Lecture Notes in Computer Science

The LNCS series reports state-of-the-art results in computer science research, development, and education, at a high level and in both printed and electronic form. Enjoying tight cooperation with the R&D community, with numerous individuals, as well as with prestigious organizations and societies, LNCS has grown into the most comprehensive computer science research forum available.

The scope of LNCS, including its subseries LNAI and LNBI, spans the whole range of computer science and information technology including interdisciplinary topics in a variety of application fields. The type of material published traditionally includes

- proceedings (published in time for the respective conference)
- post-proceedings (consisting of thoroughly revised final full papers)
- research monographs (which may be based on outstanding PhD work, research projects, technical reports, etc.)

More recently, several color-cover sublines have been added featuring, beyond a collection of papers, various added-value components; these sublines include

- tutorials (textbook-like monographs or collections of lectures given at advanced courses)
- state-of-the-art surveys (offering complete and mediated coverage of a topic)
- hot topics (introducing emergent topics to the broader community)

In parallel to the printed book, each new volume is published electronically in LNCS Online.

Detailed information on LNCS can be found at
www.springer.com/lncs

Proposals for publication should be sent to
LNCS Editorial, Tiergartenstr. 17, 69121 Heidelberg, Germany
E-mail: lncs@springer.com

ISSN 0302-9743

Lecture Notes in Computer Science
LNCS LNAI LNBI

springer.com

Gavrilova et al. (Eds.)

LNCS 3982

ICCSA 2006

Marina Gavrilova et al. (Eds.)

Computational Science and Its Applications – ICCSA 2006

International Conference
Glasgow, UK, May 2006
Proceedings, Part III

3 Part III

Springer

Lecture Notes in Computer Science 3982

Commenced Publication in 1973
Founding and Former Series Editors:
Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

Marina Gavrilova Osvaldo Gervasi
Vipin Kumar C.J. Kenneth Tan
David Taniar Antonio Laganà
Youngsong Mun Hyunseung Choo (Eds.)

Computational Science and Its Applications – ICCSA 2006

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

Springer

Volume Editors

Marina Gavrilova
University of Calgary, Canada
E-mail: marina@cpsc.ucalgary.ca

Osvaldo Gervasi
University of Perugia, Italy
E-mail: ogervasi@computer.org

Vipin Kumar
University of Minnesota, Minneapolis, USA
E-mail: kumar@cs.umn.edu

C.J. Kenneth Tan
OptimaNumerics Ltd., Belfast, UK
E-mail: cjtan@optimanumerics.com

David Taniar
Monash University, Clayton, Autralia
E-mail: david.taniar@infotech.monash.edu.au

Antonio Laganà
University of Perugia, Italy
E-mail: lag@unipg.it

Youngsong Mun
SoongSil University, Seoul, Korea
E-mail: mun@computing.soongsil.ac.kr

Hyunseung Choo
Sungkyunkwan University, Suwon, Korea
E-mail: choo@ece.skku.ac.kr

Library of Congress Control Number: 2006925086

CR Subject Classification (1998): F, D, G, H, I, J, C.2-3

LNCS Sublibrary: SL 1 – Theoretical Computer Science and General Issues

ISSN 0302-9743
ISBN-10 3-540-34075-0 Springer Berlin Heidelberg New York
ISBN-13 978-3-540-34075-1 Springer Berlin Heidelberg New York

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India
Printed on acid-free paper SPIN: 11751595 06/3142 5 4 3 2 1 0

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 shear 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
Chih Jeng Kenneth Tan
David Taniar
Antonio Laganà
Youngsong Mun
Hyunseung Choo

Organization

ICCSA 2006 was organized by the Institute of Electrical Engineers (IEE)(UK), the University of Perugia (Italy), Calgary University (Canada) and Minnesota University (USA).

Conference Chairs

Vipin Kumar (University of Minnesota, Minneapolis, USA), Honorary Chair
Marina L. Gavrilova (University of Calgary, Calgary, Canada), Conference Co-chair, Scientific
Osvaldo Gervasi (University of Perugia, Perugia, Italy), Conference Co-chair, Program

Steering Committee

Vipin Kumar (University of Minnesota, USA)
Marina L. Gavrilova (University of Calgary, Canada)
Osvaldo Gervasi (University of Perugia, Perugia, Italy)
C. J. Kenneth Tan (OptimaNumerics, UK)
Alexander V. Bogdanov (Institute for High Performance Computing and Data Bases, Russia)
Hyunseung Choo (Sungkyunkwan University, Korea)
Andres Iglesias (University of Cantabria, Spain)
Antonio Laganà (University of Perugia, Italy)
Heow-Pueh Lee (Institute of High Performance Computing, Singapore)
Youngsong Mun (Soongsil University, Korea)
David Taniar (Monash University, Australia)

Workshop Organizers

Applied Cryptography and Information Security (ACIS 2006)

Sherman S.M. Chow (New York University, USA)
Joseph K. Liu (University of Bristol, UK)
Patrick Tsang (Dartmouth College, USA)
Duncan S Wong (City University of Hong Kong, Hong Kong)

Approaches or Methods of Security Engineering (AMSE 2006)

Haeng Kon Kim (Catholic University of Daegu, Korea)
Tai-hoon Kim (Korea Information Security Agency, Korea)

Authentication, Authorization and Accounting (AAA 2006)
Haeng Kon Kim (Catholic University of Daegu, Korea)

Computational Geometry and Applications (CGA 2006)
Marina Gavrilova (University of Calgary, Calgary, Canada)

Data Storage Devices and Systems (DSDS 2006)
Yeonseung Ryu (Myongji University, Korea)
Junho Shim (Sookmyong Womens University, Korea)
Youjip Won (Hanyang University, Korea)
Yongik Eom (Seongkyunkwan University, Korea)

Embedded System for Ubiquitous Computing (ESUC 2006)
Tei-Wei Kuo (National Taiwan University, Taiwan)
Jiman Hong (Kwangwoon University, Korea)

4th Technical Session on Computer Graphics (TSCG 2006)
Andres Iglesias (University of Cantabria, Spain)
Deok-Soo Kim (Hanyang University, Korea)

GeoComputation (GC 2006)
Yong Xue (London Metropolitan University, UK)

Image Processing and Computer Vision (IPCV 2006)
Jiawan Zhang (Tianjin University, China)

Intelligent Services and the Synchronization in Mobile Multimedia Networks (ISS 2006)
Dong Chun Lee (Howon University, Korea)
Kuinam J Kim (Kyonggi University, Korea)

Integrated Analysis and Intelligent Design Technology (IAIDT 2006)
Jae-Woo Lee (Konkuk University, Korea)

Information Systems Information Technologies (ISIT 2006)
Youngsong Mun (Soongsil University, Korea)

Information Engineering and Applications in Ubiquitous Computing Environments (IEAUCE 2006)
Sangkyun Kim (Yonsei University, Korea)
Hong Joo Lee (Dankook University, Korea)

Internet Communications Security (WICS 2006)
Sierra-Camara Josè Maria (University Carlos III of Madrid, Spain)

Mobile Communications (MC 2006)
Hyunseung Choo (Sungkyunkwan University, Korea)

Modelling Complex Systems (MCS 2006)
John Burns (Dublin University, Ireland)
Ruili Wang (Massey University, New Zealand)

Modelling of Location Management in Mobile Information Systems (MLM 2006)
Dong Chun Lee (Howon University, Korea)

Numerical Integration and Applications (NIA 2006)
Elise de Doncker (Western Michigan University, USA)

Specific Aspects of Computational Physics and Wavelet Analysis for Modelling Suddenly-Emerging Phenomena in Nonlinear Physics, and Nonlinear Applied Mathematics (PULSES 2006)
Carlo Cattani (University of Salerno, Italy)
Cristian Toma (Titu Maiorescu University, Romania)

Structures and Molecular Processes (SMP 2006)
Antonio Laganà (University of Perugia, Perugia, Italy)

Optimization: Theories and Applications (OTA 2006)
Dong-Ho Lee (Hanyang University, Korea)
Deok-Soo Kim (Hanyang University, Korea)
Ertugrul Karsak (Galatasaray University, Turkey)

Parallel and Distributed Computing (PDC 2006)
Jiawan Zhang (Tianjin University, China)

Pattern Recognition and Ubiquitous Computing (PRUC 2006)
Jinok Kim (Daegu Haany University, Korea)

Security Issues on Grid/Distributed Computing Systems (SIGDCS 2006)
Tai-Hoon Kim (Korea Information Security Agency, Korea)

Technologies and Techniques for Distributed Data Mining (TTDDM 2006)
Mark Baker (Portsmouth University, UK)
Bob Nichol (Portsmouth University, UK)

Ubiquitous Web Systems and Intelligence (UWSI 2006)
David Taniar (Monash University, Australia)
Eric Pardede (La Trobe University, Australia)

Ubiquitous Application and Security Service (UASS 2006)
Yeong-Deok Kim (Woosong University, Korea)

Visual Computing and Multimedia (VCM 2006)
Abel J. P. Gomes (University Beira Interior, Portugal)

Virtual Reality in Scientific Applications and Learning (VRSAL 2006)
Osvaldo Gervasi (University of Perugia, Italy)
Antonio Riganelli (University of Perugia, Italy)

Web-Based Learning (WBL 2006)
Woochun Jun Seoul (National University of Education, Korea)

Program Committee

Jemal Abawajy (Deakin University, Australia)
Kenny Adamson (EZ-DSP, UK)
Srinivas Aluru (Iowa State University, USA)
Mir Atiqullah (Saint Louis University, USA)
Frank Baetke (Hewlett Packard, USA)
Mark Baker (Portsmouth University, UK)
Young-Cheol Bang (Korea Polytechnic University, Korea)
David Bell (Queen's University of Belfast, UK)
Stefania Bertazzon (University of Calgary, Canada)
Sergei Bespamyatnikh (Duke University, USA)
J. A. Rod Blais (University of Calgary, Canada)
Alexander V. Bogdanov (Institute for High Performance Computing and Data Bases, Russia)
Peter Brezany (University of Vienna, Austria)
Herve Bronnimann (Polytechnic University, NY, USA)
John Brooke (University of Manchester, UK)
Martin Buecker (Aachen University, Germany)
Rajkumar Buyya (University of Melbourne, Australia)
Jose Sierra-Camara (University Carlos III of Madrid, Spain)
Shyi-Ming Chen (National Taiwan University of Science and Technology, Taiwan)
YoungSik Choi (University of Missouri, USA)
Hyunseung Choo (Sungkyunkwan University, Korea)
Bastien Chopard (University of Geneva, Switzerland)
Min Young Chung (Sungkyunkwan University, Korea)
Yiannis Cotronis (University of Athens, Greece)
Danny Crookes (Queen's University of Belfast, UK)
Jose C. Cunha (New University of Lisbon, Portugal)
Brian J. d'Auriol (University of Texas at El Paso, USA)
Alexander Degtyarev (Institute for High Performance Computing and Data Bases, Russia)
Frederic Desprez (INRIA, France)
Tom Dhaene (University of Antwerp, Belgium)
Beniamino Di Martino (Second University of Naples, Italy)
Hassan Diab (American University of Beirut, Lebanon)
Ivan Dimov (Bulgarian Academy of Sciences, Bulgaria)
Iain Duff (Rutherford Appleton Laboratory, UK and CERFACS, France)
Thom Dunning (NCSA and University of Illinois, USA)
Fabrizio Gagliardi (Microsoft, USA)
Marina L. Gavrilova (University of Calgary, Canada)
Michael Gerndt (Technical University of Munich, Germany)
Osvaldo Gervasi (University of Perugia, Italy)
Bob Gingold (Australian National University, Australia)
James Glimm (SUNY Stony Brook, USA)

Christopher Gold (Hong Kong Polytechnic University, Hong Kong)
Yuriy Gorbachev (Institute of High Performance Computing and Information Systems, Russia)
Andrzej Goscinski (Deakin University, Australia)
Jin Hai (Huazhong University of Science and Technology, China)
Ladislav Hluchy (Slovak Academy of Science, Slovakia)
Xiaohua Hu (Drexel University, USA)
Eui-Nam John Huh (Seoul Women's University, Korea)
Shen Hong (Japan Advanced Institute of Science and Technology, Japan)
Paul Hovland (Argonne National Laboratory, USA)
Andres Iglesias (University of Cantabria, Spain)
Peter K. Jimack (University of Leeds, UK)
In-Jae Jeong (Hanyang University, Korea)
Chris Johnson (University of Utah, USA)
Benjoe A. Juliano (California State University at Chico, USA)
Peter Kacsuk (MTA SZTAKI Researc Institute, Hungary)
Kyung Wo Kang (KAIST, Korea)
Carl Kesselman (USC/ Information Sciences Institute, USA)
Daniel Kidger (Quadrics , UK)
Haeng Kon Kim (Catholic University of Daegu, Korea)
Jin Suk Kim (KAIST, Korea)
Tai-Hoon Kim (Korea Information Security Agency, Korea)
Yoonhee Kim (Syracuse University, USA)
Mike Kirby (University of Utah, USA)
Dieter Kranzlmueller (Johannes Kepler University Linz, Austria)
Deok-Soo Kim (Hanyang University, Korea)
Vipin Kumar (University of Minnesota, USA)
Domenico Laforenza (Italian National Research Council, Italy)
Antonio Laganà (University of Perugia, Italy)
Joseph Landman (Scalable Informatics LLC, USA)
Francis Lau (The University of Hong Kong, Hong Kong)
Bong Hwan Lee (Texas A&M University, USA)
Dong Chun Lee (Howon University, Korea)
Dong-Ho Lee (Institute of High Performance Computing, Singapore)
Sang Yoon Lee (Georgia Institute of Technology, USA)
Tae-Jin Lee (Sungkyunkwan University, Korea)
Bogdan Lesyng (ICM Warszawa, Poland)
Zhongze Li (Chinese Academy of Sciences, China)
Laurence Liew (Scalable Systems Pte, Singapore)
David Lombard (Intel Corporation, USA)
Emilio Luque (University Autonoma of Barcelona, Spain)
Michael Mascagni (Florida State University, USA)
Graham Megson (University of Reading, UK)
John G. Michopoulos (US Naval Research Laboratory, USA)
Edward Moreno (Euripides Foundation of Marilia, Brazil)

Youngsong Mun (Soongsil University, Korea)
Jiri Nedoma (Academy of Sciences of the Czech Republic, Czech Republic)
Genri Norman (Russian Academy of Sciences, Russia)
Stephan Olariu (Old Dominion University, USA)
Salvatore Orlando (University of Venice, Italy)
Robert Panoff (Shodor Education Foundation, USA)
Marcin Paprzycki (Oklahoma State University, USA)
Gyung-Leen Park (University of Texas, USA)
Ron Perrott (Queen's University of Belfast, UK)
Dimitri Plemenos (University of Limoges, France)
Richard Ramaroson (ONERA, France)
Rosemary Renaut (Arizona State University, USA)
Reneé S. Renner (California State University at Chico, USA)
Paul Roe (Queensland University of Technology, Australia)
Alexey S. Rodionov (Russian Academy of Sciences, Russia)
Heather J. Ruskin (Dublin City University, Ireland)
Ole Saastad (Scali, Norway)
Muhammad Sarfraz (King Fahd University of Petroleum and Minerals, Saudi Arabia)
Edward Seidel (Louisiana State University, USA and Albert-Einstein-Institut, Potsdam, Germany)
Jie Shen (University of Michigan, USA)
Dale Shires (US Army Research Laboratory, USA)
Vaclav Skala (University of West Bohemia, Czech Republic)
Burton Smith (Cray, USA)
Masha Sosonkina (Ames Laboratory, USA)
Alexei Sourin (Nanyang Technological University, Singapore)
Elena Stankova (Institute for High Performance Computing and Data Bases, Russia)
Gunther Stuer (University of Antwerp, Belgium)
Kokichi Sugihara (University of Tokyo, Japan)
Boleslaw Szymanski (Rensselaer Polytechnic Institute, USA)
Ryszard Tadeusiewicz (AGH University of Science and Technology, Poland)
C.J. Kenneth Tan (OptimaNumerics, UK and Queen's University of Belfast, UK)
David Taniar (Monash University, Australia)
John Taylor (Streamline Computing, UK)
Ruppa K. Thulasiram (University of Manitoba, Canada)
Pavel Tvrdik (Czech Technical University, Czech Republic)
Putchong Uthayopas (Kasetsart University, Thailand)
Mario Valle (Swiss National Supercomputing Centre, Switzerland)
Marco Vanneschi (University of Pisa, Italy)
Piero Giorgio Verdini (University of Pisa and Istituto Nazionale di Fisica Nucleare, Italy)
Jesus Vigo-Aguiar (University of Salamanca, Spain)

Jens Volkert (University of Linz, Austria)
Koichi Wada (University of Tsukuba, Japan)
Stephen Wismath (University of Lethbridge, Canada)
Kevin Wadleigh (Hewlett Packard, USA)
Jerzy Wasniewski (Technical University of Denmark, Denmark)
Paul Watson (University of Newcastle Upon Tyne, UK)
Jan Weglarz (Poznan University of Technology, Poland)
Tim Wilkens (Advanced Micro Devices, USA)
Roman Wyrzykowski (Technical University of Czestochowa, Poland)
Jinchao Xu (Pennsylvania State University, USA)
Chee Yap (New York University, USA)
Osman Yasar (SUNY at Brockport, USA)
George Yee (National Research Council and Carleton University, Canada)
Yong Xue (Chinese Academy of Sciences, China)
Igor Zacharov (SGI Europe, Switzerland)
Xiaodong Zhang (College of William and Mary, USA)
Aledander Zhmakin (SoftImpact, Russia)
Krzysztof Zielinski (ICS UST / CYFRONET, Poland)
Albert Zomaya (University of Sydney, Australia)

Sponsoring Organizations

Institute of Electrical Engineers (IEE), UK
University of Perugia, Italy
University of Calgary, Canada
University of Minnesota, USA
Queen's University of Belfast, UK
The European Research Consortium for Informatics and Mathematics (ERCIM)
The 6th European Framework Project "Distributed European Infrastructure for Supercomputing Applications" (DEISA)
OptimaNumerics, UK
INTEL
AMD

Table of Contents – Part III

Workshop on Approaches or Methods of Security Engineering (AMSE 2006, Sess. A)

General Tracks

Using UML Packages for Designing Secure Data Warehouses

Rodolfo Villarroel[1], Emilio Soler[2], Eduardo Fernández-Medina[3], Juan Trujillo[4], and Mario Piattini[3]

[1] Departamento de Computación e Informática. Catholic University of Maule,
Avenida San Miguel 3605 Talca, Chile
rvillarr@spock.ucm.cl
[2] Departamento de Informática. University of Matanzas,
Autopista de Varadero Km. 3. Matanzas, Cuba
emilio.soler@umcc.cu
[3] Alarcos Research Group. Information Systems and Technologies Department,
UCLM-Soluziona Research and Development Institute,
University of Castilla-La Mancha
Paseo de la Universidad, 4 - 13071 Ciudad Real, Spain
{Eduardo.FdezMedina, Mario.Piattini}@uclm.es
[4] Departamento de Lenguajes y Sistemas Informáticos. University of Alicante,
C/San Vicente S/N 03690 Alicante, Spain
jtrujillo@dlsi.ua.es

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

M. Gavrilova et al. (Eds.): ICCSA 2006, LNCS 3982, pp. 1024 – 1034, 2006.

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 kinowledge, 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).

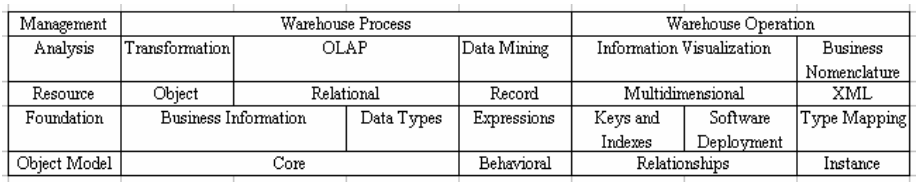

Fig. 1. CWM metamodel layering and its packages

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.

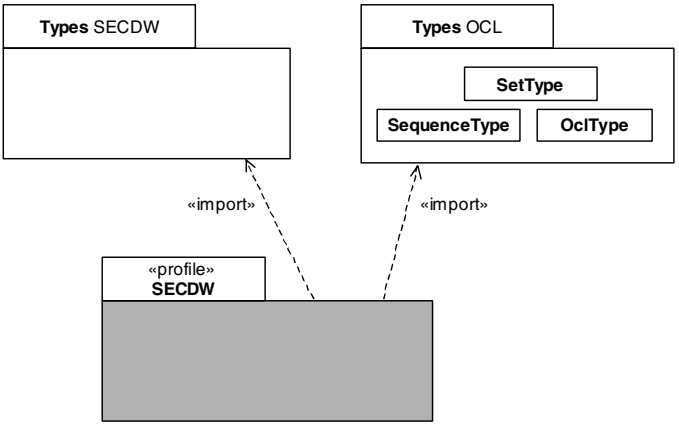

Fig. 2. High level view of our SECDW profile

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

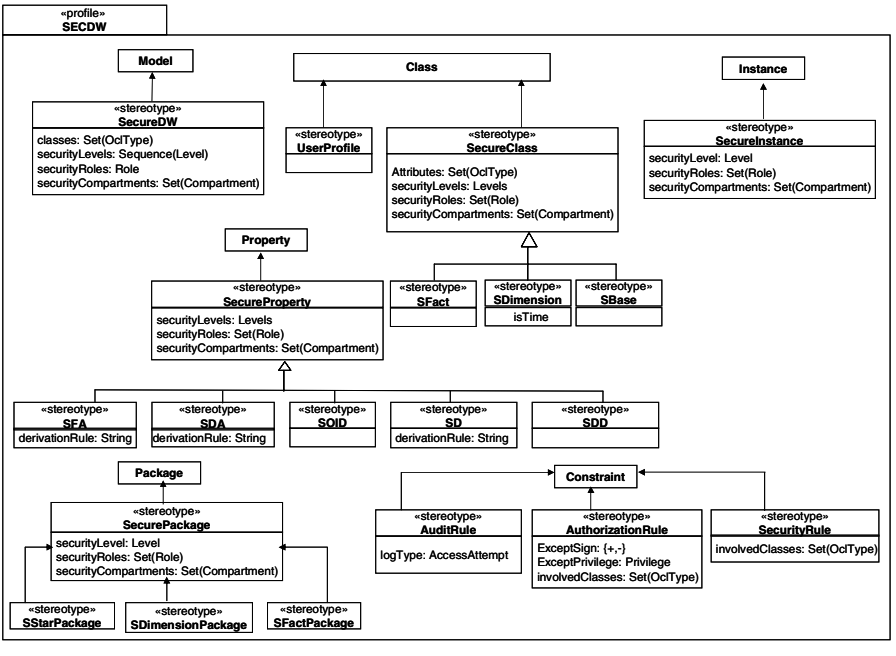

Fig. 3: New stereotypes

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.

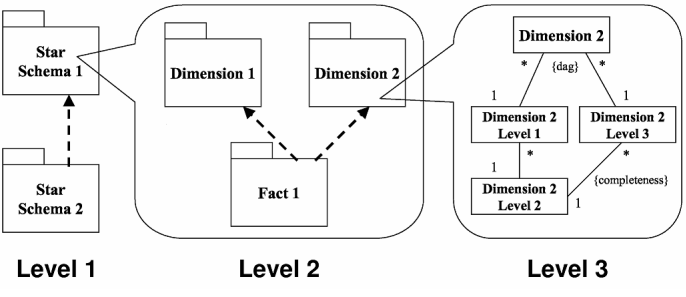

Fig. 4. Levels of a MD model explosion using packages

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.

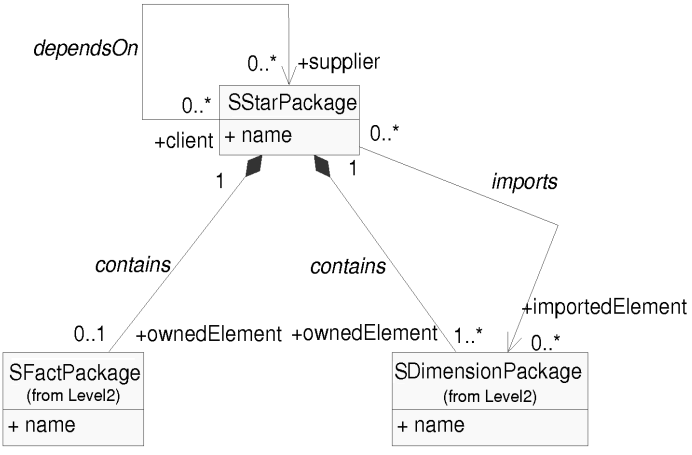

Fig. 5. Metamodel: level 1

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

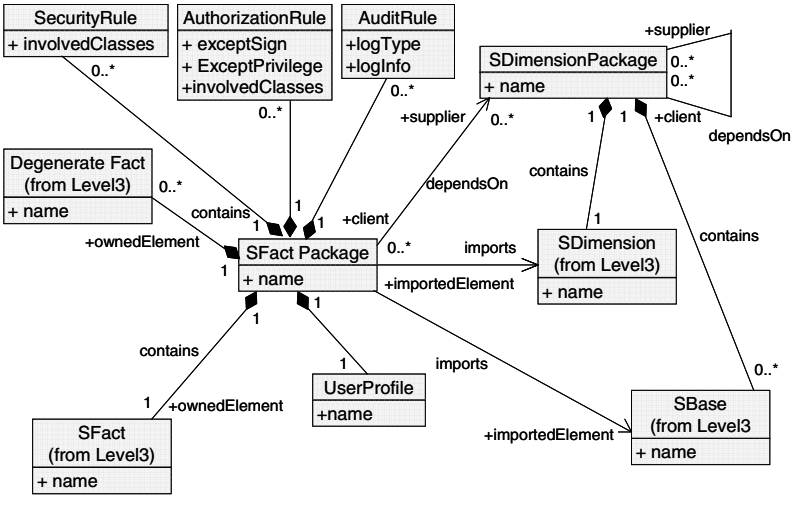

Fig. 6. Metamodel: level 2

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.

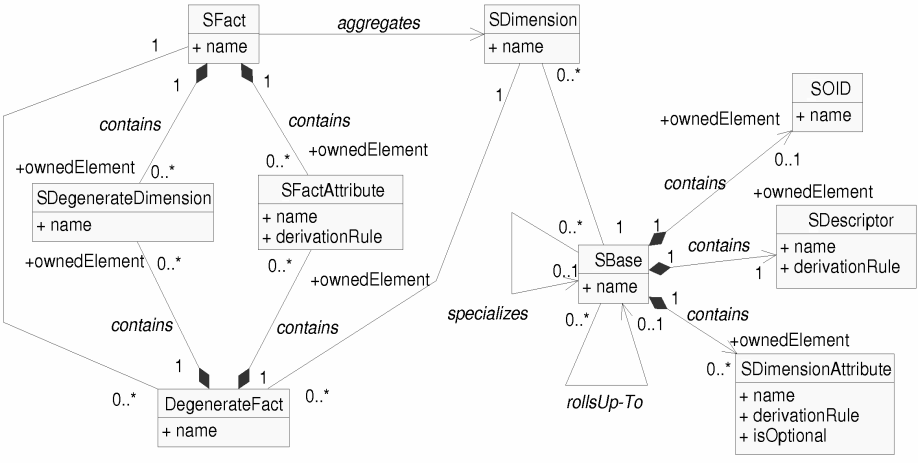

Fig. 7. Metamodel: level 3

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.

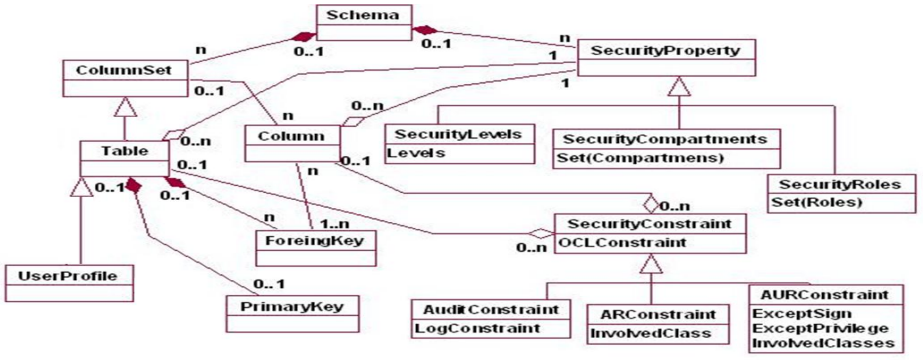

Fig. 8. Secure Relational Modeling for Data Warehouses

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.

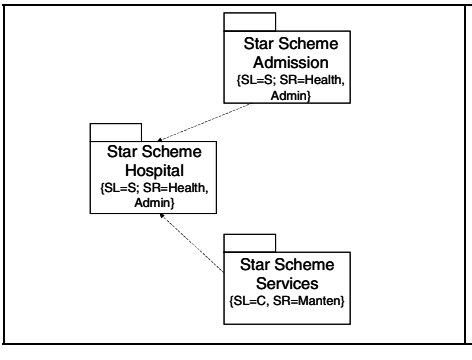

Fig. 9 (a). Level 1: Model Definition

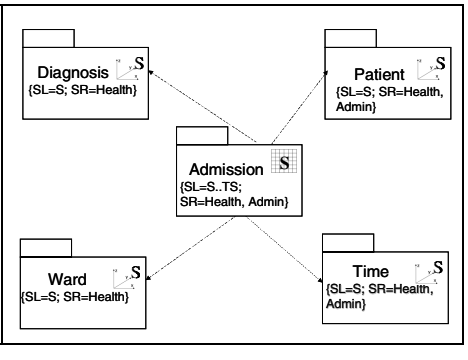

Fig. 9 (b). Level 2: Star schema Admission Definition

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.

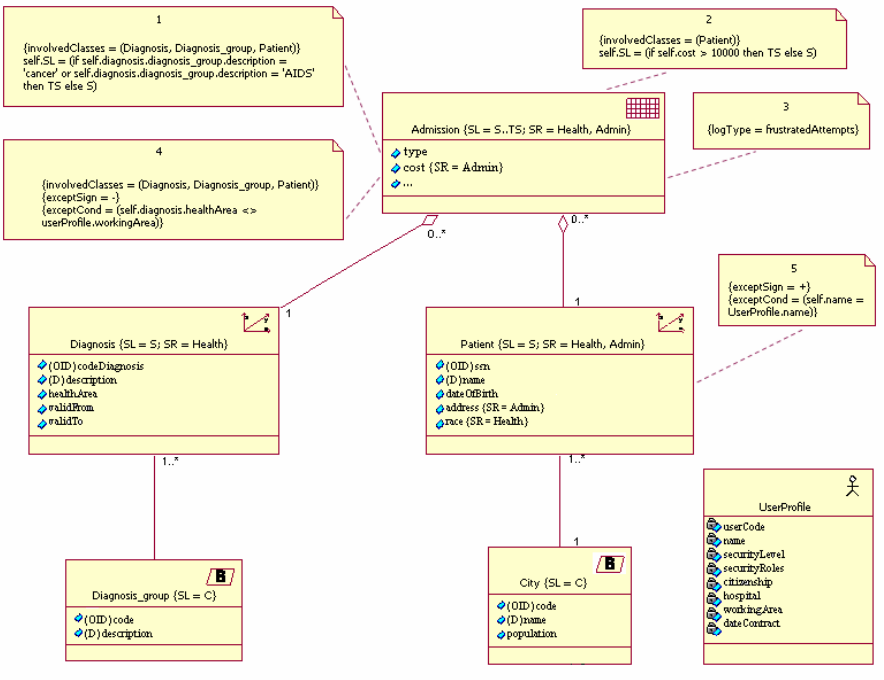

Fig. 10. Level 3: Content of SFactPackage Admission

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 inmediate 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.

Acknowledgements

This research is part of the RETISTIC (TIC2002-12487-E) and METASIGN (TIN2004-00799) projects from the Spanish Ministry of Education and Science, the MESSSENGER (PCC-03-003-1) and DIMENSIONS (PBC-05-012-2) projects from the Regional Science and Technology Ministry of Castilla-La Mancha, the DADASMECA project (GV05/220) from the Regional Government of Valencia, and the COMPETISOFT project (506PI0297) financed by CYTED.

References

1. Devanbu, P. and Stubblebine, S.: *Software engineering for security: a roadmap*. in *Proceedings of the Conference on The Future of Software Engineering*. Ireland (2000)
2. Dhillon, G. and Backhouse, J.: *Information system security management in the new millennium.* Communications of the ACM (2000) **43**(7):125-128
3. Fernández-Medina, E., Trujillo, J., Villarroel, R., and Piattini, M.: *Extending the UML for Designing Secure Data Warehouses*. in *Int. Conference on Conceptual Modeling (ER 2004)*. Shanghai, China: Springer-Verlag. LNCS 3288 (2004)
4. Ferrari, E. and Thuraisingham, B.: *Secure Database Systems*, in *Advanced Databases: Technology Design*, Piattini, M. and Díaz, O., Editors, Artech House: London (2000)
5. Golfarelli, M., Maio, D., and Rizzi, S., *The Dimensional Fact Model: A Conceptual Model for Data Warehouses.* Int. Journal of Cooperative Information Systems (IJCIS), (1998) **7.**(2-3): 215-247.
6. Katic, N., Quirchmayr, G., Schiefer, J., Stolba, M., and Min Tjoa, A.: *A Prototype Model for Data Warehouse Security Based on Metadata*. in *9th Int. Workshop on Database and Expert Systems Applications (DEXA'98).*Vienna. IEEE Computer Society (1998)
7. Luján-Mora, S., Trujillo, J., and Song, I.Y.: *Multidimensional Modeling with UML Package Diagrams*. in *Int. Conference on Conceptual Modeling - ER 2002*.Tampere, Finland: Springer. LNCS 2503 (2002)
8. Mazon, J., Trujillo, J., Serrano, M., and Piattini, M. Applying MDA to the development of data warehouses. in 8th ACM Int. Workshop on Data Warehousing and OLAP (DOLAP'05). Bremen, Germany (2005) 57-66
9. Priebe, T. and Pernul, G.: *Towards OLAP Security Design - Survey and Research Issues.* in *3rd ACM Int. Workshop on Data Warehousing and OLAP (DOLAP'00)*. USA (2000)
10. Rosenthal, A. and Sciore, E.: *View Security as the Basic for Data Warehouse Security*. in *2nd Int. Workshop on Design and Management of Data Warehouses (DMDW'00)*. Sweden (2000)

11. Sapia, C., Blaschka, M., Höfling, G., and Dinter, B.: *Extending the E/R Model for the Multidimensional Paradigm*. in *1st Int. Workshop on Data Warehouse and Data Mining (DWDM'98)*. Singapore: Springer-Verlag LNCS 1552 (1998)
12. Trujillo, J., Palomar, M., Gómez, J., and Song, I.Y., *Designing Data Warehouses with OO Conceptual Models.* IEEE Computer, special issue on Data Warehouses, 2001(34): 66-75.
13. Tryfona, N., Busborg, F., and Christiansen, J.: *starER: A Conceptual Model for Data Warehouse Design*. in *ACM 2nd Int. Workshop on Data Warehousing and OLAP (DOLAP'99)*. Missouri, USA: ACM (1999)
14. Villarroel, R., Fernandez-Medina, E., Trujillo, J., and Piattini, M.: *Towards a UML 2.0/OCL extension for Designing Secure Data Warehouses*. in *3rd. Int. Workshop on Security in Information Systems (WOSIS 2005)*. Miami, USA: INSTICC Press (2005)