DIGIMOULD -DIGITAL MOULDING FOR THE CERAMIC INDUSTRY- A CONTRIBUTION TO MASS CUSTOMIZATION

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ABSTRACT

The present paper sets out the objective of the European project "DigiMould- Digital Moulding for the Ceramic Industry- A Contribution to Mass Customization". The project deals with applying the concept of "mass customization" to ceramic production, thus attempting to improve the competitiveness of the ceramic industry in international markets. The term "mass customization" can be described as the process that enables "manufacturing each customized individual product (according to the requirements and preferences of the client) as rapidly as standard products (in the catalogue) without involving additional costs". At present, this concept has been applied successfully in other sectors, such as the textile or footwear branch. The project focuses on "mass customization" of ceramic borders and ornamental ceramics and tableware (vessels, teapots, jugs, cups, etc.). In order to apply "mass customization", a new design process and new production technologies are required to perform all the steps involved, from the definition of ceramic design to the production of the mould for this design, as automatically as possible. The project consists of developing these new design processes and technologies, by designing a prototype capable of maximizing the automation of mould production for the manufacture of the customized ceramic item. With this project, the manufacturers will have the possibility of offering their clients high-quality, customized products.

1. INTRODUCTION

Competitiveness in the ceramic industry is determined by the industry's ability to react quickly to market changes. Products with distinguishing features and high quality typically have better market prospects.

Market success due to fast production times without high costs can only be achieved by applying innovative methods and processes, from product design to its mass production. Considerable progress has been made in recent years in developing fast CAD/CAE technologies and prototyping. While the use of these procedures, and in particular fast prototyping, has certainly led to successful results in certain subareas, the constraints in the processing of photopolymer materials properties currently still cause models to be made, first as examples and then as prototypes, according to conventional methods with ensuing high costs and high lead times. New procedures for producing prototypes therefore need to be developed.

Moreover, clients increasingly demand products that stand out because of a high degree of customization in addition to high quality, low price and short delivery times. These types of products and services can only be achieved by modern production methods and a policy of mass customization, which is the approach followed in other sectors, such as the textile or footwear branch.

The expression "mass customization" combines two contradictory terms, namely "mass production" and "customization"[1] [2] [3] [4] [5]. Stanley Davis created this term in his book "Future Perfect". Taking the textile industry as an example to start with, he described the phenomenon of customized production for the first time. According to Davis, "mass customization" means that "each customized t-shirt is made as quickly as identical t-shirts with no additional cost for this reason". In a research study at MIT (Massachusetts Institute of Technology), B. Joseph Pine first investigated "mass customization". In 1993, Pine presented his results in his book "Mass Customization". Pine can be considered the intellectual father of "mass customization" and is at present the most important advocate of this concept, not only in theory but also in practice, since via his consulting company "Strategic Horizons", Pine has helped numerous companies advantageously implement the principles of "mass customization".

In line with this approach, the European project DigiMould(*) (project number CRAFT-1999-70784) has developed a system for the automatic production of moulds for ceramic products - tableware, borders, ornamental ceramics, etc. - taking into account the requirements for implementing mass customization.

(*)This European project is being conducted by a consortium made up of five companies (SMEs) and four technological Institutes. The SME participants in the project are: Neue Keramische Werke Haldensleben GmbH (Germany), TOZETO S.L (Spain), GPK-Neuhaus Schmidt & Henkel GbR (Germany), Ingeniería P.C. (Spain) and S.D.I. Engineering Hes a Spol. (Czech Republic). The participating technological Institutes are: Alicer, Centre for Innovation and Technology in Industrial Ceramic Design (Spain), ITC-AICE, Instituto de Tecnología Cerámica (Spain), Fraunhofer Institute for Factory Operation and Automation (Germany) and Fraunhofer Institute for Production Systems and Design Technology (Germany).

In general, putting "mass customization" into practice, particularly in ceramic production, requires satisfying the following requirements during manufacture:

- The products that meet the different needs of each individual demand must have a (relatively) broad market.
- The cost of customized products must correspond approximately to standard mass-produced product costs.
- Through communication with each individual client, mass customization fabricates products that exactly meet specific customer needs. This means that each product made can be unique.
- The process adopted for mass customization must be the simplest possible process for the clients.

Applying the foregoing requirements to ceramic manufacturing requires developing a new design process and new production technologies to enable the process to be as fully automated as possible, from the definition of mould design to the production of this mould.

In DigiMould, the mould can be defined in different ways. If a physical model is available, this can be digitized using an optical device (digitizer). If such a physical model is unavailable for reproduction, the model can be designed or modelled using modern CAD tools. The problem with these tools is that they usually require specialist knowledge, which can only be acquired after intensive training with this tool. For this reason, to enable the client (who may not be acquainted with these CAD systems) to design his own model, the project has developed a CAD tool. This CAD tool, which works on the Internet platform, allows designing ceramic pieces in a simple, user-friendly way, taking into account all the technical requirements that a piece must satisfy to enable it to be subsequently demoulded in a transparent way for the user. The CAD tool is the key to mass customization, since the client must be able to design the piece by himself, without requiring prior knowledge of CAD tools and their use in the ceramic sector. After the desired product has been designed, and with it the mould to be created, the mould needs to be made. In order to make this in the most automatic possible way, the CAD tool generates a file with the data concerning the mould, which is translated by numerical control software to a machining file that is automatically sent to a milling machine to begin the mould milling process.

2. DESCRIPTION OF THE DIGIMOULD PROJECT

In general, to apply "mass customization" in practice and in particular for the manufacture of ceramic products, the supply chain needs to be redefined, in order to be as fully automatic as possible. Figure 1 shows this redefinition for the application of "mass customization" in the ceramic industry.

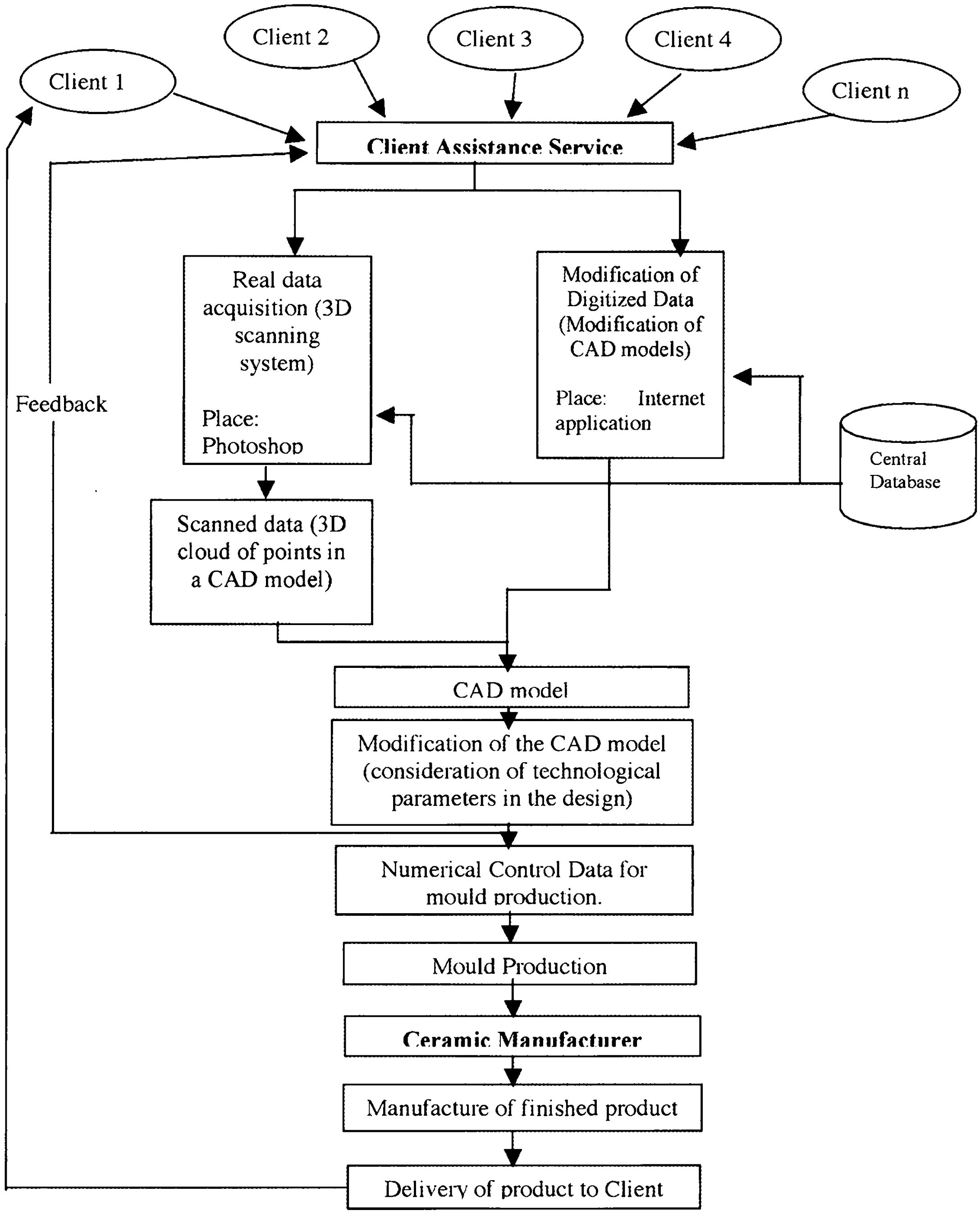


Figure 1. Supply chain from product design to client delivery.

This redefinition and present state of the art have led to the need for new developments, which the DigiMould project has addressed in the course of its performance:

1) Development of flexible and interactive tools for the definition of the product according to customization requirements:
   a. Product configuration tool with the aid of a user friendly CAD tool, based in Internet.
   b. Digitizer for digitization of a product model.
2) Enabling creation and modification of a CAD model, taking into account the technological parameters of ceramic manufacture.

3) Conversion of the modified CAD model in a Numerical Control programme.
4) Manufacture of the ceramic mould using a milling machine.

The definition of the characteristics and design of the mould to be made can be achieved in different ways, depending on the initial situation:

- If a physical example is available for reproduction, this model can be digitized using optical measurement technologies. These technologies allow rapid and very flexible digitization, achieving high resolution in lateral and lengthwise directions. In the course of the project, two digitizer concepts have been studied: for ceramic pieces in 2.5D (ceramic borders) and 3D (ornamental ceramics). The study of two different concepts is mainly because the ceramic floor and wall tile industry does not need the high technical capabilities of a 3D digitizer - in general, for the digitization of borders, fewer degrees of freedom of movement are required, and therefore fewer axes, so that the process will be faster and more economical using a 2.5D digitizer. The digitizers to be used in the project were already available. On the one hand, a commercial 2.5D digitizer is involved that has been modified and optimized for suitable operation in the project. Another commercial 3D digitizer has similarly been optimized and modified for use in the project, based on an optimum 3D digitizer at the lowest possible price while maintaining a robust operating mode.
- If no physical example is available for reproduction, the model can be constructed or modelled using modern CAD tools. For the use of these tools, specialized knowledge is generally required as a result of intensive learning activities. However, as an alternative, the CAD tool developed for the project offers the client the possibility of actively designing the model without needing such previous knowledge of CAD tools. The CAD tool for the design of the model has also been divided into two functions: one for the case of 2.5D ceramics (borders), and another one for the case of 3D ceramics (ornamental ceramics). The CAD tool works on Internet and has been developed using JAVA technology. The result of the CAD tool is a file with the data of the model to be milled, which is transferred to the numerical control conversion software of the milling machine for ultimate milling of the plaster moulds.

After designing the outer shape of the customized ceramic product using the digitizers or CAD tool, a set of data is obtained for milling the mould. One of the main objectives of the project has been the development of a software package that converts the digitized cloud of points and CAD 3D models into a numerical control programme. Once again, the generation of the numerical control data for the milling process has been subdivided in 2 dimensions, the 2.5D part and the 3D part. In the case of 3D geometries, the conversion of the data to numerical control data is complicated. The reason for this difficulty resides in the high number of degrees of freedom of the milling machine to be used, since the project has studied the use of a milling machine with 3 degrees of rotating freedom, which are added to the 3 degrees of freedom of translation. If it is intended to use this milling machine with this high number of degrees of freedom, it is necessary to develop new algorithms for reconstructing the surfaces. For this, new conversion algorithms were tested using products from the ceramic industry, and the results were compared with commercial methods. Optimum results were obtained using a completely automatic conversion tool, which means an innovative present advance. However, once again, the use of this type of milling machines is not necessary for the manufacture of 2.5D moulds for ceramic borders, since in this case a milling machine with 3 axes produces optimum results. Therefore, in the project it was decided to use two milling machines, involving a milling machine with 5 axes of freedom for the manufacture of moulds for 3D products (ornamental ceramics), and another milling machine with 3 axes of freedom for the manufacture of moulds for ceramic borders, each adapted to the manufacturing needs of moulds in the 2 dimensions, 2.5D and 3D. At the present time, in the frame of the project, the possibility is being studied of using a milling machine with 4 axes for both cases, whose market price is similar to the cost of the milling machines with 3 axes, and which could yield optimum results for the milling of moulds for borders (2.5D) and moulds for ornamental ceramics (3D). Ingeniería P.C. is the company in charge of developing this milling machine with 4 axes, a task that is currently being carried out. The prototype of this milling machine will be tested for the creation of moulds for 2.5D pieces and for moulds of 3D pieces. The results will be evaluated and if the resulting moulds and milling process meet the desired technical requirements (minimum roughness, continuity, resolution, milling rate, etc.) the project will use the milling machine with 4 axes for the manufacture of moulds for borders and ornamental ceramics.

After conversion of the model data to numerical control data for control of the milling machine, a plaster mould is made for the manufacture of customized ceramic products.

Therefore in the project the following key results have been obtained:

- 2.5D and 3D digitizers.
- CAD tool.
- Software for conversion of model data to numerical control data.
- 2.5D and 3D milling machine.

The development of the project has been organized in different tasks based on the expected results. The following sections describe the work performed for achieving each of these results, of which the first task was the definition of the characteristics of the customizable ceramic products.

2.1. DEFINITION OF THE CONFIGURABLE CHARACTERISTICS OF THE CERAMIC PRODUCTS TO BE CUSTOMIZED

As with other aspects, for the definition of the configurable characteristics the project has a twofold focus:

In the case of ceramic products in 2.5D, the project centres on the customization of ceramic borders consisting of:

- A profile
- One o more textures distributed along the border
- One or more reliefs (decorative patterns) distributed along the border (Figures 2 and 3 show examples of these patterns).

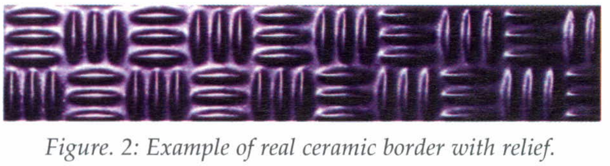


Figure. 2: Example of real ceramic border with relief.

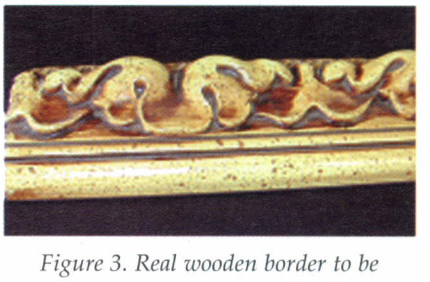


Figure 3. Real wooden border to be reproduced in a ceramic border.

The limitations of the borders to be designed are based on the boundary conditions of the moulding/demoulding process. The most important limitations are related to the angles of the profile of a border. Current milling machines with 3 axes do not allow creating 90° angles, which is a constraint that is taken into account in the CAD tool, which does not allow the user to create borders with these angles. In addition, the way in which the border is extracted from the mould (Figure 4) sets other limits to the border. The demoulding process of a piece is performed vertically, moving the piece in the direction of the Z-axis in one sole direction. Thus, the designed border should not contain any element (profile or decoration) that could prevent this movement or damage the piece in the demoulding process.

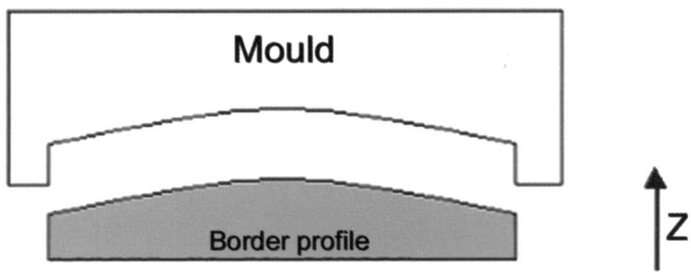
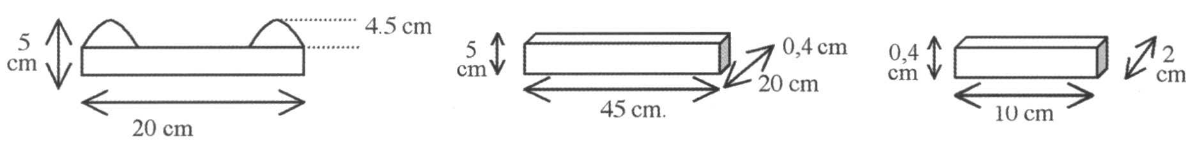


Figure 4: Border demoulding process.

The size of the borders to be created is also limited according to the following figure (Figure 5):



a) Profile limits *b) Maximum parameters* *c) Minimum parameters*

Figure 5. Graphic illustration of the profile of a border and its limits.

On the other hand, the textures and decorations to be stored in the project database are linked to a series of restrictions, which are set out below:

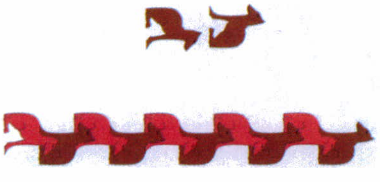
- The texture is a .bmp image in a scale of greys at a resolution of 100 pixels/cm, since this is the optimum resolution to obtain good results in the milling process. The depth limit of the texture has been set at 1 mm. The texture can be located according to two types of relief on the border: "under relief skin" and "above relief skin"; the term "skin" in this case refers to the fact that the texture always fits the border profile.
- Each decoration on the piece will consist of a decorative element distributed along the border that follows one of 7 classic distribution patterns, described below:
  - Moving the decorative element horizontally along the piece as many times as possible, holding the same spacing between them (Figure 6.a)
  - The second and third pattern (Figures 6.b and c. respectively) consist of completing the decorative element with its symmetrical image, either horizontally or vertically respectively, and moving the resulting element along the piece as many times as possible, holding the same spacing between them.

- The fourth pattern (Figure 6.d) consists of calculating the symmetrical image of the decorative element, and alternating the real image and the symmetrical one along the piece, moving both images, holding the same spacing between them.
- The fifth pattern (Figure 6.e) rotates the decorative element 180 degrees and slides the result along the piece.
- The sixth pattern (Figure 6.f) completes the decorative element with its symmetrical image, both vertically and horizontally, and then slides the result along the entire piece.
- Finally, the seventh pattern (Figure 6.g) consists of rotating the initial decorative element 180°, creating a new decorative element, which we could call base element, whose symmetrical image is calculated; the base element and its symmetrical image are then alternated and slid along the piece.


a) First distribution pattern


b) Second distribution pattern


c) Third distribution pattern


d) Fourth distribution pattern


e) Fifth distribution pattern


f) Sixth distribution pattern

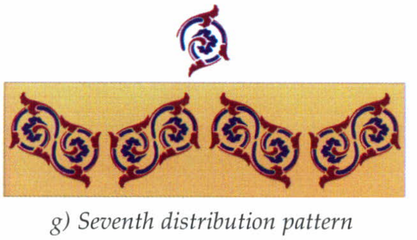

g) Seventh distribution pattern

Figure 7. Distribution patterns that can be used to distribute decorative elements in DigiMould.

The decoration is also a .bmp image in a scale of greys at a resolution of 100 pixels/cm. Its maximum depth is 4mm. Finally, the types of reliefs that can be applied are: "under relief", "above relief", "under relief skin" and "above relief skin".

The textures and decorative elements were used in ceramic border design and in decorating volumetric ornamental ceramics. Therefore, they are all entered in a database developed in Access, which is the database that the CAD tool uses.

It may be noted that a border can be made up of each of the three mentioned elements (profile, texture and decoration), by a combination of some of these, or just by a single one.

As far as the 3D part of the project is concerned, i.e., the design of volumetric or ornamental ceramics, during the design of these types of products a user can decide:

- 3D geometry of the object (outer shape)
- Colour
- Texture and decoration on the piece (such as reliefs); the previously described patterns and distribution are used for the positioning of the decorations on ornamental ceramics.

The limits of these types of products have been set as:

- Height: 350 mm.
- Width/depth: 350 mm.

The 3D geometry of the object to be designed also has certain limitations, just as in the case of ceramic borders. The user defines the shape of the volumetric object from a 2D contour with the following characteristics:

- They represent those products that are symmetrical on a rotation axis,
- can be rotated according to a circular or elliptical profile (rotation axis = Y-axis),
- can be escalated in height and width,
- consist of a finite set of segments,
- a segment can be a line or an arc (with a positive or negative radius),
- the connection between segments can be sharp or rounded,
- allow a maximum number of 4 segments,
- therefore $2^4 = 16$ basic shapes are obtained

Figure 8 shows several examples of possible 2D contours in the project, which generate some of the basic shapes.

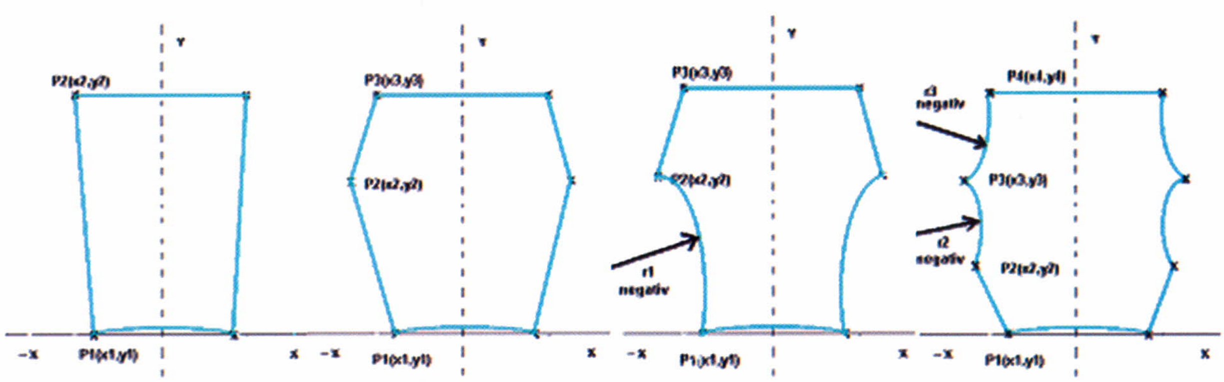


Figure 8. Examples of 2D contours (basic shapes).

In the case of configuring the characteristics of volumetric pieces, the ceramic restrictions are also taken into account during design under the CAD tool with regard to the demoulding process and the milling process for the proper fabrication of these pieces.

2.2. DEFINITION AND DEVELOPMENT OF OPTIMUM DIGITIZERS FOR DIGIMOULD

The following task in the project consisted of adapting or developing the optimum digitizers for the project.

In the context of the DigiMould project, as already mentioned previously, two different digitizers have been modified and adapted for the project. The main reason for the decision to use two different digitizers for ceramic borders (2.5D) and for ornamental ceramics (3D) lies in the fact that the technical problems stemming from 2.5D product digitization differ from those deriving from 3D product digitization. Although a 3D digitizer could digitize 2.5D products, the present ceramic floor and wall tile market does not need the great number of capabilities that 3D digitizers have, while the process will also be faster using 2.5D digitizers (as they require fewer degrees of freedom of movement and therefore fewer axes). Another added advantage for the use of 2.5D digitizers is that they are much less expensive than 3D digitizers, making the process more economical for the ceramic tile companies if they use 2.5D digitizers.

Thus, for the production of moulds for ceramic borders, under the supervision of Alicer and taking into account economic considerations, the commercial 2.5D digitizer of Ingeniería P.C. has been modified for the automatic supply of digitized data for the project database. The 2.5D digitizer will be used to feed this database with textures and decorations.

The improvements made in this digitizer have consisted of increasing its speed and useful reading surface, and enabling optimum communication of this digitizer with the other elements of the project.

The result of the digitization process is an image in a scale of greys. The software of this digitizer is therefore divided in two parts: one part devoted to data logging and the other to adjusting the level of greys and the generation of the image in a scale of greys (in raw format). The resulting image always needs to be modified and filtered to eliminate defects such as "holes" in the textures, and this modification needs to be made by a designer using PhotoShop. Subsequently, through a PhotoShop automatism, the images are entered in the database. The following diagram (Figure 9) shows the communication flow of the digitizer with the database.

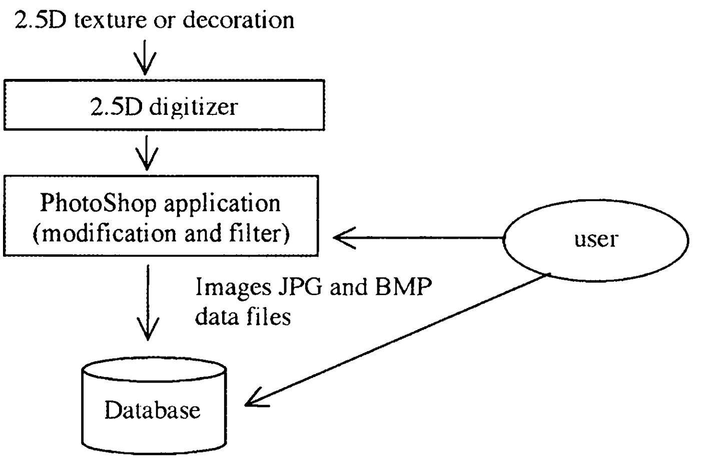


Figure 9. Flow chart of digitizer communication.

In accordance with the configurable characteristics of volumetric ceramic products, the 3D digitizer consists of a rotation unit and a further translation unit to move the object, and two laser sensor systems for digitizing the outer shape of the object (Figure 10).

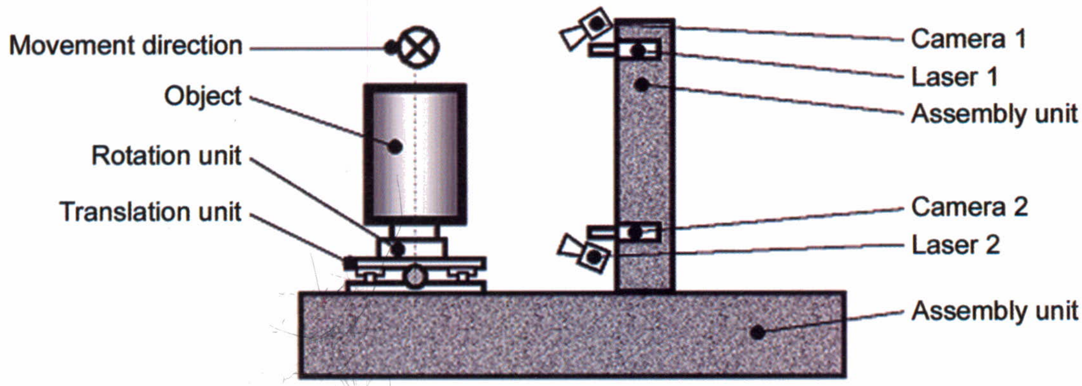


Figure 10. Schematic illustration of the 3D digitizer.

Each laser sensor works according to the triangulation principle. Each laser system consists of a camera and a laser diode. A beam of flat light generated by the laser diode intersects with the digitized object and generates a contour section, which is photographed by the camera (Figure 11).

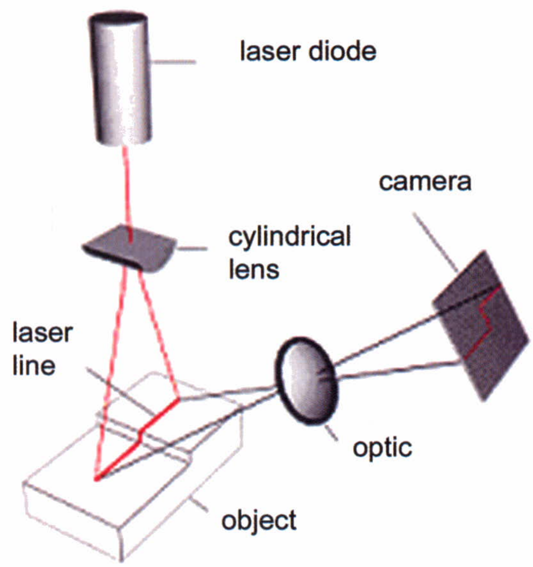


Figure 11. Principle of the laser sensors used.

The objects are digitized, translating and rotating them using the rotation and translation units, simultaneously taking successive photographs of contour sections. The result of this digitization process is a 3D cloud of points with approximately 100,000 3D points.

An important characteristic of the developed 3D digitizer is that it has a simple and robust calibration process, which has been developed within the project.

2.3. DEFINITION AND IMPLEMENTATION OF THE CAD TOOL

The following task in the project consisted of the development of a CAD tool that once again had two variants: 2.5D and 3D, for the design of ceramic borders and ornamental ceramics respectively. The CAD tool has been developed in such a way as make its use as simple as possible, so that a non-expert user of this type of tool is able to design the product that he wishes in a short time. The CAD tool works under Internet and has been implemented in the JAVA development environment.

The requirements for the use of this tool are:

- Internet navigator (preferably MS Internet Explorer)
- Plug-in in Java execution environment (which can be downloaded via a link from the application itself).

The CAD tool is fed and feeds a database in Access that is stored in the CAD application server. The selection of Access as a database stems from the convenience and facility of using this technology for small and medium-sized companies, since most of them have Access databases at their facilities and are acquainted with the operation and maintenance of these databases. This database stores different data, such as the users of the application, models of profiles, textures and decorations, models designed by the users of the application to allow reusing them in the design of other models based on these, or in making new orders of the same model, etc. To assure privacy in the designs, a user will only be able to redesign or repeat a model designed by himself; for this the database keeps track of which user has made each model. The database has been designed to enable development of a multilingual CAD tool.

The CAD tool is accessed from the Web site of the manufacturing company. Since a multilingual tool is involved, the first step is selection of the language. Next, the user must decide whether he wishes to design a ceramic border or an ornamental ceramic item. Finally, in order to be able to access the CAD tool and use this, the user must register; he then has a login and password that will allow him to authenticate himself and initiate the use of the tool (Figure 12).

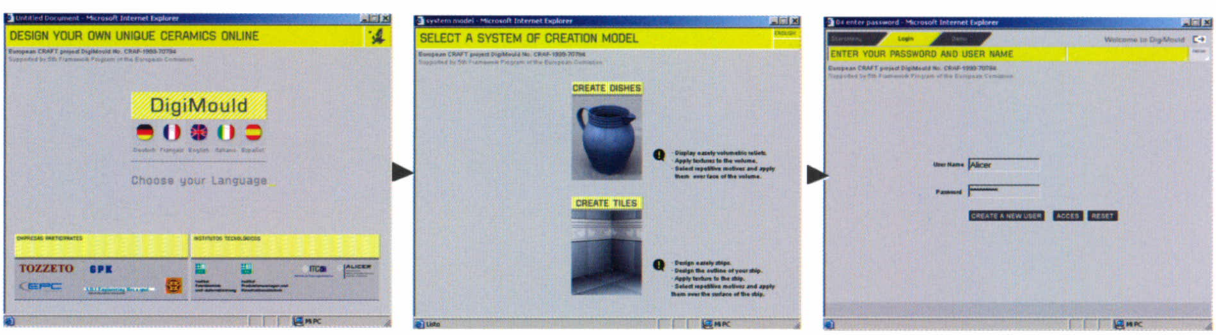


Figure 12. First Web pages of the CAD tool: selection of the language, type of product to be designed and authentication.

In the 2.5D variant, the CAD tool is implemented using Java 2D and Java 3D for the graphic design parts of the borders (design of the profile, distribution of textures and decorations on the surface of the borders, and 3D visualization of the designed model) and Java Server Pages and Servlets for the implementation of CAD tool logic.

In this part of the tool, the user has been authenticated, and he can choose to perform different actions, from modifying or reproducing a model made by himself on other occasions to creating a new border. If he decides to redesign a border, he selects the desired border and proceeds to modify either its profile, or the distribution of textures or decorations associated with it, or all the parts.

In the case of designing a new border, the user must first introduce the parameters of the border (width, height, length, depth of profile relief), and can then select one of the profiles from the database linked to the user, or create a new one. The profiles, just like the models, are stored in the database linked to the name of the user that created these, so that each user can only use profiles created by himself and the "universal" profiles, i.e., the common format profiles that are linked to a non-real user and are accessible to all users of the application. After designing the profile, the user can design a distribution of textures on the border and/or a distribution of decorations. Both the textures and the decorations are stored in the Access database of the manufacturing company.

The graphic design part of the borders is implemented as Java applets, and these applets are:

- Creation of a new profile: the user can create lines, quadratic and cubic curves for the creation of profiles. At this point the applet does not allow performing any operation that would lead to the design of a profile that could not be made (constraints because of the milling angle and demoulding). Figure 13 shows the graphic appearance of this applet.

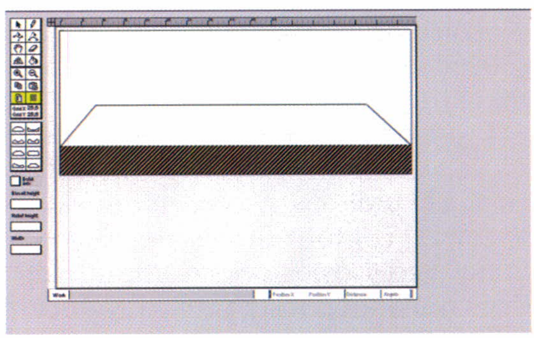


Figure 13. Example of a profile designed with the applet for the creation of new profiles.

- Distribution of textures on the border: this applet allows the user to distribute various textures on the piece in a simple way. This applet enables previsualizing if any decorations have previously been distributed on the piece in the form of layers, in order to adapt the design of the textures to the one of the decorations. Figure 14 shows the graphic appearance of this applet, which is practically identical to that of the following one.

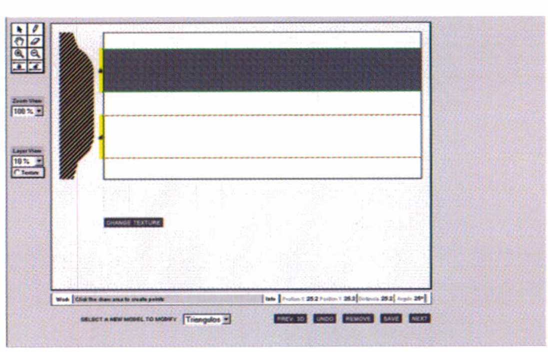


Figure 14. Graphic appearance of the applet for texture distribution on the designed product.

- Distribution of decorative elements on the border: this allows distributing decorations on the ceramic piece, according to one of the 7 patterns defined for this purpose. Again, this applet allows visualizing the distribution of previously created textures (should they exist), in order to distribute the decorations taking into account this distribution of textures.

- 3D visualization of the designed model: this applet has been developed using Java 3D technology and displays a three-dimensional representation of the design. The user can vary the point of view in order to observe the design from different angles. Figure 15 shows an example of this visualization from two different angles of visualization.

Figure 15. Images of 3D visualization of a test border in the project.

When the user has saved the design as valid, the CAD tool automatically generates the RAW file of this model, which is then automatically sent to the numerical control software of the milling machine in order to proceed with machining and subsequent milling.

The 3D variant of the CAD tool has also been developed using Java technology. First, the user must define the 2D contour of the ceramic object. Then this contour can be combined with additional accessories, for example, lids, handles and spouts. In both cases, the software does not allow designing a product that cannot be made later, either because it cannot be milled or because it cannot be demoulded. This variant connects with the 2.5D part applet for the distribution of textures and decorations, for the distribution of these elements on the designed 3D object. The following figure (Figure 16) depicts the configuration chain of one of these products. A 3D visualizer of the product has similarly been developed using JAVA 3D technology, which offers a realistic previsualization of the product.

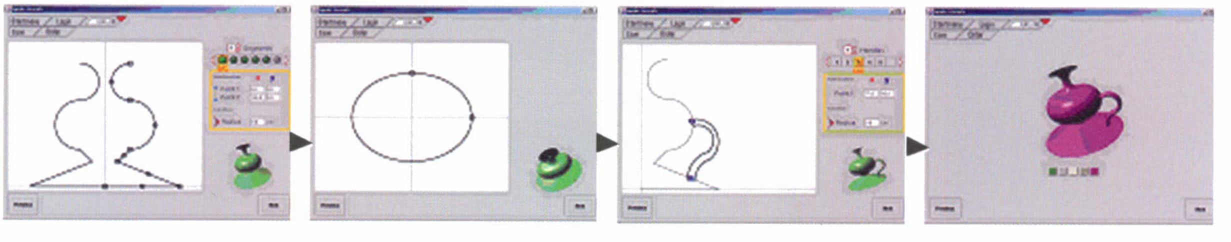


Figure 16. Design flow an ornamental ceramic product.

The functionality of the 3D variant of the CAD tool is complemented by the use of EDS/Unigraphics to import the customized design file and automatically generate the CAD model for the creation of the mould. This is highly innovative, since the modelling of complex products via the Internet has not been possible till now.

2.4. DEFINITION AND IMPLEMENTATION OF THE CONVERTER TO NUMERICAL CONTROL DATA

The converter to numerical control data is able to convert either a cloud of points, generated by the digitizer, or a 2.5D and 3D model, designed by CAD tools, to a numerical control programme (of machining) for the milling machine.

Once again this task has two variants: 2.5D and 3D. In the 2.5D variant, the converter is able to translate the received RAW file, either after a digitization process or after a design process with the CAD tool in the machining file which the 2.5D milling machine used in the project requires. The selected converter for this purpose is the one developed by Ingeniería P.C., which has been modified to receive the data automatically and processes these to obtain the machining file in the most automatic possible way. This converter also allows translation of the machining file obtained after conversion to other machining standards such as ISO, HEIDENHAIN or ROLAND.

In the case of 3D geometries, the conversion to numerical control data is more complicated due to the high number of degrees of freedom, since we must handle 3 degrees of rotating freedom together with 3 degrees of translation freedom. After a study of the state of the art of various existing CAM systems (for example like TEBIS, DELCAM, NC-SOFT, CIMATRON, KNOTENPUNKT, MASTERCAM and VOLCAM) in the DigiMould project, it was decided to implement the following converter to numerical data concept for the 3D parts:

- If the input data come from the 3D digitizer, the digitized 3D cloud of points is approached with a triangular mesh.
- If the input data come from the CAD tool, the generated CAD model will automatically be converted to numerical control data, also using a professional CAD tool (like Unigraphics).

2.5. DEFINITION OF THE MILLING MACHINE TO BE USED

Once again, as the technical problems of milling 2.5D products are different from the technical problems of milling 3D products, a different milling machine has been selected for each case, because although a 3D milling machine could also mill 2.5D products, these machines are more expensive than the 2.5D milling machines and their great capacity is unnecessary for this type of product. The 2.5D milling machine selected is marketed by Ingeniería P.C., and involves a milling machine of 3 axes (3 degrees of freedom). With regard to the 3D part, a study was also made of the state of the art in milling machines of 5 axes (5 degrees of freedom). In this case a milling machine is being used of the LPZ 500 type with 5 axes, of the MAP Company (Berlin), which has been fitted out for milling plaster.

3. CONCLUSIONS

In the course of the project, different technologies have been developed that enable "mass customization" for ceramic products (ceramic borders and ornamental ceramics).

The technologies developed for the 2.5D and 3D digitizers are completely applicable to other non-ceramic materials, such as plastic, wood or metal. Their only limitation is the dependence of the digitized result on the optical characteristics of the object (transmission, absorption, reflection), because both digitizers are based on optical sensors.

The use of the CAD tool allows any user to easily define and configure the profile, texture and relief of his borders or decorative objects, enabling customization of these products.

As far as the converter to numerical control data is concerned, the development effected is applicable in all the processes where CAD tools and digitizers are used, such as in the design, prototyping and manufacture of 2.5D and 3D objects.

Finally, the technology developed for the milling of plaster is applicable in different sectors, such as the porcelain industry and in building construction (for example in manufacturing stucco).

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