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Database Design in the Context of the SPICE Process Dimension

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Abstract

Databases are more and more used in applications different to traditional business information systems, such as telecom network management, control systems, mobile computing, inter- and intranet supported applications, data warehousing and data mining. Problems derived from the use of the applications, often, have their source in inappropriate databases. A proper process definition and assessment may help to alleviate these problems. Complexity and size of these systems and of the associated databases let us think of paying the required attention to the database design process in terms of assessment. Database design process and products have specific characteristics that make them neatly different from the design of software components produced in traditional procedural languages. However database design is often viewed as the design of just another module, not requiring specific interest from an architectural and complexity application analysis, what is not often true. Within this paper we present some of the results of a research work oriented to understand the database design process in the context of the SPICE - ISO/IEC 15504 framework. We describe database design base practices and products in terms SPICE and analyse those areas where holes or conflicts have come up.

1. Introduction

Databases (DBs) are the core of information systems. At present the use of databases is not constrained to traditional business information systems. They are, ever more, part of systems such as network management, data warehouse, control or command systems. Internet is providing new applications schemes that have as a backend large or even huge databases.

DB importance with respect to whole application is increasing as long as technology is supporting new functionalities every day. Database design, for instance relational database design, presents some characteristics that make it different from conventional software module design. To implement an application in a procedural language, such as C, you have to design a rather declarative body. To decompose a module into a number sub-modules, achieving a use hierarchy, has a different meaning with a database schema. We cannot do exactly the same operation. This is the case of relational databases. The sub-schema is a different concept to that of sub-module. This has a repercussion on the architecture concept as well.

Some other characteristics stress the difference between databases and other software components. Databases have persistent contents. These contents vary across the database life. And even when the quality of the database product and implementation process is excellent, the system may perform poorly as long as quality of data is not good.

SPICE-ISO/IEC 15504 Technical Report [ISO/IEC 15504] offers guidance to process assessment and improvement, on a general-purpose basis. Therefore, we understood that there was enough interest to study up to what extent SPICE could be used effectively to perform an assessment of a database design process. And, up to what extent the assessment of a project containing database design/implementation could present some kind of holes.

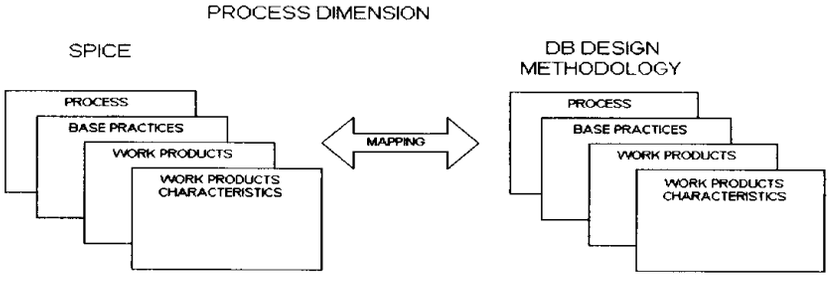

Figure 1 - SPICE vs. DB Design Methodology Process Dimension

Within this paper we present the results of our study in which we compare and analyse the feasibility of producing software process assessments using SPICE for projects containing database development. We present our approach and conclusions with respect to the Process dimension. We have focussed our work in relational databases. However it can be easily applied to other data models. However, object models present some characteristics that should be analysed before extending our conclusions to them.

Within this section, Introduction, we present the paper guidelines. Next section, Mapping between a Generic DB Design Methodology and SPICE, describes the basis for a process mapping between a Generic DB Design Methodology and SPICE. Work-products Mapping describes this issue. Finally we present a number of conclusions.

2. Mapping between a Generic DB Design Methodology and SPICE

Some good material containing DB design approaches and methodologies can be found in literature, such as in [Elsmasri, 1997], [Batini, 1992] and [De Miguel, 1999]. However available material lacks of a systematisation such as that used to describe SPICE base practices. Therefore we decided to use some material developed by ourselves that provided a systematic approach for data warehouse development and extend it to support database design. The original methodology for data warehouse was called MEDITA. We called the extension for DB design EMEDITA.

This methodology has been defined according to the Spanish Public Administration System Development methodology, Metrica version 2 [Metrica, 1995]. This made the work more challenging as long as it meant that we were starting from a methodology not specifically defined to fit into IS 12207 [ISO/IEC 12207, 1995] process model *a priori*. On the other side it represented a usual situation for the available DB support material.

EMEDITA provides us with methodological support for both On line Transaction Processing (OLTP) and On Line Analytical processing (OLAP) projects through selecting the proper components and processes. Main innovations are, compared with other data base design models, its component orientation, and the inclusion of an incremental life cycle model. It allows us the generation of extended data base schemas for already operational databases, as well as the inclusion of processes oriented specifically to edge issues: data quality assurance, and data warehouse/data mart. As we shall explain below we consider data quality as a new dimension, together with process and product quality.

The first step was to establish a number of tasks that, eventually, could be mapped onto SPICE base practices. Prior to the mapping between EMEDITA and the SPICE reference model a mapping between EMEDITA and IS 12207 [ISO/IEC 12207, 1995] was carried out. There are two reasons to perform this mapping. Firstly, IS 12207 is a widespread standard, universally recognised, and it was interesting to know the goodness of our model when contrasted against IS12207, moreover when a similar mapping exists for SPICE. Secondly, in the future it would be easier for us to work in terms of IS 12207.

SPICE reference model is a standard whose approach differs from that of EMEDITA. We consider this a very interesting issue from the research point of view. SPICE proposes a general-purpose development model, and it establishes a number of processes that are oriented to conventional software development. On the other hand it is composed of two different dimensions: process and capability.

The process-dimension mapping between EMEDITA and TR15504 Reference model was performed as follows. Figure 2 shows a very general approach to database design and implementation. A mapping from every EMEDITA process to the proper TR15504 Process Reference model was produced. The mapping was done maintaining the maximum coherence degree between both models and trying to adjust as much as possible the contents of both models. Figure 3 represents a summary of the mapping.

The most outstanding problem found is the different philosophy in both models. SPICE, despite offering a reference model that could be considered as generic, is nevertheless neatly oriented to the development of products characterised as (executable) software modules in conventional programming languages. Most of SPICE processes might be valid in the field of databases though they might need specific extensions. However we encountered some problems in mapping some processes more specific to DB: conceptual-model or logical-model schema design did not fit well at all, as explained in the following paragraphs.

Support processes (Management, Documentation and Acquisition) were easy to map and in a very satisfactory fashion.

2.1. Base practices Mapping

In the previous section we described the first step: to identify a set of SPICE processes that would guide the definition of the assessment model, guaranteeing the compatibility with SPICE model. The second step was to find a set of base practices. Base practices are essential, as they are indicators of process performance, what it is essential for determining the goodness of the process.

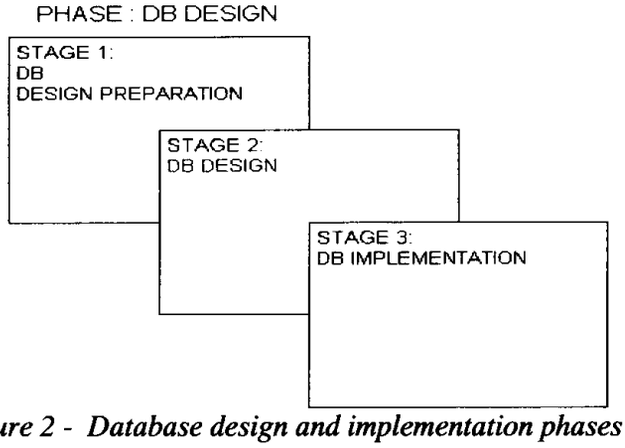

Figure 2 - Database design and implementation phases

Let us go back to the structure of EMEDITA DB design methodology as shown in figure 2. We have focus our attention on the DB design stage as an example to illustrate the mapping of SPICE base practices. The DB design stage is regarded as being representative of the DB design context. It is also a good example to demonstrate the sometimes-hard task of finding a suitable set of SPICE practices that fully characterised the purposes of DB specific base practices.

The different activities that must be carried out according to EMEDITA are structured in Phases, which contain Stages, which contain Tasks. These tasks are divided in subtasks, which are the basic activities. Looking into these subtasks a set of SPICE practices have been defined as a first step (figure 4).

The DB design stage is the second stage of the DB design Phase. This phase is divided into three stages. The first stage in this phase is the preparation for the DB design, which is the part of the design in charge of gathering all the needed information and data for the design of the DB. The third and last stage of the phase is the implementation of the DB, which is the part of the design where the implementation of transactions is done and the DB is loaded.

We shall focus our attention in the DB design stage as we think it is the most characteristic for our purposes.

Let us consider those base practices resulting from the study of the methodology subtasks, and those other associated to SPICE processes for a subtask. That means that, for each subtask, base practices have been defined taking into consideration two aspects: actions to be performed in order to achieve the goals of the subtask and the guidelines proposed in the SPICE base practices defined in SPICE general evaluation model.

As it can be seen in figure 5, a great number of subtasks have been mapped onto the SPICE Software design process (ENG 1.3), which corresponds to the Engineering process category. The purpose of this process is to define a design for the software that will meet the requirements, which is similar to what the DB design stage does according to the information provided in stage 1 of this the DB design Phase.

All the processes carried out to obtain the DB Conceptual model (see figure 5) have been mapped onto the base practice BP1, Develop architectural design. Although DB design literature does not clearly states it, we have considered that the architecture of the DB system, taking into account SPICE perspective, may be regarded as its conceptual and external schemas. The degree of consistency associated to this mapping depends on the extent this concept of Architecture might or might not be appropiate within a DB context.

The rest of the processes mapped onto the Software design process gather tasks to refine the DB conceptual model to, eventually, obtain the DB physical model. Therefore the corresponding base practices have been mapped with BP3 Develop detailed design.

The activity of obtaining a detailed design from the abstract idea that a conceptual model can represent is also applicable to a DB design. Starting from the conceptual design the DB is modified and refined according to the conceptual & logical design and the DBMS. In that sense, this process can be easily mapped to the ordinary detailed design process specified in SPICE.

Within the process ENG 1.3, there is also another base practice: BP2 Design interfaces. This activity is not used at all in a DB design. DB views design could fit here but they have not been considered. Therefore it should be omitted from the mapping.

The rest of subtasks within this stage were related to documentation generation, documentation study, customer needs and customer validation. These subtasks have a clear associated SPICE process (Basically in the Support and Customer-Supplier categories) and no problems were found in their mapping.

MEDITA	MEDITA Processes	DB	DW	15504	15504 Processes	Type	Alternative mapping		
1	Project Initiation	X	X						
1.1	Project planning and goals definition	X	X	CUS.1	Acquisition process	Basic			
1.1.1	Project goals identification	X	X	CUS.1.1	Acquisition preparation process	Component			
1.1.2	Involved areas identification	X	X	CUS.1.1	Acquisition preparation process	Component			
1.1.3	Participants identification and organisation	X	X	ORG.3	Human resource management process	Extended	Acquisition preparation process	¥	
1.1.4	Project general planning	X	X	MAN.2	Project management process	New	Supply process|Acquisition preparation process	¥	
1.2	Project start	X	X	CUS.1.1	Acquisition preparation process	Component			
1.2.1	Project scope definition	X	X	CUS.1.1	Acquisition preparation process	Component	Project management process	¥	
1.2.2	Involved areas study	X	X	CUS.1.1	Acquisition preparation process	Component			
1.2.3	Involved areas data needs	X	X	CUS.1.1	Acquisition preparation process	Component			
1.2.4	Project environment definition	X	X	CUS.2	Supply process	Basic			
1.2.5	Initial planning preparation	X	X	MAN.2	Project management process	New	Supply process|Acquisition preparation process	¥	
1.2.6	Cost-benefit analysis	X	X	CUS.1.1	Acquisition preparation process	Component	Supply process	¥	
1.3	Revisit contents	X	X	CUS.1.2	Supplier selection process	Component			
1.3.1	Initial planning refinement	X	X	CUS.1.2	Supplier selection process	Component			
1.3.2	Standards adoption	X	X	CUS.1.2	Supplier selection process	Component			
2	Data base design	X							‡
2	Data warehouse design		X						‡
2.1	Data base design preparation	X		CUS.1	Development process	Basic			‡
2.1	Data warehouse design preparation		X	CUS.1	Development process	Basic			‡
2.1.1	Data source study	X	X	ENG.1.1	System requirements analysis and design process	Component			
2.1.2	Event analysis		X	ENG.1.1	System requirements analysis and design process	Component			‡
2.1.3	Storage capability estimation	X	X	ENG.1.1	System requirements analysis and design process	Component			
2.2	Data base design	X							‡
2.2	Data warehouse design		X						‡
2.2.1	System architecture definition		X	ENG.1.1	System requirements analysis and design process	Component	Supply process		‡
2.2.2	Logical model design	X	X	ENG.1.3	Software design process	Component			
2.2.3	Physical model design	X	X	ENG.1.3	Software design process	Component	Software construction process	¥	
2.2.4	Data source analysis	X	X	ENG.1.5	Software requirements analysis process	Component	Software design process		
2.2.5	Interface design	X	X	ENG.1.5	Software requirements analysis process	Component	Software design process		
2.2.6	Architecture components analysis		X	ENG.1.1	System requirements analysis and design process	Component			‡
2.2.7	Revisit component specification		X	CUS.2	Supply process	Basic			‡
2.2.8	Standard packages evaluation	X	X	CUS.1.1	Acquisition preparation process	Component	Supply process	¥	
2.2.9	Data quality strategies definition	X	X	MAN.3	Quality management process	New	System requirements analysis and design process	¥	
2.2.10	Inherited components integration study	X	X	ENG.1.1	System requirements analysis and design process	Component			
2.2.11	System initial documentation	X	X	SUP.1	Documentation process	Extended	Software design process		
3	Architecture components implementation		X	ENG.1.4	Software construction process	Component			‡
4	System integration study	X	X						
4.1	System integration planning	X	X						
4.1.1	Participants identification and organisation	X	X	ORG.3	Human resource management process	Extended	Software integration process	¥	
4.1.2	General planning	X	X	MAN.2	Project management process	New	Software integration process	¥	

‡ Process not common to DB & DW ¥ It can be mapped to different processes

Figure 3- EMEDITA vs. SPICE

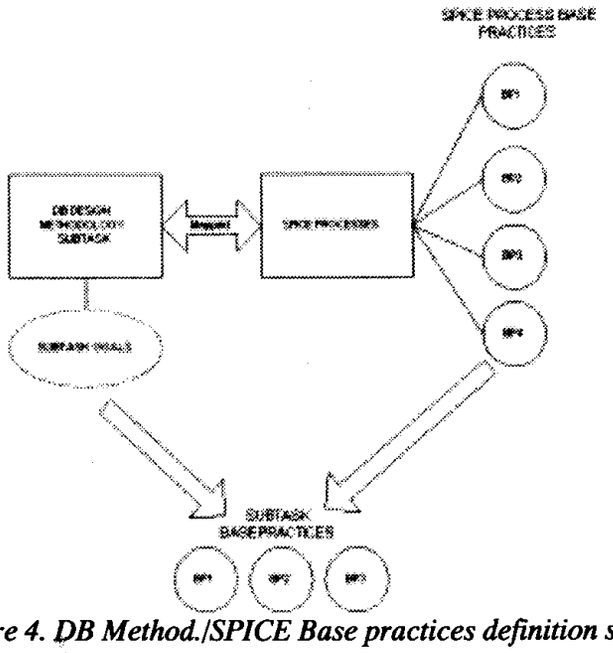

Figure 4. DB Method./SPICE Base practices definition strategy

2.2. Work products Mapping

One of the main differences between SPICE and EMEDITA DB design methodology is work products. SPICE defines a set of inputs and outputs for each process in a general-basis. Thus, what base practices will need or produce is determined in general terms for conventional software modules. This general-basis results in a lack of DB specific products.

Spice work products are associated with processes. Hence ENG 1.3, has as work product inputs: software requirements, system design/architecture and customer documentation. It is far beyond doubt that these inputs are also inputs in the DB design stage, but they do not have the same characteristics. It cannot be taken for granted that these work products are representative of the DB context without defining their specific characteristics. As a matter of fact DBs main difference with other conventional software modules is based on the information that requirements, architecture and customer documentation shall contain.

Moreover there are other activities in the DB context that SPICE do not take into account, basically because they are specific of DB, such as Data quality. This is a task that must be performed in stage 1 of the DB design Phase, being an input of stage 2. This task unknown for SPICE and its results are, therefore, missing. A justification of why this task should be considered can be found in [Garbajosa, 2000].

Stage	Task	Subtask	Practices
1. DB design	1. First design approach	1. Entity identification	1. Entity determination and description
		2. Relations identification	1. Relation determination and description
		3. Attributes identification	1. Entity Attributes determination
		4. Keys identification	1. Entity keys determination
		5. Conceptual design	1. E/R model
			2. External schema design
		6. Documentation	1. Documentation
	2. Transactions design DBMS independent	1. E/R revision	1. Documentation study
			2. E/R modification
		2. Transactions design	1. Transactions specification
		3. Documentation	1. Documentation generation
	3. DBMS choice	1. DBMS choice	1. DBMS election
			2. Customer validation
			3. Documentation
	4. Logical design	1. Normalise and design changes	1. Initial tables definition
			2. 1FN
			3. 2FN
			4. 3FN
			5. FNBC
			6. Practical changes study
			7. Perform necessary changes
			8. Documentation
		2. E/R final diagram	1. Obtain E/R final diagram
		3. Obtain tables	1. Obtain tables with key and attributes
			2. Documentation
		4. Integrity study	1. Attributes domain definition
			2. Insertion and deletion constraints
			3. Insertion and deletion rules
			4. Triggers study
			5. Documentation
		5. Specific logic design	1. Data and constraints definition according to the DBMS
			2. DB creation sentences definition
			3. Documentation
	5. Physical design	1. Physical design	1. DB Store files definition
			2. Files location
			3. Query frequency study
			4. Index election
			5. Documentation
	6. Design Verification	1. Design verification	1. Documentation study
			2. Design formal approval
			3. Documentation

Figure 5 – DB design stage practices

Subtasks	SPICE process	Base practices	SPICE base practices
Entity identification	ENG 1.3: Software design process	Entity determination and description	BP1: Develop SW architectural design
Relations identification		Relations determination and description	
Attributes identification		Determine entities and relations attributes	
Keys identification		Entity keys determination	
Conceptual design		E/R model, External schema design	
E/R revision		E/R modification	BP3: Detailed design
Transactions design		Transactions specification	
Normalise and design changes		Get initial tables, 1FN, 2FN, 3FN, FNBC, changes.	
E/R final diagram		Obtain E/R final diagram	
Obtain tables		Obtain tables with keys and attributes	
Integrity study		Determine attribute domains Constraints study, rules, triggers	
Specific logic design		Data and constraints definition according to the DBMS DB creation sentences definition	
Physical design		DB store files definition, Files location, Query frequency study, Index election	

Figure 6 – Mapping with SPICE processes and base practices

The outputs that SPICE proposes for ENG 1.3 comprise the Database design work products. As this paper is illustrating, the level of complexity associated with a DB design deserves a deeper level of detail than just a general overview. Moreover, outputs in a DB design depend much one on each other, and are essential in each stage. Therefore to lack or to miss-produce one of them would result in a negative assessment. Hence, the more outputs are explicitly defined in the reference model the better the assessment will be done.

The outputs that each practice shall produce are represented in figure 7. None of them is explicitly referenced in SPICE. On the other hand DB work products are easy to define without the help of SPICE. Let us take, for instance, the base practice Transactions specification. It is obvious that the work product for this base practice will be a group of Transactions. However it is true that there is a lack of guidance to characterise what properties a good transaction should have, what shall be essential in an assessment and what SPICE should support from our point of view.

PRACTICES	WORK PRODUCTS
Entity determination and description	Entities within the DB
Relation determination and description	Relations among entities
Entity Attributes determination	Attributes
Entity keys determination	Keys
E/R model	E/R first approach
External schema design	External schema
E/R modification	E/R improvements
Transactions specification	DB Transactions
DBMS election	DBMS choice
Initial tables definition	Initial tables
1FN	1FN Tables
2FN	2FN Tables
3FN	3FN Tables
FNBC	FNBC Tables
Obtain E/R final diagram	E/R final diagram
Obtain tables with key and attributes	Tables with key and attributes
Data and constraints definition according to the DBMS	Constraints
DB creation sentences definition	Creation sentences
DB Store files definition	DB Store files
Files location	Location
Query frequency study	Frequency
Index election	Index

Figure 7 – Base practices and work products

3. Conclusions

The first conclusion that we can draw is that the mapping of a generic DB design process onto the Spice reference model is not that easy. We have used a specific but general and powerful methodology EMEDITA, but results should not change much from one methodology to another. Actually we understand that DB design tasks have not been fully contemplated within SPICE. We could say that DB design tasks would feel at ease in SPICE but it would not be easy at al to identify them in such a context.

As far as base practices are concerned, a conceptual problem arises. In the mapping, for SPICE base practice *Develop software architecture* there was a need to compare the architecture concept to conceptual design. It seems that it is possible to integrate both ideas. However the uncertainty still remains, because this mapping is forced by the need of expressing the methodology with SPICE, overlooking the lack of accuracy in this decision.

This inflexibility is a consequence of the great difference among DB systems and conventional software modules design that, from our point of view, SPICE does not address.

Work products have represented the most difficult part of the mapping. Some of those of SPICE turned out to be valid for the DB methodology, but the characteristics were completely different for the SPICE specifications.

Some other DB work products did not appear at all in SPICE as the base practices that produce them were also missing. An important case was Data Quality, a difficult practice for which SPICE offers no guidance to perform an assessment. We are also studying this issue more in depth.

We believe that the SPICE process dimension lacks from a number issues required if we want to apply SPICE for the assessment of DB design processes. It may fail to ensure that assessments following its guidelines are taking into consideration all the needed good practices.

On the other side SPICE structure would support well the extensions that we suggest it might interesting to introduced.

Acknowledgements

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