ARCHITECTURE OF A GRAPHIC INFORMATION SYSTEM FOR REDESIGNING TASKS AND WORKFLOW MANAGEMENT IN CERAMIC TILE DESIGN ENVIRONMENTS

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ABSTRACT

The present work seeks to address the feasibility of applying the design approach known as "Concurrent Engineering" to the field of textile and ceramic design. For this purpose the specific problems of these industrial sectors are analysed, and some performance lines to achieve this objective are proposed.

This work is a continuation of a research line that deals with the development of specific design tools adapted to the concrete needs of these industrial sectors. These tools have been developed in the context of the research project FECETEX (Ref. at foot of page 5), which has yielded the preliminary version of the Design Pattern Information System (SIMOD) application.

SIMOD is a data management system generated by the processes involved in the design phase of a ceramic or textile product. It presents a modular architecture, and provides two types of functionalities. On the one hand it implements decorative pattern editing, cataloguing and analysis functions to support the creative processes of the design department (SAEMOD module) and a database management system with specific capabilities for managing these decorative patterns (SIGRID module).

Starting with the SIMOD system, it is sought to expand its architecture to incorporate the basic functionalities of a product data management (PDM) system focused on managing the textile and ceramic design process. For this, a new so-called CLIECOL (Collaborative Client) system module is defined, which integrates advanced editing tools for exploiting the decorative pattern database, and which facilitates the work of the design team.

The development of this new module involves formalising the design process followed in the textile and ceramic sectors. For this an activities modelling methodology, IDEF0, is used, which provides the necessary information for the definition of the architecture of the supporting PDM system for collaborative design.

1. DESIGN METHODOLOGIES

The development of new products is an essential activity for the survival and competitiveness of a company. Different strategies exist for improving the new product development process, but most of them focus on fostering the role of design and shortening the product development cycle. Available tools for achieving these objectives include: *Concurrent Engineering, Total Quality Management (TQM), Failures and Effect Modal Analysis (AMFE), two or three-dimensional CAD, Value Analysis, Competitive Evaluation, etc.* Of all these techniques two stand out at present: concurrent engineering and value analysis:

> Value analysis, according to Guinjoan and Pellicer [1], is a technique for reducing company costs and increasing product value in the design phase. To meet this objective it uses a set of basic elements: The industrial product or process, the need for it, the functions that it will carry out to satisfy the detected needs, product cost, and product value (degree of utility divided by cost).
>
> Concurrent engineering fosters the idea of teamwork, i.e., pursues the development of the so-called collaborative design environment. With this technique integration of design is sought with the rest of the company's primary activities (production, marketing, logistics, etc), since product final cost depends on these interactions [2]. This technique already constitutes a common approach in industrial sectors such as the automobile or aeronautical industry, and it has given rise to the enormous development of Product Data Management (PDM) Systems [3]

While value analysis focuses directly on aspects relating to product development cost, concurrent engineering does so indirectly, integrating the different aspects of product life cycle from the initial phases of the design process.

2. SEQUENTIAL ENGINEERING VS. CONCURRENT ENGINEERING

The traditional design method consists of a sequential development process (Figure 1), which typically begins with the determination of certain needs through market analysis. The range of prices and performances desired by potential consumers of the new product is thus found. This information is transformed into a series of specifications that allow the Design Department to define product characteristics (materials, shapes, geometries, etc.). After elaborating the whole design documentation, this is distributed to the other departments of the company (Production, Sales, etc.) with the ultimate objective of putting the new product into the consumer's hands as soon as possible.

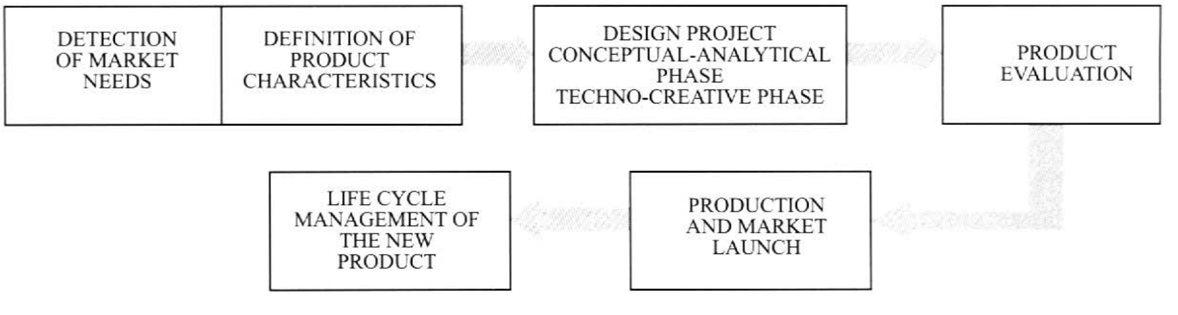

Figure 1. Sequential Engineering: Generic phases of the product launching process.

The traditional method defines a sequential process in which different players intervene, each with different objectives. In this case, designers are mainly interested in the functionality and performance of their products, and they very rarely take into account or consider the production processes. This avenue does not allow any exchange of ideas among the users that could affect the product development process, except on highly sporadic occasions, usually associated with the impossibility of meeting some technical requirement fixed in a previous process phase.

Design is therefore carried out in relative isolation among the different departments involved. This methodology could be termed Sequential Engineering, and as a result of its way of working, any later change in the original design causes delays and additional costs. Moreover, the most serious feature is that a great number of modifications and alterations take place in the last stages of the product development phase, precisely when these are most expensive and difficult to incorporate, since in many cases investments have already been made in production means. The costs of carrying out modifications in the design increase logarithmically the later this is done in the work in progress in the product life cycle. For this reason, it is important that the entire functional, structural and technical requirements of the whole product life cycle are included during the design phase, to avoid such problems.

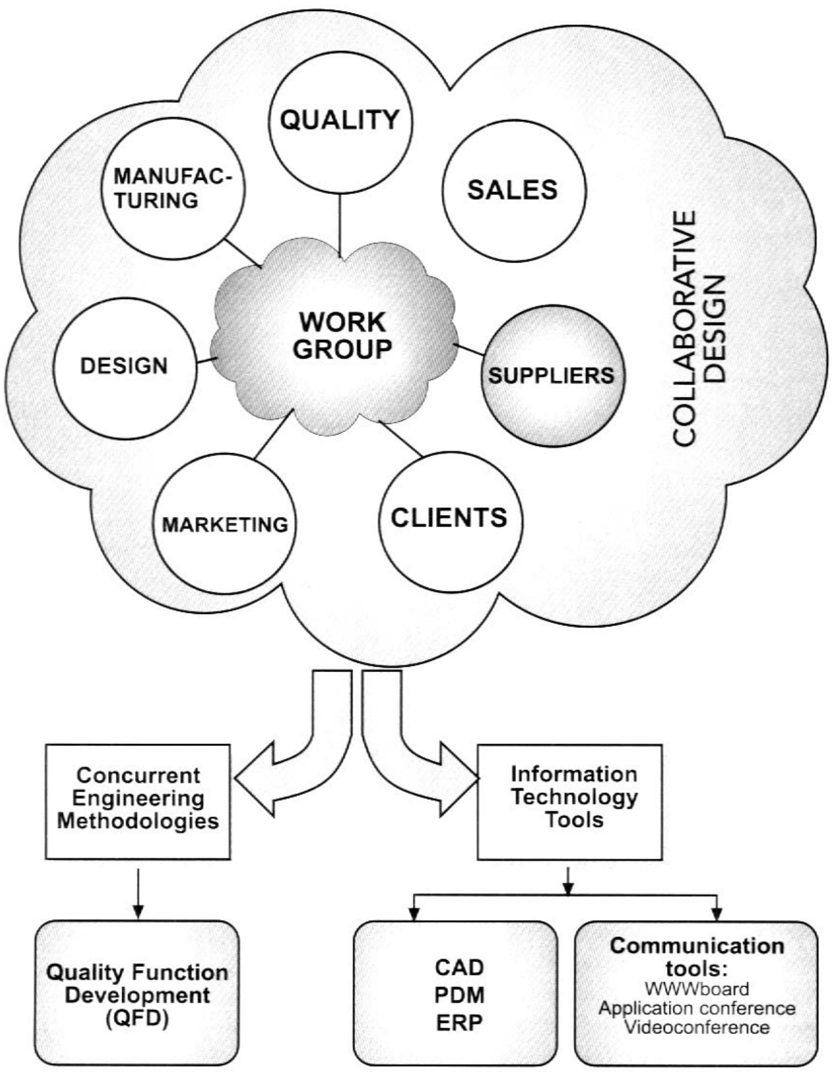

Figure 2. Collaborative Design Model based on Concurrent Engineering.

The foregoing highlights the importance of design for the future of the company, a circumstance that is verified if we consider that this stage accounts for approximately 5% of total product cost, while however the decisions taken in this stage determine 70% of product cost.

We thus need to reinforce design and provide the tools that will allow all the elements present in the full product life cycle to appear in design. This requires simultaneity and concurrence of design activities. Design for a product life cycle should consider all the stages that a product goes through from its conception to its withdrawal.

Concurrent Engineering seeks integrated product development through the creation of multidisciplinary teams in which all the elements of the company's production structure are represented (Figure 2). Important aspects for success in implementing this work approach include:

- Accurate determination of client needs. For this, there are methodologies such as quality function development (QFD).
- Taking into account production processes through their corresponding design considerations. For this there are a multitude of "Design for X" (DfX) techniques.
- Using Information Technologies, as supporting elements for teamwork. For this, of enormous interest are the product data management (PDM) systems.

The main benefits of Concurrent Engineering can be summarised as follows:

- Tight integration of departments.
- Improved control of design and production costs.
- Shorter product development times.
- Heightened competitiveness in all senses

3. PRODUCT DATA MANAGEMENT (PDM) SYSTEMS

Product Data Management (PDM) Systems provide the infrastructure that allows the design team to put into practice the Concurrent Engineering work approach. These systems can in the most general case include modules or subsystems that address part of the needs appearing during the product development cycle. These parts or elements could be classified as follows:

1. Design process management system
2. Management system for engineering changes
3. Management system for product configuration
4. File system and electronic forwarding of documentation.

Most of these systems have a structure (Figure 3) based on information management in three different environments. On one hand, a characteristic work area for each user, in which the user does his daily work, and to which only he has access. When the user considers that the work carried out on a certain object no longer needs to be his exclusive possession, this object can then be shared with other users through the common work area (work group). Lastly there is a general store for objects (vault), where the objects are kept that are considered to have reached their final state, and where they are to be kept.

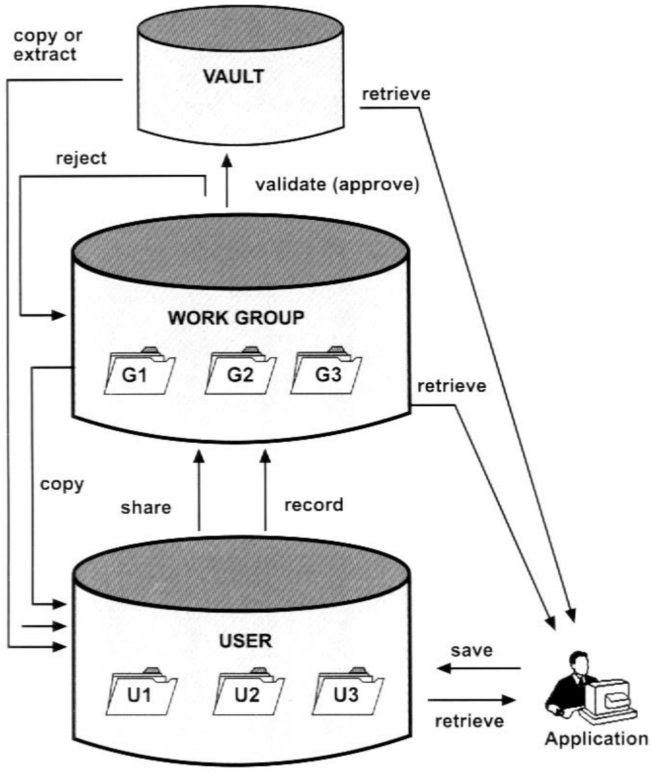

Figure 3. Generic structure of a PDM system.

Most PDM systems at least offer tools for design process management. For this it is necessary to define the possible states or reviews ("release levels") through which a design can pass during its development cycle from conception to final definition. The elements that make up the design usually also have an additional attribute, such as the version that would correspond to the different iterations an object passes through during its definition in a certain review.

To facilitate collaboration among the different members of the work team, it is necessary to define a series of parts or roles in order to reflect electronically the dynamics of a real work team. For this, some rules for accessing the objects in the database are defined, depending on the state of the design and of the user's role.

Apart from basic design process management functions, some systems provide support in implementing modifications in the design (also known as engineering changes), which arise during the product development process. When the need to make a change is detected, it is necessary to communicate this information to the person that should carry out the task, to provide him with the necessary supporting information, and to monitor the modification.

Another subsystem found in many PDM systems is product configuration management. In the case of products that have a complex configuration, i.e. which present a high number of variants or configurations, these tools facilitate management of the lists of product pieces and variants. Lastly, another type of functionality present in these systems is the filing and electronic forwarding of documentation. This enables exploiting the advantages of a PDM system, by later reusing the information associated with the design of a product. For this reason, most PDM systems provides modules for long term information storage ("vaulting") and tools to carry out searches for objects in the data store or vault.

To be noted among the advantages of implementing a PDM system are:

- Eliminates the search process and re-creation of lost or not misplaced data.
- Facilitates the flow of information in the work group.
- Eliminates time spent working with outdated information.
- Provides an active notification system to keep the members of the team informed.
- Allows geographically dispersed teams to work together.
- Development time and overall costs can drop significantly.

4. APPLICATION OF THE CONCURRENT ENGINEERING CONCEPT IN THE TEXTILE AND CERAMIC SECTORS

In the sectors that we are dealing with, namely ceramics and textile, there are some specific characteristics that establish clear differences with regard to industrial sectors that are successfully applying the "Concurrent Engineering" work approach. On one hand, the design phase has certain differentiating characteristics compared with that of other sectors where this methodology has been applied with success. A pronounced difference is that unlike other industrial sectors, much design information is still handled in non-digital formats. This is an obstacle to using computer tools to facilitate design process management, because a basic requirement is having all the information in a digital format. Furthermore, the type of computer applications used in these fields, usually general purpose computer tools, such as photographic retouching and graphic design applications, do not usually have specific modules for product data management. Instead this management is directly in the users' hands, with the corresponding problems of working with outdated information, difficulty of file searches and risk of data losses.

Therefore, it is therefore necessary to lay the groundwork that will enable developing tools to facilitate the creative work of the designers, and management of the arising flow of information generated during the design process.

To be mentioned in this context is the work carried out in the FECETEX[1] project, in which *SIMOD (Design Pattern Information System)* has been developed. Set up initially as a system for cataloguing and editing decorative patterns, at present time it is a platform for a feasibility study on the incorporation of a design methodology based on the concept of concurrent engineering, applied to the textile and ceramic sectors. For this, two lines of work are being followed:

Line 1: Modelling of the processes

- Analysis of current design activity using IDEF0 models [4] in order to show how the information flows and is transformed across a set of design process-related activities.
    - Organisational Aspects. Analysis of the organisational structure of the company.
    - Analysis of the Information Flow of Product data.
    - Relation with suppliers, subcontractors and clients.
    - Type of information.
    - Data exchange mechanisms.
    - Analysis of developed product characteristics.
    - Analysis of Product Life Cycle.

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Line 2: Definition of product data management (PDM) system architecture

- Definition of the possible design states:
  - Definition of the possible states ("releases levels") through which a design can pass in its development cycle, from conception to final definition.
  - Definition of review and version attributes
- Definition of the parts (roles) of the design team members:
  - Definition of parts or roles that allow electronically reflecting the dynamics of a real work team.
- Definition of access rules as a function of the state of the design and role of the user.
- Definition of transfer rules between the user's local workspace, the workspace of the work group and the data vault.

5. SIMOD ARCHITECTURE

Next we will describe the modular architecture of the *SIMOD* system, which will serve as the infrastructure to a new module aimed at facilitating the design work by applying the "Concurrent Engineering" approach. For more information on *SIMOD*, please consult the communication [5].

SIMOD is conceived as a system mainly for the design department. It is usual that in this environment, several workstations will need to access the same source of information at the same time. It is also obvious that some *SIMOD* modules can be of interest for other company departments, which also access these. This way of concurrent, distributed work is solved in computer systems in many ways: distributed components, via the *Web* and Client/Server, to name but a few. An example of a *Web*-based Information System is found in the presentation of engineering projects [6]. The combination of the *Web* and the language used, VRML (Virtual Reality Modelling Language) allows users to obtain numerical data and graphics of the required engineering model together.

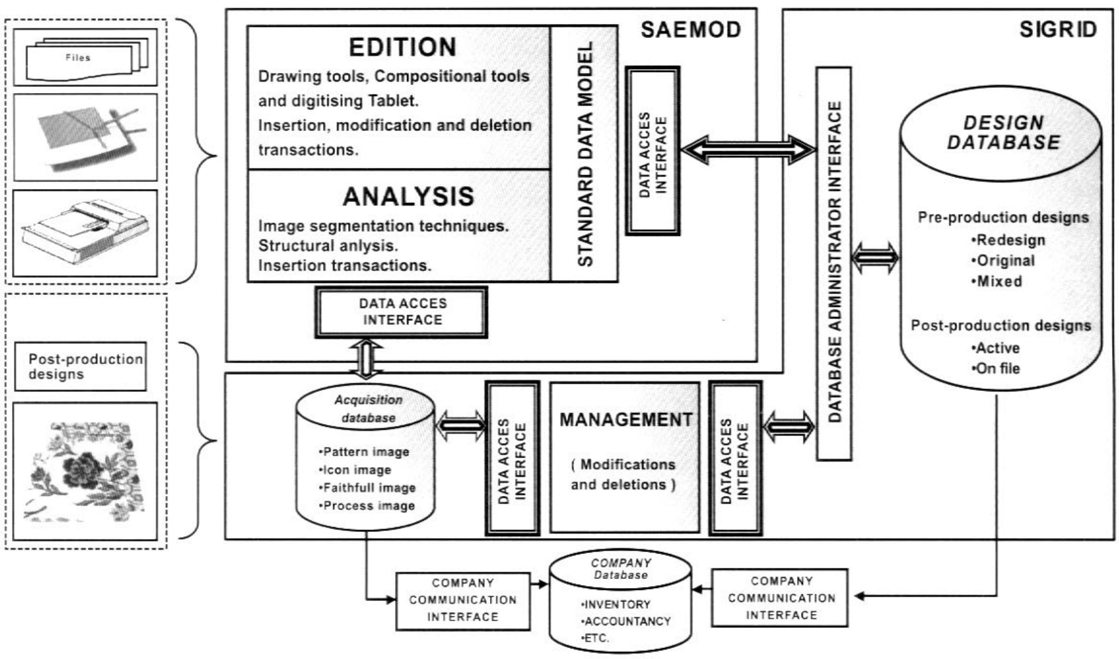

Figure 4. SIMOD architecture .

We have opted for a Client/Server architecture for two main reasons: First, it is the way of working most widely found in the literature, therefore ensuring its operativeness [7]. In the second place, although the system will be implemented initially in a local net environment, the architecture and technology used will enable scaling the system for the Internet, if this should be desired in the future. Figure 4 sets out the simplified architecture of *SIMOD*. It shows the modular structure of the system:

SAEMOD module: *Design Pattern Analysis and Editing System*. This module implements two independent applications and it forms the Client application.

Analysis Tool: This is the environment for comprehending the digitised designs. It consists of a set of operators with a specific purpose for analysing and cataloguing the designs, and another set of transactions with the database. This module is explained in detail in the communications [8,9].

Edition Tool: This is the editing environment of the information stored in the DB, where the expert designer can retrieve technical information under a controlled interrogation language. This environment will provide a set of working operations to generate new designs based on existing ones.

SIGRID module: *Design Information Retrieval and Management System*. This is made up of the set of implemented Databases (relational entities, integrity restrictions, etc.), and what we have called their *Management Tool*. Now we shall go on to explain in more detail the characteristics of this module that manages the design store or vault.

6. SIGRID MODULE

In every industrial process it is usual to find information of common interest to different users. Multiple access is usually solved by centralising the information. In the textile environment there are studies that solve this problem in departments such as that of production [10]. During the production process a set of parameters is stored automatically, while others need to be keyed in at a computer. In our case information for the design process is involved, and just as in the study mentioned, a great part of the information is stored automatically in the existing DB, while another part needs to be entered by the user.

The graphic data management and retrieval system constitutes the Server application that will be installed in a dedicated machine, which therefore centralises the information. The minimum functions that the server needs to provide are assured by the selected database management system (SGBD) itself, Microsoft SQLServer. These functions are:

Resource administrator

Security administrator

Data administrator

Consultation administrator

Database system administrator

Error administrator

The relational DBs have been and continue to be widely used as image databases, in traditional areas ranging from medicine and education to the most modern areas such as e-commerce [11,12,13,14].

SIGRID consists mainly of two independent DBs implemented with a Management System (SGBD) that follows the *Entity-Relation* model, and a user application dedicated to DB management.

Acquisition Database: This is the basic management and storage system of fabric and tiling images. It is the company image bank. Each design is represented by a set of related registers containing information on the acquisition process and file references in a bit map. For each design a constant number of necessary images has been obtained for pre-processing and inventorying. A User's Method has been drawn up, in which the whole process is described for digitising the textile or ceramic design resources of the Companies. This document is divided in three sections: The tools used in the system, description of the typology of the images to be acquired and the steps to be followed in the process.

Design Database: This is the basic management and storage system of the scientific-technical information on the industrial designs. Each design is represented by a set of related registers, so that at one address the synthesis of the design is defined and at another its analysis.

Although the *SGBD* facilitates most of the tasks such as: creation of tables, validation rules, integrity rules, triggers, views, stored procedures, security and copies, there are others that need to be implemented in a user's application:

Management Tool: This is an environment of database information administration, independently of the graphic pattern analysis and design. Its fundamental objective is maintenance of the data and control of errors made by users in their interaction with the database.

6.1. DESIGN INFORMATION TYPOLOGY

The typology of the information handled by the system, will on the one hand be the retrieved information of the SIGRID module by means of a user-friendly search system by content, and on the other hand, direct input by the user through an Edition module. We can establish a design classification based on their situation regarding the production process. Thus the designs to be stored in the database are classified in two big groups: *pre-production* and *post-production*.

A *Post-production* design in the database is a set of registers that represent a product (fabric or tiling) already manufactured at the company, previously digitised to form part of the computer system. These in turn can be:

Active designs: all the designs being used in the current year and those of previous years that are commercially productive, the rest being designs on file.

Designs on File: the remaining designs that the company keeps as private resources and to which recourse is had on occasions for redesigning purposes.

In this case there is no information on the origin of the design. The input to SIMOD is direct after digitising and comprehending the design through the Analysis tool.

A *Pre-production* design is a set of registers relative to a new design generated from the computer system and which is therefore a potential company product. These in turn can be:

- Redesigns. Generated from the primitive ones stored in the Design DB
- Original Designs: Generated from scratch, either with Editing tools alone or in combination with patterns from a peripheral data input.
- Mixed Designs: Generated from a combination of design elements from different sources (database, digitising tablets, etc)

Table 1 shows the relation of possible designs with the different elements that will participate in the process:

SUBTYPE	EXTERNAL DATA			EDITING TOOL			ANALYSIS TOOL	DB OUTPUT
	SCANNER	TABLET	CAD	DRAWING TOOLS	DIGITAL TABLET	COMPOSIT. TOOLS		
REDESIGN						X		X
ORIGINAL DESIGN	X	X	X	X	X	X	X	
MIXED DESIGN	X	X	X	X	X	X	X	X

Table 1. Characteristic of possible Pre-production Design subtypes.

6.2 USERS

The planning study detected three types of potential users and their access permission to the databases, in terms of their functions and the applications with which they interact. Table 2 sets out these relations.

- *Technical User*: this is the most important user and for whom the implemented System is designed. He is the expert designer, and therefore has the technical and scientific knowledge required to interrogate the system by means of a Controlled Language and to exploit the implemented design tools.
- *System Administrator*: this is the person directly in charge of data maintenance and correct operation of the system.
- *External User*: Any member of the company with permission to access the design database. He is a user for whom views of the data are defined, according to his information needs. His interaction is usually not from one of the SIMOD interfaces, but from the company computer system's characteristic environment.

USERS	APPLICATIONS	FUNCTIONS	ACCESS PERMISSION
TECHNICIANS	EDITING TOOL DB DESIGN	Industrial redesign Technical consultation on Design, statistics, analysis, etc.	Operations in a single active register: Insertions Modifications Deletions Joint operations
SYSTEM ADMINISTRATOR	ACQUISITION DB DESIGN DB MANAGEMENT TOOL	Correction of erroneous data input by the user Data updating Administration of DB accessing permission General maintenance of the System	Total Access Permissions at all User Levels. Control of restrictions is at SGBD level.
EXTERNAL	Set of views of DESIGN DB provided by the company's own Application	Functions inherent to each existing department: Sales Administration Management	Joint operations Reading

Table 2. SIMOD functions, interacting applications and user access permission.

7. PROPOSAL OF A COLLABORATIVE ENVIRONMENT FOR DESIGN TASKS IN THE CERAMIC AND TEXTILE SECTOR

Implementing a design methodology based on the Concurrent Engineering concept usually requires having a series of design tools in place to facilitate teamwork. In the context of the SIMOD Design Pattern Information System set out above, the possibility has been detected of extending the initial architecture of the system to support a basic PDM functionality for design process management. For this, it is sought to develop a *Collaborative Design Client (CLIECOL)* for textile and ceramic industry production (Figure 5).

The main objective of CLIECOL is to provide the design tool (*SIMOD Edition* module) with the capacity to access the mass of information generated during the design process, in an organised way. For this, CLIECOL will afford a functionality that allows managing the workflow inside the design department and will also facilitate design retrieval under a controlled industrial design vocabulary.

CLIECOL will be bounded in the SIMOD, so that it will provide the *Edition* module, now called *Design*, with a communication capacity with three data access levels:

- Local level, where the user does his daily work
- Work group level, where the user shares his work with the rest of the members of his design team
- Design database storage level, where the company design resources are stored (SIGRID module, Figure 4), both the already produced designs and those awaiting production.

Access to the three levels will be conditioned by the capacities assigned to the different user types, establishing a conditional access that can also vary depending on the level of updating ("release level") of the objects in the database.

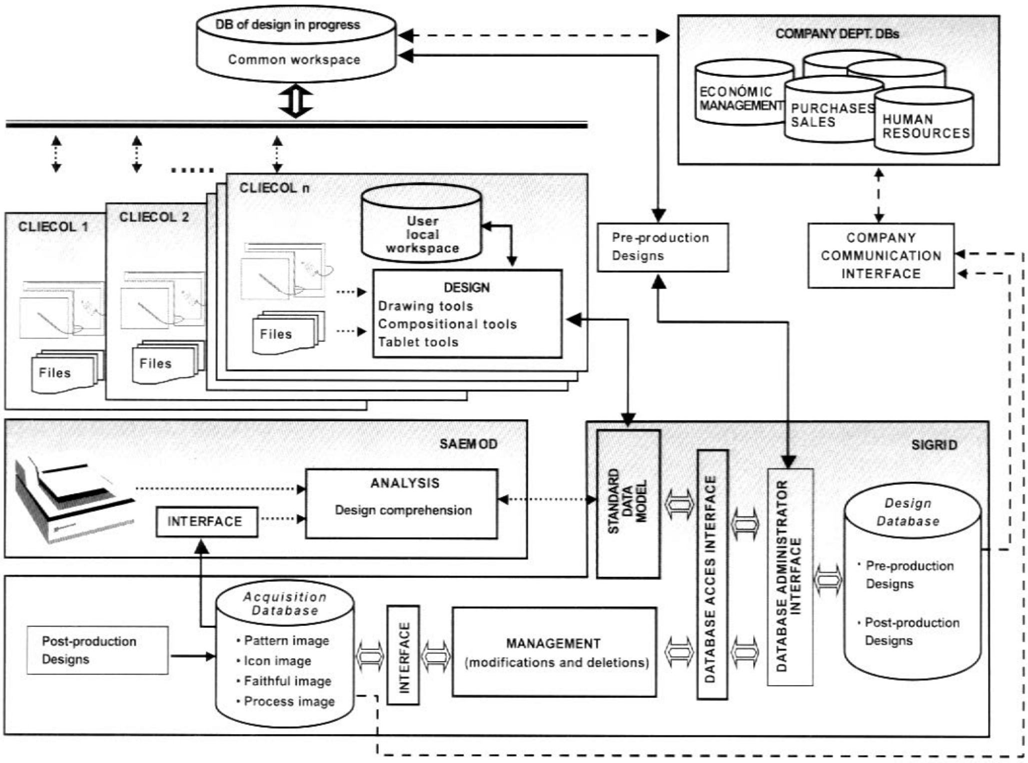

Figure 5. Collaborative environment architecture for redesign tasks in the ceramic and textile industry.

The proposed system meets the theoretical expectations of an environment that supports a design methodology based on the Concurrent Engineering concept. We have integrated a basic product data management (PDM) functionality in such a way as to enable a team of designers to address in parallel the development of a design project. The three-tier architecture: local, group and vault facilitates parallel organisation of different tasks in the team, allowing thorough control of the workflow. This functionality, supplemented with an advanced edition tool, will allow exploiting all the potentiality of the SAEMOD and SIGRID modules at present available.

8. CONCLUSIONS

Since the capacity to develop new products is a factor that places companies in a competitive position in the marketplace, companies are directing their efforts towards improving the product development process. The common objective of the different existing strategies is to shorten the product development cycle. Of all the phases of this cycle, the design phase is the most time consuming.

Of all the existing techniques to improve the design phase, we have selected so-called Concurrent Engineering, as it is currently the most outstanding technique.

The problem of the ceramic and textile industrial sectors has been analysed to enable applying the collaborative work environment advanced by Concurrent Engineering. In this analysis two obstacles have been detected, namely: the quantity of design process-related information not stored in a digital format, and the non-existence of a product development data management process.

As a result of this analysis two lines of action have been defined:

- *Lines 1: Modelling of processes*
- *Line 2: Definition of a product data management (PDM) system architecture*

In the frame of this second line of action, to define the *PDM* architecture, we have used a Design Pattern Information System (SIMOD). SIMOD is a system developed in a research project whose objective was to create a system for cataloguing and editing decorative patterns.

A first approach has been set out for the PDM Planning process, defining user profiles and the typology of the information handled by the system.

SIMOD's dynamic, modular architecture has enabled it to be adapted for a first collaborative environment proposal, giving rise to a new module called CLIECOL *Collaborative Design Client.*

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