World Multiconference on Systemics, Cybernetics and Informatics

July 23-26, 2000
Orlando, Florida, USA

PROCEEDINGS

Volume VIII
Computer Science and Engineering: Part II

Organized by IIIS

International
Institute of
Informatics
and Systemics

Member of the International
Federation of Systems Research
IFSR
Co-organized by IEEE Computer Society
(Chapter: Venezuela)

EDITORS
Jong Kun Lee
Matjaz Juric
Agostino Bruzzone
Daniel Klovshy
Masahiro Fujita

ISBN 980-07-6694-4

ISAS SCI 2000

PROGRAM COMMITTEE

Chairman: Prof. William Lesso (USA)

Invited Sessions Organizers

Adamchik, Victor (USA)
Agrawal, Dharma (USA)
Allanson, Jen (UK)
Andina de la Fuente, Diego (Spain)
Arndt,Timothy (USA)
Aveledo, Marianella (Venezuela)
Aziz , Soulhi (France)
Barros Justo, José Luis. (Spain)
Begovic, Miroslav (USA)
Bellahsene, Zohra (France)
Bemley, Jesse (USA)
Benedicenti, Luigi (Canada)
Bordetsky, Alex (USA)
Branco, Paulo Costa (Portugal)
Bruzzone, Agostino (Italy)
Cockburn, Alistair. (USA)
Crozat, Stephane (France)
Cuthbert, Laurie (UK)
Chen, Colin (USA)
Cheng, Edward (USA)
Cherif, Adel (Japan)
David, Amos (France)
Dillon, Tharam (Australia)
Doepp, Manfred (Austria)
Dudeck, Joachim W. (Japan)
Eiji, Nakano (Japan)
Erkmen, Ismet (Turkey)
Erkollar, Alptekin (Austria)
Feng, Ling (Netherlands)
Fijani, Amir (USA)
Ferri, Francesc J. (Spain)
Freeman, Walter J. (USA)
Fujita, Masahiro (Japan)
Funabiki, Nobuo (Japan)
Genero, Marcela (Spain)
Gershman, Alex B.(Canada)
Gutierrez, Rafael S.(USA)
Hammell II, Robert J. (USA)
Holmes, Donald (USA)
Hu, Jiankun (Australia)
Huber, Reinhold (Germany)
Iglesias F., Carlos A. (Spain)
Isern, Geminal (Venezuela)
Izquierdo, Ebroul (UK)
Juric, Matjaz B. (Slovenia)
Kazemian, Hassan B. (UK)
Kharatishvili, Guram (Georgia)
Khenchaf, Ali (France)
Kiguchi, Kazuo (Japan)
Klovsky, Daniel (Russia)
Kozma, Robert (USA)
Kraiem, Naoufel (Tunisia)
Kudo, Mineichi (Japan)
Kurihara, Yukio (Japan)
Labidi, Sofiane (Brazil)
Lam, Kai Pui (Hong Kong)
Laroussi, Bouguila (Japan)
Lee, Dong-Ik (Korea)
Lee, Jong Kun (Korea)
Lombardo, Pierfrancesco (Italy)
Loutfi, Mohamed (UK)
Martinez Ramon, Manuel (France)
Mayr, Heinrich C. (Austria)
Millan, Thierry (France)
Moreira, Joao (Austria)
Murai, Tetsuya (Japan)
Nada, Nader (USA)
Nishida, Shogo (Japan)
Novosel, Damir (USA)
Norcio, Anthony (USA)
Patel, Ahmed (Ireland)
Perez Diaz, Arturo (Spain)
Norcio, Anthony (USA)
Pham, Tuan (Australia)
Piattini, Mario (Spain)
Racherla, Gopal (USA)
Rashid, Awais (UK)
Richard, Paul (France)
Roan, Jinshyang (Taiwan)
Rogozan, Alexandrina (France)
Sancho, José Luis (Spain)
Sankar, Ravi (USA)
Shi, Yuhui (USA)
Simen, Francis Yakam (France)
Soriano, Miquel (Spain)
Suarez, Alvaro (Spain)
Succi, Giancarlo (Canada)
Suehiro, Naoki (Japan)
Tadj, Chakib (Canada)
Tiako, Pierre F. (France)
Tharam Dillon (Australia)
Will, Hart (Canada)
Wolfmann, Jacques (France)
Wong, Kainam Thomas (Hong Kong)
Yu, Kai-Bor (USA)
Yuan, Dongfeng (China)
Zurera, Manuel Rosa (Spain)

Other PC Members

Abi-Raad, M (Australia)
Abolfazlian, K. (Denmark)
Aguilar, José (Venezuela)
Al-Qaimari, G. (Australia)
Albanese, A. (USA)
Albarran, Mario (USA)
Alegra, Mario (Italy)
Andonian, Greg (Canada)
Artemis, G-H. (Greece)
Atkinson-A., J. (Chile)
Aveledo, M. (Venezuela)
Aydin, Emin D. (Turkey)
Barkaoui, K. (France)
Barroso, C. (Brazil)
Behar, P.A. (Brazil)
Belkhatir, N. (France)
Benzekri, A. (France)
Boquete, L. (Spain)
Botelho, Luis (Portugal)
Bouras, Abdelaziz (France)
Carvalho, J (Portugal)
Cernuzzi, L (Paraguay)
Cherif, Adel (Japan)
Chiang, C. (USA)
Cohen, Eli (USA)
Coutinho, M. (USA)
Crawfis, R. (USA)
Cubero, J. (Spain)
DeMichiell, R. (USA)
Di Martino, B. (Italy)
Diaz, G. (France)
Drakunov, S. V. (USA)
Druzdzel, M. (USA)
Dubois, D. (Belgium)
Dumdum, UR. (USA)
Elomaa, T. (Finland)
Erosa, M (Mexico)
Fernandez, Jorge (USA)
Freilicot, C. (France)
Frias, M. F. (Brazil)
Fulantelli, G. (Italy)
Galal, A. (Egypt)
Ge, S. (Singapore)
Gian, P. (Italy)
Girardi, R. (Uruguay)
Glanville, R. (England)
Goldman, C. (Israel)
González, C. (Venezuela)
Gordillo, F. (Spain)
Gordon, T. (Germany)
Gori, M. (Italy)
Granja A., J. C. (Spain)
Grigoris, A. (Australia)
Guvenir, A. H. (Turkey)
Hamid, A. (USA)
Herrera, F. (Spain)
Heudin, J.C. (France)
Hiong N. Anne Hee (USA)
Ho, J. (USA)
Horiuchi, Y. (Japan)
Horvath, L. (Hungary)
Hurley, P. (USA)
Husein, T. (UK)
Hwang, Y. (Taiwan)
Ibnkahla, M. (France)
Jacomet, M. (Switzerlan)
Jarzabek, S. (Singapore)
Kabanza, F. (Canada)
Kasabov, N. (New Zealand)
Kohout, L. (USA)
Kribbe, W. (Holland)
Kroell, C. (Germany)
Kundu, S. (USA)
Kutti, S. (Australia)
Lara, F. (Mexico)
Laurent, H. (France)
Lee, I. (Korea)
Lee, S. -Y. (Korea)
Lee, Te-Won (USA)
Lee-Kwang, Hyung (Korea)
Lefevre, T (Thailand)
Leonardis, A. (Slovenia)
Li, J. (USA)
Likothanassis, S. (Greece)
Losavio, F. (Venezuela)
Luzeaux, D. (France)
Maciaszek, L. (Australia)
Mammeri, Z. (France)
Martens, R. (Belgium)
MartinVide, C. (Spain)
Masatake, S. (Japan)
Mathur, A. (USA)
Matsuura, T. (Japan)
Mazure, B. (France)
Megalooikonomou,V. (USA)
Minai, A. (USA)
Mordeson, J. (USA)
Mosterman, P. (Germany)
Nada, N. (USA)
Naranjo, M. (France)
Ng, P. (USA)
Nyongesa, H. (United Kingdom)
Ogier, J.c (France)
Okada, Minoru (Japan)
Pandzio, I. (China)
Parul, S. (India)
Pascal, L. (France)
Pessoa, L. (Brazil)
Phua, Ka. (Singapore)
Ponomarev, D. (Russia)
Pons, A. (Canada)
Prueitt, P. (USA)
Quaresma, Paulo (Portugal)
Rahanu, Harjinder (UK)
Ralf, S. (Switzerland)
Raman, A. (USA)
Ramaswamy, S. (USA)
Randrup, A. (Denmark)
Resteanu, C. (Romania)
Roko, K. (USA)
Ron, S. (USA)
Rytter, W. (Poland)
Saksonov, E. (Russia)
Sala, D. (USA)
Sanderson, M. (USA)
Sanderson, M. (USA)
Savolainen, V. (Finland)
Schartz, David. (Israel)
Selcuk, C. (USA)
Shankle, W. (USA)
Shen, W. (Canada)
Shih, T. (Taiwan)
Siv, F. (Sweden)
Smith, M. (Canada)
Sobh, T. (USA)
Spenceley, S. (Australia)
Sum, J. (Kong Kong)
Suttner, C. (Germany)
Takahashi, S. (Colombia)
Takeda, F. (Japan)
Takizawa, M. (Japan)
Talia, D. (Italy)
Tastle, W. (USA)
Tezak, O. (Slovenia)
Thawonmas, R. (Japan)
Tianruo, Y. (Sweden)
Tjhie, D. (Canada)
Torra, V. (Spain)
Toutain, F. (France)
Van Solingen, R. (USA)
Vasilakos, T. (Greece)
Vityaev, E. (Russia)
Wai, Lam (Hong Kong)
Walker, E. (USA)
Wang, J. (Hong Kong)
Welzer, T. (Slovenia)
Wermter, S. (United Kingdom)
Wills, E. (Venezuela)
Won, Y. (USA)
Woodcock, A.(United Kingdom)
Wrycza, S. (Poland)
Wu, H. (USA)
Xia, F. (Macau)
Xiaoping, Jia (USA)
Yang, J. (USA)
Yasser, E. (Egypt)
Zadeh, J. (USA)
Zahariadis, T. (Greece)
Zaliwski, A. (Poland)
Zboril, F. (Czech Republic)
Zeadally, S. (USA)
Zeeuw, G. (Holand)
Zhang, C. (Canada)
Zheng, J. (Australia)
Zhu, G. (Singapore)
Zoltan, C. (Venezuela)

ADDITIONAL REVIEWERS

Aboelela, Emad (USA)
Adami, Andre (Brazil)
Adel, Cherif (Japan)
Ajmone Marsan, Marco (Italy)
Akiyama, Yoshihiro (Japan)
Akoumianakis, Demosthenes (Greece)
Alaya Cheikh, Faouzi (Finland)
Almeida Lima, Pedro (Portugal)
Altun, Arif (Turkey)
Amann, Bernd (France)
Amer, Aishy (Canada)
Andersen, Tom (Denmark)
Antani, Sameer (USA)
Arabnia, Hamid (USA)
Aracil, Javier (Spain)
Arato, Peter (Hungary)
Arieli, Ofer (Israel)
Arlitt, Martin F (USA)
Arora, Rajan (India)
Arteaga Pérez, Marco A. (Mexico)
Arts, Thomas (Swedan)
Aziz, Soulhi (France)
Baggia, Paolo (Italy)
Barabanov, Andrey E. (Russian)
Baran, Benjamin (Paraguay)
Barbour, Ahmed E (USA)
Bartoli, Jacques Andre (France)
Baþoðlu, Nuri (Turkey)
Batos, Vedran (Croatia)
Baumgartner, Albert (Germany)
Belo, Orlando (Portugal)
Ben Dhaou, Imed (Swedan)
Bergerman, Marcel (Brazil)
Beritelli, Francesco (Italy)
Berler, Alexander (Greece)
Bernando, Luis (Portugal)
Berndtsson, Mikael (Sweden)
Bischof, Horst (Austria)
Black, Paul E.
Boissiere, Guillaume (USA)
Bomarius, Frank (Germany)
Boquete, Luciano (Spain)
Botelho, Luis (Portugal)
Brasileiro, Francisco (France)
Breedvelt, Ilse (Netherlands)
Bruin, D.D. (Netherlands)
Burhard, Hans-Dieter (Germany)
Burian, Adrian (Finland)
Cai, Ning (Hong Kong)
Caileanu, Corneliu (Romania)
Calude, Cristian S. (New Zeland)
Calveras-Augé, Anna (Spain)
Carbajo, M. (Spain)
Carvalho, Joao (Portugal)
Cela, Jose (Spain)
Celka, Patrick (Australia)
Chacón, Oscar (Mexico)
Chang, Ray-I (Taiwan)
Changchi, Chuleeporn (USA)
Chen, Amy (USA)
Chen, Deji (USA)
Cheng, Runwei (Japan)
Cherif, Mehmel (Japan)
Chohra, Amine (Germany)
Chou, Li-Der (Taiwan)
Christensen, Ken (USA)
Chwif, Leonardo (Brazil)
Coiffet, Philippe (France)
Colombani, Yves (France)
Comley, Vivian Edward (UK)
Consoli, Alfio (Italy)
Costa, Joao P. (Portugal)
C-Peres, Valerie (Singapore)
Cremilleux, Bruno (France)
Da, Ruan (Belgium)
Dai, W.W. (Singapore)
Daniele, Riccio (Italy)
Davison, Robert (Hong Kong)
De Bonis, Annalisa (Italy)
De Felipe, Javier (Spain)
De Florio, Vincenzo (Belgium)
De Queiroz, Ricardo (USA)
Debon, Renaud (France)
Dehmubed, Rohinton (USA)
Delmas, Patrice (France)
Demetrescu, Camil (Italy)
Demounem, Laurence (France)
Denzler, Joachim (USA)
Djeraba, Chabane (France)
Djuric, Petar M. (USA)
Dobrowiecki, Tadeusz (Hungary)
Douros, Ioannis (UK)
Druzdzel, Marek (USA)
Duffy, Nigel (USA)
Duong, Vu N. (France)
Dutta, Sourav (India)
Elomaa, Tapio (Finland)
Erdogan, Nadia (Turkey)
Ezawa, Kazuo (USA)
Ezra Kwok, K. (Canada)
Fabian, Martin (Sweden)
Fan, Guoliang (USA)
Faro, Alberto (Italy)
Fatikow, Sergej (Germany)
Favaro, John (Italy)
Fertalj, Kresimir (Croatia)
Ficarra, Francisco (Italy)
Fidge, Colin (Australia)
Fischer, Claude (France)
Floreano, Dario (Switzerland)
Flusser, Jan (Czech Republic)
Forgacs, Istvan (Hungary)
Förster, Dirk (Germany)
Frei, Christian (Switzerland)
Fuchs, Siegfried (Germany)
Fuh, Chiou-Shann (Taiwan)
Fujita, Masahiro (Japan)
Fung, Lance C.C. (Australia)
Gallegos, Fred
Gallegos, Frederick (USA)
Galvez, Jose Maria (Brazil)
García, Francisco Javier (Spain)
Gary, C. Alexander
Giron, Franck (Germany)
Goepffarth, Rolf Gregor (Germany)
Gonzalez-Banos, Hector Hugo
Granja Alvarez, Juan (Spain)
Gresse, Christiane (Brazil)
Griffiths, Ian (UK)
Guenter, Rudolph (Germany)
Gupta, Anshul
Guvenir, H. Altay (Turkey)
Hanachi, Chihab (France)
Hassan, Amer
Heyden, Anders (Sweden)
Hidalgo, Ignacio (Spain)
Higashiyama, Yoichi (Japan)
Hirakawa, Masahito (Italy)
Holgado, Javier (Spain)
Holsbach Costa, Márcio (Brazil)
Hong, Youlian (Hong Kong)
Hoogeweegen, Martijn (Netherlands)
Hu, Guangshu (China)
Huang, Chengquan
Huang, Jingwei (China)
Hui, Lucas (Hong Kong)
Huijuan, Yang (Singapore)

Hulicki, Zbignieww (Poland)
Hulin, Martin (Germany)
Husar, Peter (Germany)
Huw, Oliver
Imae, Joe (Japan)
Impagliazzo, Leonardo (Italy)
Janczura, Chris (Australia)
Janousek, Vladimir (Czech Republic)
Jautzy, Olivier
Johnson, John (USA)
Jolion, Jean-Michel (France)
Juergen, Branke (Germany)
Kaaniche, Mohamed (France)
Kabiri, Peyman (UK)
Kalpic, Damir (Croatia)
Kamata, Hiroyuki (Japan)
Kang Hoh, Phua (Singapore)
Kankanhalli, Mohan (Singapore)
Kasemian, Hassan B (UK)
Kawahara, Hideki (Japan)
Kawarazaki, Noriyuki (Japan)
Keong, Ng Wee (Singapore)
Keravnou-Papaeliou, Elpida (Cyprus)
Khanbaghi, Maryam (Canada)
Kim, Sam Myo (Korea)
Komosinski, Maciej (Poland)
Krishnan, Paddy (New Zealand)
Kuhns, Fred
Kuo, Chin-Haw
Kusumoto, Shinji (Japan)
Lam, Wai (Hong Kong)
Lara R, Domingo (Mexico)
Larin, Vladimir (Ukraine)
Larnac, Mireille (France)
Lee, Hyo Jong
Lee, Lyndon (UK)
Lee, Richard
Leger, Alain (France)
Leonardis, Ales (Singapore)
Lien, Yao-Nan (Taiwan)
Likothanassis, Spiros (Greece)
Lima, Pedro (Portugal)
Lin, Ming
Liou, Jing-Chiou
Liu, Alan (Taiwan)
Lopes de Souza, Paulo (Brazil)
Lorenz, Pascal (France)
Loukas, Nikos (Greece)
Lundin, Fred J (Sweden)
Luo, Yupin (China)
Luzeaux, Dominique (France)
Maierhofer, Martin (UK)
Mämmelä, Aarne (Finland)
Man Lap, Chung (Hong Kong)
Manrer, Calvin (USA)
Marconi, Lorenzo (Italy)
Mareels, Iven (Australia)
Masahiro, Hiji (Japan)
Matsuura, Takenobu (Japan)
Maurer, Calvin
McLeod, Chris (UK)
Messa, Kenneth (USA)
Metter, Jeffrey
Michelucci, Dominique (France)
Mika, Sato-Ilic (Japan)
Milic, Ljiljana (Yugoslavia)
Mitobe, Kazutaka (Japan)
Moerkotte, Guido (Germany)
Monteiro, Edmundo (Portugal)
Mordes
Mordeson, John
Morimoto, Yasuhiko (Japan)
Mosterman, Peter (Australia)
Mullery, Geoff
Munack, Axel (Germany)
Nakajima, Tatsuo (Japan)
Neagu, Gabriel (Romania)
Nesi, Paolo (Italy)
Newby, Gregory (USA)
Newsome, Mark
Nguyen, Hung (Australia)
Nguyen, X.T. (Australia)
Ninholt, Anton (Netherlands)
Nordström, Kjell (Sweden)
Ohya, Akihisa (Japan)
Omologo, Maurizio (Italy)
Oonincx, Patrick J. (Netherlands)
Orth, W (Germany)
Osborn, Tom (Australia)
Paek, Yunheung (Korea)
Palm, Rainer (Germany)
Pavlidou, Niovi (Greece)
Perkowski, Marek (Portugal)
Petrou, Maria (UK)
Pham, Tuan (Australia)
Pietrobon, Steven S. (Australia)
Pin, Ooi Boon (Singapore)
Ping, Gan Boon (Singapore)
Pinto, Augusto Cesar (Brazil)
Polani, Daniel (Germany)
Potter, Don
Prakash, S.R. (India)
Puyul-Gruart, Josep (Spain)
Qi, Hairong
Qusay, H Mahmoud (Canada)
Ramakrishnan, Sita (Australia)
Raymond, N.G. (Hong Kong)
Reiter, Heinrich
Reza, Khorramshahgol
Richard, Paul (France)
Rihar, Marjan (Singapore)
Rittberger, Marc (Germany)
Rohr, Karl (Germany)
Romanczuk, Annya (France)
Roszkowska, Elzbieta (Poland)
Rybinski, Henryk (Poland)
Ryszard, Kowalczyk (USA)
Sahan, Sorina (Romania)
Santos del Riego, A. (Spain)
Santos, Rafael (Brazil)
Sarty, Gord (Canada)
Savolainen, Vesa (Finland)
Savorski, Victor (Russia)
Sawada, Hiroshi (Japan)
Schwartz, Alan
Schwartz, David (Israel)
Seckin, Gamze
Seetharaman, Aparna
Shalvi, Doron
Sharma, Gaurav
Shih, Timothy (Taiwan)
Sokolsky, Oleg
Solaiman, Bassel (France)
Stempokovsky, Alexander (Russia)
Sterian, Andrew
Steyer, Jean Philippe (France)
Sties, Manfred (Germany)
Suarez Sarmiento, Alvaro(Spain)
Suguri, Hiroki (Japan)
Sum, John (Hong Kong)
Sun, Koun Tem (Taiwan)
Sun, Ron (USA)
Surma, Jerzy (Poland)
Syed, Mahbub
Szabolcsi, Róbert (Hungary)
Szulman, Sylvie (France)
Tenreiro Machado, J.A. (Portugal)
Teraoka, Fumio (Japan)
Thaden, Larry
Thaden, Lawrence
Todd, Wareham (Canada)
Torrens, Francisco (Spain)
Torres, Luis (Spain)
Tronci, Enrico (Italy)
Tsakalis, Kostas
Tsukiyama, Shuji (Japan)
Ubar, Raimund (Estonia)
Usai, Elio (Italy)
Van de Walle, Rik (Belgium)
Venturini, Gilles (France)
Vuik, Kees (Netherlands)
Wang, Yanying
Wclam, Stephen (Hong Kong)
Wen, Jyh-Horng (Taiwan)
Westphall, Carlos B. (Brazil)
Will, Matthias O. (Germany)
Wong, Tom (Croatia)
Worring, Marcel (Netherlands)
Xi, Hongwei
Yahara, Taishi (Japan)
Yahya, Adnan
Yehia, Ramzi Riad
Yu, Weihai (Norway)
Zahan, Sorina (Romania)
Zara, Jiri (Czech Republic)
Zárate, L.E. (Brazil)
Zboril, Frantisek (Czech Republic)
Zecevic, Aleksandar
Zhang, Rongjun
Zhiying, Zhou (China)
Zhou, Duan Ning (Hong Kong)
Zoubir, Mammeri (France)

ISAS
SCI 2000

ACADEMIC AND SCIENTIFIC CO-SPONSORS

- WOSC: World Organization on Systemics and Cybernetics (France)
- The Centre for Systems Studies (UK)
- Systems Society of Poland
- Society Applied Systems Research (Canada)
- Slovenian Artificial Intelligence Society
- Simon Bolivar University (Venezuela)
- Polish System Society (Poland)
- Italian Society of Systemics
- ISSS: International Society for the Systems Sciences (USA)
- ISI: The International Systems Institute (USA)
- IEEE/Latin-America
- IFSR: International Federation of Systems Research (Austria/USA)
- IEEE Computer Society (Chapter: Venezuela)
- Cybernetics and Human Knowing: A Journal of Second Order Cybernetics and Cybersemiotics (Denmark)
- CUST, Engineer Science Institute of the Blaise Pascal University (France)
- Concurrency and Architecture Group, the Telematics Engineering Departament of The University of Las Palmas of Gran Canaria, Spain.
- The Tunisian Scientific Society (Tunisia)

HONORARY PRESIDENTS

Bela Banathy
Stafford Beer
George Klir

PROGRAM COMMITTEE CHAIR

William Lesso

GENERAL CHAIR

Nagib Callaos

ORGANIZING COMMITTEE CHAIR

Belkis Sanchez

PROCEEDINGS PRODUCTION PROCESS CHAIRS

María Sánchez
Juan Manuel Pineda

3

QUALITY METRICS FOR OBJECT-RELATIONAL DATABASES

Coral Calero and Mario Piattini
Grupo ALARCOS
University of Castilla-La Mancha
Ronda de Calatrava, 5
13071, Ciudad Real (Spain)
e-mail: {ccalero, mpiattin}@inf-cr.uclm.es

ABSTRACT

Quality is a critical success factor for all economical and organisational aspects, and especially in Information Systems (IS). It is important that the software applications can be evaluated for every relevant quality characteristic using validated metrics. Almost all the metrics proposed are focused on programme. But databases are introduced in most of the important IS, becoming their essential core, so it is essential to dispose on metrics for databases. In this paper we present the metrics that we have proposed for two kinds of databases: the relational and the object-relational. These metrics measure internal attributes of databases, which can characterised their complexity and can help to assess database quality .

Keywords: Quality, Metrics, Relational Databases, Object-Relational Databases

1. INTRODUCTION

Quality is a critical success factor for all economical and organisational aspects, and especially in Information Systems (IS). It is important that the software applications can be evaluated for every relevant quality characteristic using validated metrics. Software engineers have been putting forward huge quantities of metrics for software products, processes and resources ([19], [7], [13]). Unfortunately, almost all the metrics proposed are focused on programme, disregarding data-related quality ([24]). But databases are introduced in most of the important IS, becoming their essential core, so it is essential to dispose on metrics for databases.

Following the ISO/IEC 9126 ([17]) quality model,several characteristics can be identified in software quality: functionality, reliability, usability, efficiency, maintainability and portability. Taking into account that maintenance arrange between 60 and 90 percent of life cycle costs ([6], [23]), we focus our work on maintainability. ISO/IEC 9126 distinguishes five subcharacteristics for maintainability: analysability, changeability, stability, testability and compliance (see figure 1). Analysability, changeability and testability are in turn influenced by complexity ([18]). However, a general complexity measure is "*the impossible holy grail*" ([12]). In [16] the author distinguishes three types of complexity: computational, psychological and representational, and for psychological complexity he considers three components: problem complexity, human cognitive factors and product complexity ([16]). The last one is our focus.

So, the metrics we define are for measure internal attributes of databases, which can characterised their complexity which can help to assess database maintainability (the external attribute).

In this paper we present the metrics that we have proposed for two kinds of databases: the relational and the object-relational.

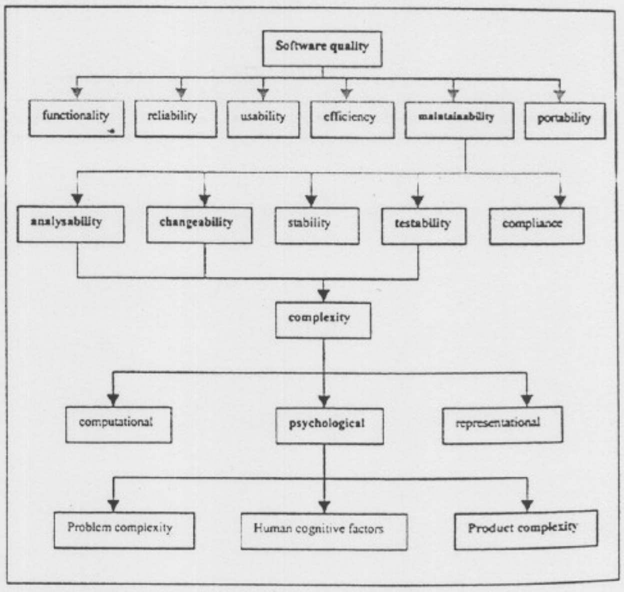


Figure 1. Relation between products complexity metrics and software quality

2. METRICS FOR RELATIONAL DATABASES

The relational model proposed by Dr. Codd in the late sixties ([9]), currently dominates the database market. In spite of their diffusion, the only indicator used to measure the quality of relational database has been the normalisation theory, upon which ([15]) propose to obtain a normalisation ratio. But normalisation is not enough to characterise database quality. In [10] the author defines a relational database management system as "a system in which, at minimum :

- The data is perceived by the user as tables (and nothing but tables); and
- The operators at the user's disposal are operators that generate new tables from old, and those operators include at least SELECT, PROJECT, JOIN".

Related with the foreign key concept, the relational model includes the referential integrity rule: the database must not contain any unmatched foreign key values ([10]).

Taking into account the characteristics of the relational databases (tables and referential integrity) we propose the following four metrics: NA, DRT, RD and COS.

NA metric. Number of attributes (NA) is the number of attributes in all the tables of the schema.

DRT metric. Depth Referential Tree (DRT) is a referential integrity related metric and is defined as the length of the longest referential path in the database schema. Every arc of the path is a referential integrity relation between two tables. The value of the metric is given by the number of arcs on the longest path. Cycles are only considered once

RD metric. Referential Degree (RD) metric is also a referential integrity related metric and is defined as the number of foreign keys in the schema.

COS metric. Cohesion of the schema (COS) is defined as the sum of the square of the number of tables per unrelated subgraph in the database:

$$COS = \sum_{i=1}^{|US|} NTUSi^2$$

|US| number of unrelated subgraphs

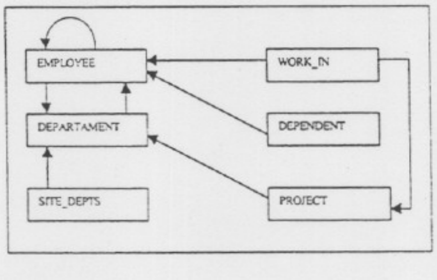
$NTUS_i$ number of tables in the unrelated subgraph "i"

Example. Applying the previous metrics to the following example taken from [11]:

```
CREATE TABLE EMPLOYEE
          (
          NAMEP    VARCHAR(15)    NOT NULL,
          INIC     CHAR,
          SURNAME VARCHAR(15)    NOT NULL,
          NSS      CHAR(9)   NOT NULL,
          DATEN    DATE,
          ADDRESS  VARCHAR(30),
          SEX      CHAR,
          SALARY   DECIMAL(10,2),
          NSSSUPER CHAR(9),
          ND       INT         NOT NULL,
  CONSTRAINT CLPEMP
          PRIMARY KEY (NSS),
  CONSTRAINT CLESUPEREMP
          FOREIGN KEY (NSSSUPER) REFERENCES
EMPLOYEE(NSS)
  ON DELETE SET NULL ON UPDATE CASCADE,
  CONSTRAINT CLEDEPTOEMP
          FOREIGN KEY (ND) REFERENCES DEPARTAMENT
(NUMBERD)
  ON DELETE SET DEFAULT ON UPDATE CASCADE);
```

```
CREATE TABLE DEPARTAMENT
          (
          NAMED    VARCHAR(15)    NOT NULL,
          NUMBERD INT             NOT NULL,
          NSSGTE   CHAR(9)   NOT NULL,
          DATEINICGTE DATE,
  CONSTRAINT CLPDEPTO
          PRIMARY KEY (NUMBERD),
  CONSTRAINT CLSDEPTO
          UNIQUE(NOMBRED),
  CONSTRAINT CLEGTEDEPTO
          FOREIGN KEY (NSSGTE) REFERENCES EMPLOYEE
(NSS)
          ON DELETE SET DEFAULT ON UPDATE CASCADE);


CREATE TABLE SITE_DEPTS
          (
          NUMBERD INT               NOT NULL,
          SITED              VARCHAR(15)          NOT
NULL,
  PRIMARY KEY (NUMBERD, SITED),
  FOREIGN KEY (NUMBERD) REFERENCES DEPARTAMENT
(NUMBERD)
  ON DELETE CASCADE ON UPDATE CASCADE);


CREATE TABLE PROJECT
          (
          NAMEPR   VARCHAR(15)   NOT NULL,
          NUMBERPR            INT        NOT NULL,
          SITEPR              VARCHAR(15),
          NUMD                INT        NOT NULL,
  PRIMARY KEY (NUMBERP),
  UNIQUE (NAMEP),
  FOREIGN KEY (NUMD) REFERENCES DEPARTAMENT
(NUMBERD));


CREATE TABLE WORK_IN
          (
          NSSE     CHAR(9)   NOT NULL,
          NUMP     INT              NOT NULL,
          HOURS    DECIMAL(3,1)     NOT NULL,
  PRIMARY KEY (NSSE, NUMP),
  FOREIGN KEY (NSSE) REFERENCES EMPLOYEE (NSS),
  FOREIGN KEY (NUMP) REFERENCES PROJECT (NUMBERP));


CREATE TABLE DEPENDENT
          (
          NSSE     CHAR(9)   NOT NULL
          NAME_DEPEND      VARCHAR(15)         NOT
NULL,
          SEX      CHAR,
          DATEAN   DATE,
          RELATION VARCHAR(8),
  PRIMARY KEY (NSSE, NAME_DEPEND),
  FOREIGN KEY (NSSE) REFERENCES EMPLOYEE (NSS));
```

We can obtain the relational graph and calculate the metrics values:



	NA	DRT	RD
EMPLOYEE	10	3	2
DEPARTAMENT	4	3	1
SITE_DEPTS	2	4	1
PROJECT	4	4	1
WORK_IN	3	5	2
DEPENDENT	5	4	1

3. METRICS FOR OBJECT-RELATIONAL DATABASES

An object-relational database schema is composed by a number of related tables. Every table have columns that can be defined as a simple data or as a complex data. The type of a simple data may be one of the classic data types as integer, number or character. A complex data is defined above a class (or a UDT, user defined type), which can be related with other classes (types) by generalisation or inheritance associations.

Size of a table. We define the table size (TS) as the sum of the total size of the simple columns (TSSC) and the total size of the complex columns (TSCC) in the table:

$$TS_i = TSSC + TSCC$$

We consider that all simple columns have a size equal to one, then the TSSC metric is equal to the number of simple columns in the table (NSA).

$$TSSC = NSA$$

And the TSCC is defined as the sum of each complex column size (CCS):

$$TSCC = \sum_{i=1}^{NCC} CCS_i$$

Being NCC the number of complex columns in the table.

The value for CCS is obtained as:

$$CCS = \frac{SHC}{NCU}$$

Being SHC the "size of the hierarchy (formed by the class and its antecesors)" above which the column is defined and NCU is the number of columns defined above this hierarchy. This expression reflects the fact that the effort to understand two complex columns decreases if both are defined over the same class.

The SHC may be defined as the sum of each class size in the hierarchy (SC):

$$SHC = \sum_{i=1}^{NCH} SC_i$$

being NCH the number of classes in the hierarchy.

The size of a class is defined as:

$$SC = \frac{SAC + SMC}{NHC}$$

being SAC the sum of the size attributes of the class, SMC the size methods of the class and NHC the number of hierarchies to which the class pertain.

The attributes of a class may also be simple or complex, then the SAC is defined as the sum of the simple attributes size (SAS, that have size equal to one like simple attributes) and the complex attributes size (CAS) in the class.

$$SAC = SAS + CAS$$

And the SMC is calculated with the version of the cyclomatic complexity of McCabe given by Li and Henry (1993):

$$SMC = \sum_{i=1}^{NMC} V_i(G)$$

being NMC the number of methods in the class

Complexity of references between tables. In object-relational databases, some characteristics of relational databases are preserved, for example referential integrity. So, for this kind of databases we can use the metrics related with referential integrity proposed for relational databases DRT and RD.

Example. Applying the metrics to the example showed in figure 3, we obtain the following values for the metrics:

SC(class_person)=3,
SC(class_projects)=3,
SC(class_emp)=7

and

SHC=13,CCS= 6.5,
TSCC=13,
TSSC=NSA=2

and finally TS=15.

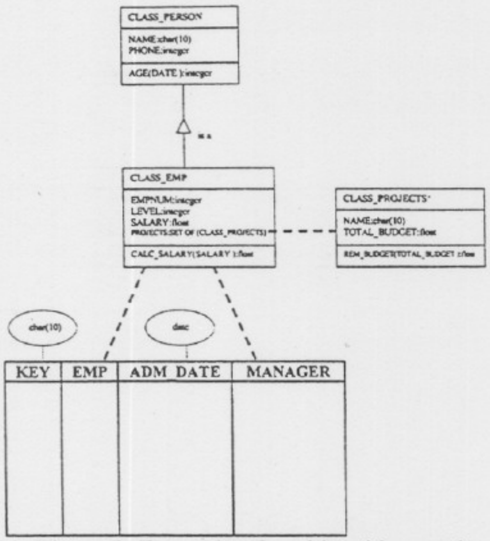


Figure 3. Example of a table with complex columns

4. CONCLUSIONS AND FUTURE WORK

It is important that the software products, and obviously databases, are evaluated for every relevant quality characteristics, using validated or widely accepted metrics. These metrics could help designers, choosing between alternative semantically equivalent schemata, the most maintainable one. Because of this, we think it is very important to measure databases and understand their contribution to the overall IS maintainability.

We have put forward different measures (for internal attributes) in order to measure the complexity that affects the maintainability (an external attribute) of relational and object-relational databases and control its quality.

It is also important to validate the metrics from a formal point of view in order to ensure its utility. Several frameworks for measure characterisation have been proposed. Some of them ([1], [25], [2]) are based on axiomatic approaches. The goal of this approach is merely definitional by defining formally desirable properties for measures for a given software attribute, so axioms must be used as guidelines for the definition of a measure. Others ([26]) are based on measurement theory which specifies the general framework in which measures should be defined. Some of the presented metrics have been formalised from both points of view, axiomatic approach ([21], [22]) and measurement theory ([3], [5]).

However, into the aspects of software measurement, the research is needed ([20]), from theoretical but also from a practical point of view ([14]). So, it is necessary to do experiments to validate the metrics. In this line we have also validate empirically some of the presented metrics ([4]). But the controlled experiments have problems (like the large number of variables that causes differences, deal with low level issues, microcosm of reality and small set of variables) and limits (do not scale up, are done in a class in training situations, are made in vitro and face a variety of threats of validity). Then, is convenient to run multiple studies, mixing controlled experiments and case studies. We are now working on this last kind of empirical validation with our metrics.

We are also adapting our framework to several RDBMS that followed the SQL:1999 model, simplifying the measures to be taken. In this way, we can give a more precise guide to the metrics usage ([8]), and develop a tool for automatic metrics collection.

ACKNOWLEDGMENTS

This research is part of the MANTICA project, partially supported by the CICYT and the European Union (CICYT-1FD97-0168) and by the CALIDAT project carried out by Cronos Ibérica (supported by the Consejería de Educación de la Comunidad de Madrid, Nr. 09/0013/1999)

REFERENCES

[1] Briand, L.C., Morasca, S. And Basili, V. (1996). Property-based software engineering measurement. IEEE Transactions on Software Engineering, Vol.22(1), pp. 68-85.

[2] Briand L.C. and Morasca S. (1997). Towards a Theoretical Framework for Measuring Software Attributes. *Proceeding of the Fourth International, Software Metrics Symposium,* 119-126.

[3] Calero, C., Piattini, M., Ruiz, F. and Polo, M. (1999a), Validation of metrics for Object-Relational Databases, *International Workshop on Quantitative Approaches in Object-Oriented Software Engineering (ECOOP99),* (Lisbon ,Portugal. June 1999), 14-18

[4] Calero, C., Piattini, M., Polo, M., Ruiz, F. (1999b) Validating referential integrity as a database quality metric. *Proceedings of the First International Conference on Enterprise Information Systems, 45-50.*

[5] Calero, C., Piattini, M., Genero, M., Serrano, M. and Caballero, I. (2000). Metrics for Relational Databases Maintainability, *UKAIS2000*, Cardiff, UK.

[6] Card, D.N. and Glas, R.L. (1990). *Measuring Software Design Quality*. Englewood Cliffs. USA.

[7] Chidamber, S. and Kemerer, C. (1994), A metric suite for object-oriented design, *IEEE Trans. Software Eng.*, vol. 20,no. 6, June, 1994, pp. 476-493.

[8] Churcher, N.J. and Shepperd, M.J. (1995). Comments on "A Metrics Suite for Object-Oriented Design". IEEE Trans. on Software Engineering, Vol. 21(3). pp. 263-265.

[9] Codd, E.F. (1970). A Relational Model of Data for Larged Shared Data Banks. CACM, Vol.13 (6). pp. 377-387.

[10] Date, C.J. (1995). An Introduction to Database Systems. 6th. Addison-Wesley, Reading, Massachusetts.

[11] Elmasri, R. and Navathe, S. (1999). *Fundamentals of Database Systems*. Third edition. Addison-Wesley. Massachussets

[12] Fenton, N. (1994). Software Measurement: A Necessary Scientific Basis. *IEEE Transactions on Software Engineering*, Vol. 20(3). pp. 199-206.

[13] Fenton, N. and Pfleeger, S. L. (1997). Software Metrics: A Rigorous Approach 2nd. edition. London, Chapman & Hall.

[14] Glass, R. (1996). The Relationship Between Theory and Practice in Software Engineering. IEEE Software, November, Vol.39 (11). pp 11-13.

[15] Gray R.H.M., Carey B.N., McGlynn N.A., Pengelly A.D., (1991), Design metrics for database systems. BT Technology J, Vol 9, 4 Oct. pp. 69-79

[16] Henderson-Sellers, B. (1996). Object-oriented Metrics - Measures of complexity. Prentice-Hall, Upper Saddle River, New Jersey.

[17] ISO, (1994). Software Product Evaluation-Quality Characteristics and Guidelines for their Use. *ISO/IEC Standard 9126*, Geneva.

[18] Li, H.F. and Chen, W.K. (1987). An empirical study of software metrics. IEEE Trans. on Software Engineering, Vol.13 (6). pp. 679-708.

[19] Melton, A. (ed.) (1996). Software Measurement. London, International Thomson Computer Press.

[20] Neil, M. (1994) Measurement as an Alternative to Bureaucracy for the Achievement of Software Quality. Software Quality Journal Vol.3 (2). pp. 65-78.

[21] Piattini, M., Calero, C., Polo, M. and Ruiz, F. (1998). Maintainability in Object-Relational Databases. . Proc of The European Software Measurement Conference FESMA 98, Antwerp, May 6-8, Coombes, Van Huysduynen and Peeters (eds.). pp. 223-230.

[22] Piattini, M., Calero, C., Polo, M. and Ruiz, F. (2000). Towards a metric suite for relational databases complexity, Accepted for IDPT 2000, June 2000, Dallas (USA)

[23] Pigoski, T.M. (1997). *Practical Software Maintenance*. Wiley Computer Publushing. New York. USA

[24] Sneed, H.M. and Foshag, O. (1998). Measuring Legacy Database Structures. Proc of The European Software Measurement Conference FESMA 98, Antwerp, May 6-8, Coombes, Van Huysduynen and Peeters (eds.). pp. 199-211.

[25] Weyuker, E.J. (1988). Evaluating software complexity measures. IEEE Transactions on Software Engineering Vol.14(9). pp. 1357-1365.

[26] Zuse, H. (1998). A Framework of Software Measurement. Berlin, Walter de Gruyter.

- Mobile Agents - Invited Session
  Organizer: J. Arturo Pérez Díaz (Spain)
- Artificial Intelligence/Expert Systems
- Document and Natural Language Processing
- Programming-Techniques
- Parallel and Distributed Systems
- Optimal Stochastic Space-time Fields Processing in Radio-engineering, Telecommunication and Global Information Systems - Invited Session
  Organizer: Daniel Klovsky (Russia)
- Pattern Recognition Methodology: Prototype and Feature Selection - Invited Session
  Organizer: Francesc J. Ferri (Spain)
- Codes, Sequences and Cryptography - Invited Session
  Organizer: Jacques Wolfmann (France)
- Web Information Integration Systems - Invited Session
  Organizer: Zohra Bellahsene (France)

VOLUME VIII

COMPUTER SCIENCE AND ENGINEERING: PART II

- Geographical Information Systems
- Sets and Data Mining
- Databases
- Modeling, Graphs and Algorithms
- Mathematical Methods and Optimization in Problem Solving Systems
- Simulation Subject - Invited Session
  Organizer: Agostino Bruzzone (Italy)
- Distributed Computing Performance - Invited Session
  Organizer: Matjaz B. Juric (Slovenia)
- Modeling and Simulation of System Based on the Petri Nets - Invited Session
  Organizer: Jong Kun Lee (Korea)
- Design Validation of Digital Systems - Invited Session
  Organizer: Masahiro Fujita (Japan)
- Data and Information Quality - Invited Session
  Organizer: Mario Piattini and Marcela Genero (Spain)
- Statistical Computing - Invited Session
  Organizer: Colin Chen (U.S.A.)

VOLUME IX

INDUSTRIAL SYSTEMS

- Robotics and Control Systems
- Control Systems