by using the relational metamodel from the CWM. However, none security and audit measures can be modeled in this metamodel.

To the best of our knowledge, only our previous works [3, 14] sets the basis for providing a conceptual model for the design of secure DWs. In this paper, our previous works are refined, adapting our UML profile for a secure multidimensional modeling to the proposal for the MD modeling with UML package diagrams [7].

3 CWM and the Four Layer Architecture of OMG

The standard OMG (Object Management Group) promotes the theory and practice of object-oriented technology in software development, based on the four-layer metamodel architecture. A model at one layer is used to specify models in the layer above. The four-layer architecture is shown in Table 1.

Table 1. The four-layer architecture of OMG

Meta-level	MOF Terms	Examples
M3	Meta-metamodel	The MOF model
M2	Metamodel, metadata	UML metamodel, CWM metamodel
M1	Model, metadata	UML models, CWM metadata
M0	Object, data	Modeled systems, data warehouse

The main purpose of the CWM is to enable easy interchange of warehouse and business intelligence metadata between warehouse tools, warehouse platforms and warehouse metadata repositories in distributed heterogeneous environments.

CWM is organized in 21 separate packages which they were grouped into five stackable layers by means of similar roles (see Fig. 1).

Management	Warehouse Process			Warehouse Operation		
Analysis	Transformation	OLAP	Data Mining	Information Visualization	Business Nomenclature	
Resource	Object	Relational	Record	Multidimensional		XML
Foundation	Business Information	Data Types	Expressions	Keys and Indexes	Software Deployment	Type Mapping
Object Model	Core		Behavioral	Relationships		Instance

Fig. 1. CWM metamodel layering and its packages

From the organization represented in Fig. 1, we will mainly focus our work (for a secure relational modeling of DWs) on the Resource layer and, more precisely, on the Relational package as a relational metamodel to describe that represent metadata of relational data resources.

4 A UML profile for Secure Multidimensional Modeling

The goal of this UML profile is to be able to design a MD conceptual model, but classifying information at the same time, in order to define which properties the user has to have in order to be entitled to gain access to information. We can define, for each element of the model (fact class, dimension class, fact attribute, etc.), its security information, specifying a sequence of security levels, a set of user compartments and a set of user roles. We can also specify security constraints considering these security attributes. Our profile will be called SECDW (Secure Data Warehouses) and will be represented as a UML package. This profile will not only inherit all properties from

the UML metamodel but it will also incorporate new data types, stereotypes, tagged values and constraints. In Fig. 2, a high-level view of our SECDW profile is provided.

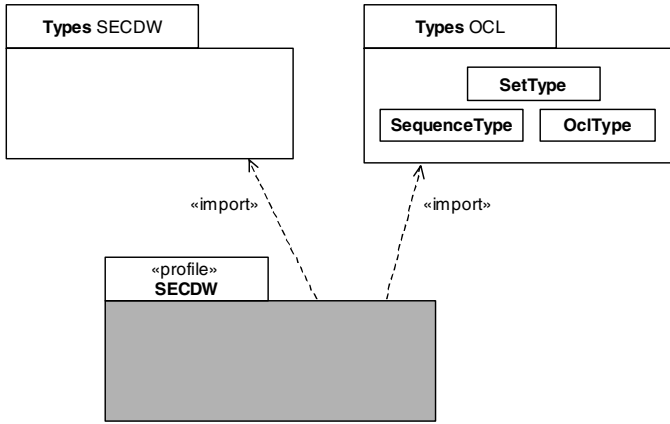


Fig. 2. High level view of our SECDW profile

We have defined a package that includes all the stereotypes that will be necessary in our profile (see Fig. 3).

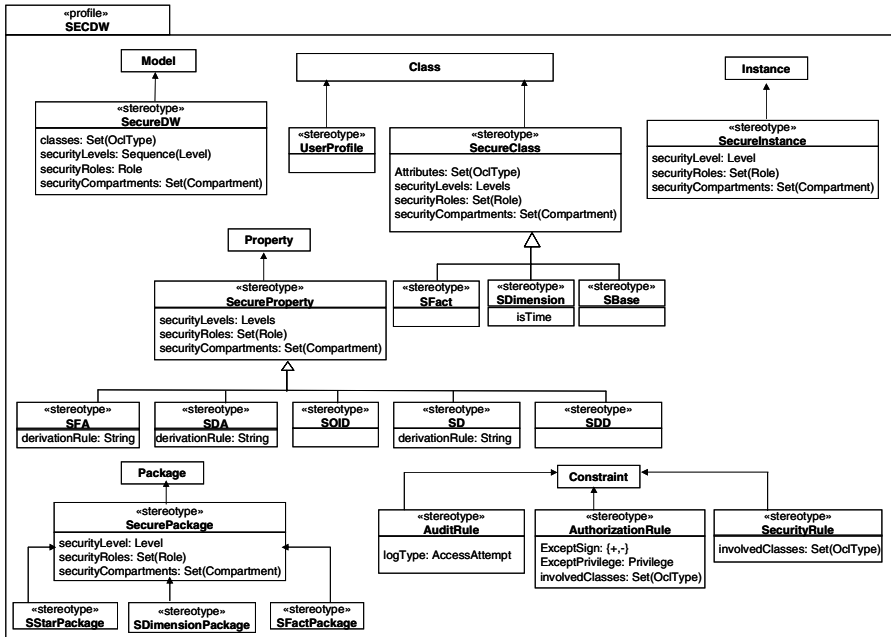


Fig. 3: New stereotypes

This profile contains four types of stereotypes:

- Secure Class, secure package and secure data warehouses stereotypes (and stereotypes inheriting information from them) that contain tagged values associated with attributes (model or class attributes), security levels, user roles and organizational compartments.
- Attribute stereotypes (and stereotypes inheriting information from attributes) and instances, which have tagged values associated with security levels, user roles and organizational compartments.
- Stereotypes that allow us to represent security constraints, authorization rules and audit rules.
- UserProfile stereotype, which is necessary to specify constraints depending on particular information of a user or a group of users.

4.1 Using UML Packages for Secure Multidimensional Modeling

In our approach, the main structural properties of MD models are specified by means of a UML class diagram in which the information is clearly separated into facts and dimensions. Our approach proposes the use of UML packages in order to group classes together into higher level units creating different levels of abstraction, and therefore, simplifying the final model.

The different levels show how one package can be further exploded by defining its corresponding elements into the next level as we describe as follows (see Fig. 4):

- **Level 1:** Model definition. A package represents a star schema of a conceptual MD model.
- **Level 2:** Star schema definition. A package represents a fact or a dimension of a star schema.
- **Level 3:** Dimension/fact definition. A package is exploded into a set of classes that represent the hierarchy levels defined in a dimension package, or the whole star schema in the case of the fact package.

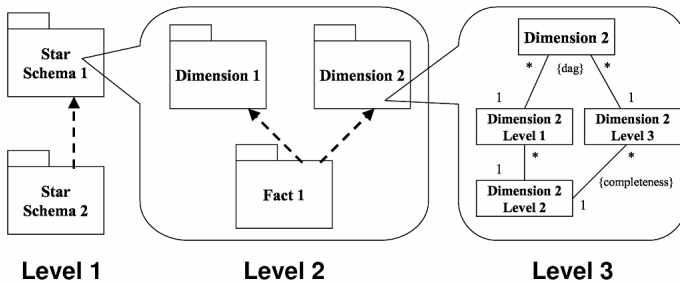


Fig. 4. Levels of a MD model explosion using packages

Next, we will present the metamodel of our OO conceptual MD approach using a UML class diagram. In order to simplify this diagram, we have divided it into three levels. In Fig. 5, the content of metamodel level1 package is shown. This

package specifies the modeling elements that can be applied at the metamodel level 1 of our approach. At this level, only the StarPackage model element is allowed.

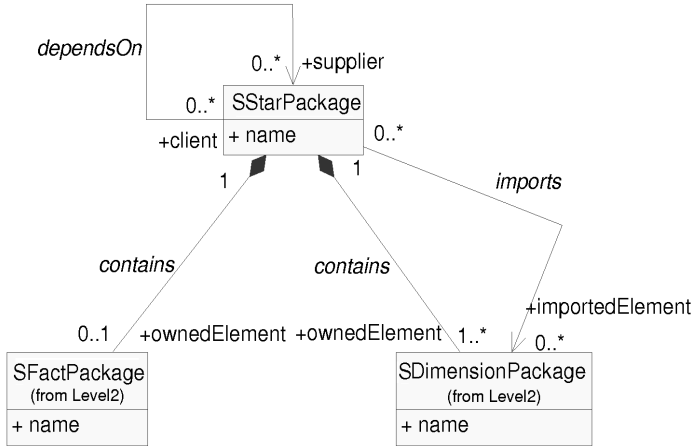


Fig. 5. Metamodel: level 1

In Fig. 6, we will show the content of metamodel level2 package.

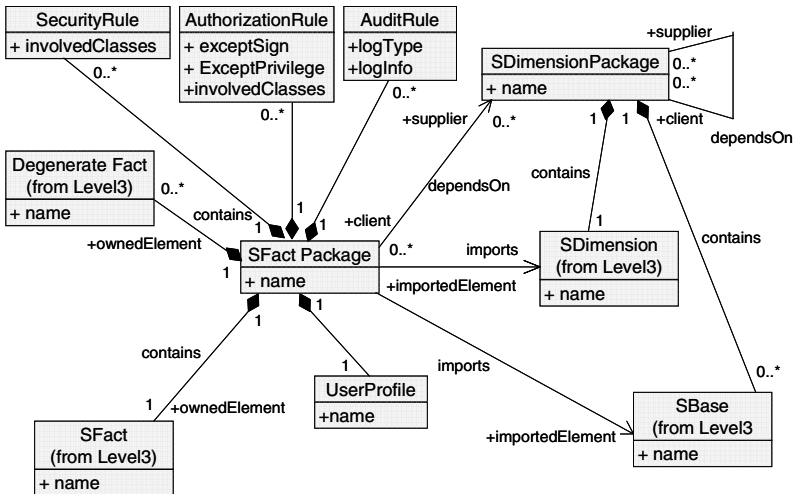


Fig. 6. Metamodel: level 2

The stereotypes SecurityRule, AuthorizationRule, and AuditRule can have the following information:

- SecurityRule (sensitivity information associated).
- AuthorizationRule (information to permit or deny access).
- AuditRule (information to analyze the user behaviour when using the system).

Finally, in Fig. 7, we will show the content of the metamodel level3 package. This diagram represents the main MD properties of our modeling approach.

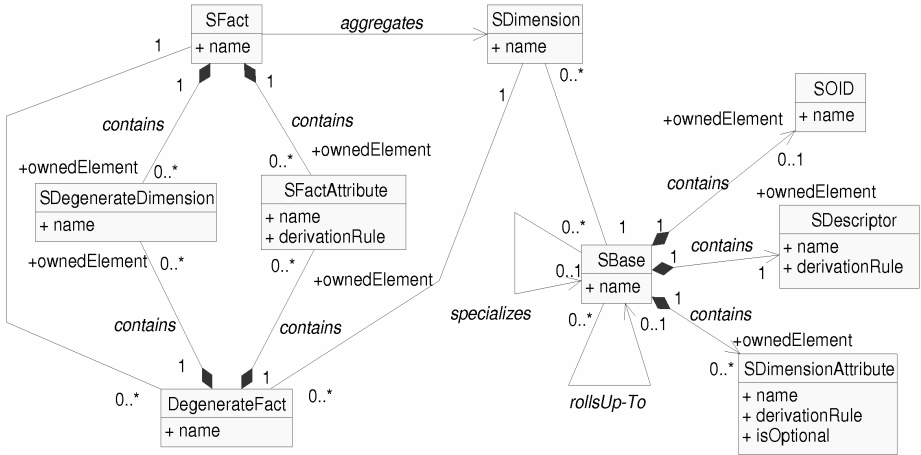


Fig. 7. Metamodel: level 3

5 Secure Multidimensional Modeling at the Logical Level

In this section we outline the relational metamodel of CWM. We only use part of the relational CWM metamodel for our purposes; which allow us to represent tables, columns, primary keys and foreign keys. However, for representing security and audit measures in the metamodel, we need to add some metaclasses. In Fig. 8 we show part of the relational CWM metamodel extended.

The Schema metaclass aim the security at the model level. SecurityProperty metaclass inherit from the Constraint metaclass and specializes as SecurityLevels, SecurityCompartments and SecurityRoles metaclasses. Furthermore, for representing security constraints, authorization rules and audit rules in the metamodel we add AUDconstraint class, ARconstraint class and AURconstraint class, which inherit from SecurityConstraint. For specify constraints depending on particular information of a user or a group of users, we introduce the userProfile metaclass. Finally, we need add associations of Table and Column metaclasses with the metaclasses introduced in order to establish security in attributes and tables. For express the constraints (AuditRule, AuthorizationRule and SecurityRule) modeled in SECDW metamodel using notes, we need to add a new attribute OCLConstraint in the SecurityConstraint metaclass.

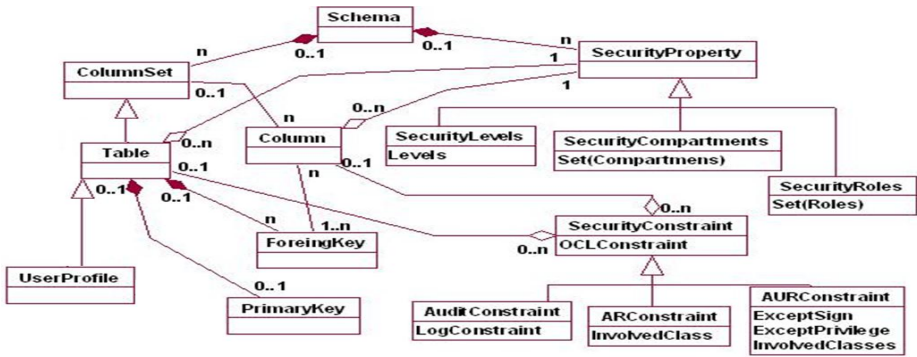


Fig. 8. Secure Relational Modeling for Data Warehouses

6 An Example of Secure Multidimensional Modeling Using Packages

In this section, we will apply our UML 2.0 extension for the conceptual design of a secure MD model in the context of a normal Health system. To do so, we will base on the new stereotypes and tagged-values stated in Fig. 3.

This example refers to a data warehouse in the area of Health, from which we have selected three data marts such as Hospital, Admission and Services. They are separated because they are used by different end users. In Fig 9 (a), we can see the three StarPackages representing the different data marts that form DW.

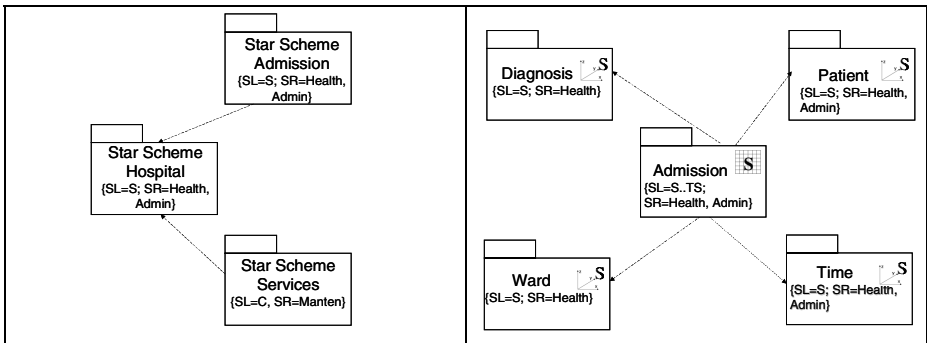


Fig. 9 (a). Level 1: Model Definition

Fig. 9 (b). Level 2: Star schema Admission Definition

We have selected the Admission Star package to study its content in a detailed way. This package has the purpose of containing each one of the admissions of patients in one or more hospitals. For instance, Fig. 9 (b) presents at the center the package representing the Admission SFact Class and at the borders packages

corresponding to each one of the secure packages that will be later represented at the following level through dimensions and hierarchy levels.

In Fig. 10, we present a detailed vision of SFactPackage Admission. In this case, as it corresponds to a secure fact package, it is shown the star schema complete. If we had chosen a dimension, it will be only detailed the modeling (including security aspects) of the dimension with its hierarchy levels. In this figure, we can see the stereotypes for the Admission Fact Class, Diagnosis and Patient Dimensions and the classification hierarchies (or Base Class) corresponding to each dimension. The tagged values are represented as static security constraints at the class or attribute level. For example, we can see that the Admission Sfact class has the security levels from Secret to TopSecret and the user roles Health and Admin. At the attribute level, there is a cost static security rule that indicates that it can only be accessed by users having the admin. role. In addition, a series of UML notes can be seen, where dynamic security constraints (that depend on a condition), authorization rules for exceptions and audit rules are represented.

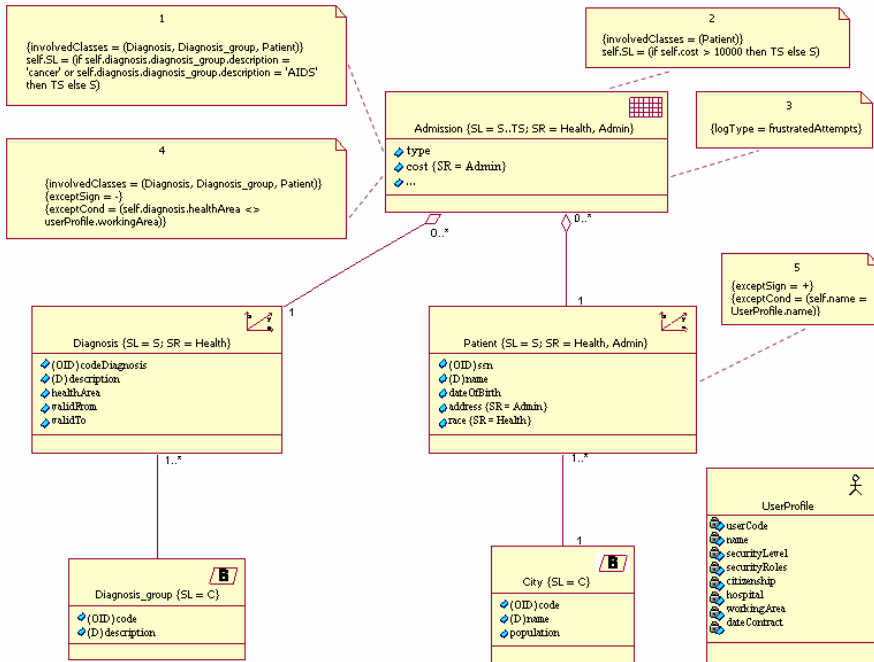


Fig. 10. Level 3: Content of SFactPackage Admission

7 Conclusions and Future Work

In this paper, we have presented a UML 2.0 profile for secure multidimensional modeling that extends previous works. To do so, we have used UML packages to represent our stereotypes, tagged values, and OCL constraints in our modeling.

Furthermore, we have presented an extension of the relational metamodel of the CWM in order to represent security and audit measures in the logical modeling of data warehouses.

Our immediate future work consists on the formal specification of all the required transformations between the conceptual and the logical models by using the Query-View-Transformation (QVT), thereby aligning our approach with the Model Driven Architecture. In this way, we will be able to specify all transformations in a formal language, thereby avoiding an arbitrary definition of these rules.

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