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Graphic Design for Ceramic Tiles

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Abstract

The development of a computer based design system for ceramic tiles forms part of a BriteEuram project aimed at providing automated quality control for ceramic tile production. The design system is expected to provide *a priori* information about each tile design to the quality control inspection stations. The differences between graphic design for paper and graphic design for ceramic are discussed, and the additional information required by the quality control system is considered.

Traditional ceramic tile design is performed on paper using a wide variety of conventional tools: pens, brushes, air brushes, etc. A completed design is separated by hand, and a silk screen produced for each colour separation. These silk screens are used to print the design on the tile biscuit, which is then fired in a kiln.

Tile design appears to have much in common with the graphic design used for conventional paper products, and hence it might be supposed that existing computer design tools can be used for ceramic tiles. Some customisation is desirable, if only to provide an annotation mechanism for passing extra design information to the quality control system. Design for ceramics and design for paper products differ, however, in several ways in the constraints they place on separations: (1) ceramics require much coarser half-tone screening than paper; (2) magenta and red inks are difficult to make for ceramics; (3) there are no standard inks for ceramics, each manufacturer makes his own; and (4) colours mix in unpredictable ways, owing to the reactions in the kiln between the chemicals used to pigment the ceramic. These constraints mean that conventional CMYK separation is of little use in ceramic tile design. This paper describes a computer design system for ceramic tiles consisting of a standard graphic design package, with suitable annotation facilities and appropriate extensions, and an automatic separation utility tailored for the needs of ceramics.

Such a computer based design system has several advantages over manual design: (1) it allows the quality control system access to the design data, incorporating annotations provided by the designer specifically for quality control; (2) it allows separations to be produced automatically, freeing the designer to spend more time designing; and (3) it allows easier previewing of different colourways, and to some extent, aids in experimenting with various design elements. Weighed against this are the disadvantages that (1) the designer must learn a new tool which replaces rather than augments her existing repertoire of tools; and (2) no computer design package is yet capable of achieving the wide range of effects possible with traditional tools.

1 Introduction

We are involved in a BriteEuram project which aims to produce an automated quality control system for ceramic tiles. The project includes computer vision techniques for inspecting tiles in the process of manufacture and extends from pattern design through inspection to mechanical handling of tiles. Our part of the project is the development of a computer design system for ceramic tiles which can pass the design information to the quality control system as *a priori* information. This paper describes tile design, manufacture, and quality control, and discusses the graphic design system that has been developed as part of the project.

2 Tile manufacturing process

A ceramic tile is made from a pressed clay biscuit coated with a ceramic glaze. This product is fired in a kiln to make the waterproof tiles used in kitchens and bathrooms across the world. Patterning ("decoration") can be applied to the tile after it is coated with its background glaze and before it is fired. A pattern is printed on the tile by a series of silk screens, one for each colour on the tile, with the obvious exception of the background glaze's colour. In addition to straightforward designs and patterns, the majority of apparently random design elements are produced using silk screens, although some mechanisms do exist for producing truly random designs.

3 Automated quality control

After firing and cooling, tiles are manually inspected for defects in both the decoration and the tile body. Inspection can be performed at up to two tiles per second for simple tiles and can be as slow as one tile every fifteen seconds for large polished floor tiles. The main aim of the BriteEuram project is to automate this quality control process, aiming at a speed of four tiles per second, for six inch square tiles.

Axiom Bildverarbeitungssysteme have successfully developed an automated inspection system for textured tiles. Such tiles are printed with a random or pseudo-random texture. Textures imitating marble and granite are common. The project aims to extend this success to patterned tiles, that is tiles containing definite elements such as birds, flowers, and non-random texturing elements.

Axiom's textural analysis system calculates a signature for an entire tile. This consists of a set of mathematical properties of an image of the tile; examples are mean and standard deviation of intensity. The signature allows a tile to be classified simply but effectively. The system trials required up to seven classes.

The pattern inspection system being developed by this project requires a more complex analysis method. Textural analysis looks at the overall visual effect of the tile; pattern analysis must look at the individual elements of the pattern. For example it is important to be able to tell whether or not a bird's beak has printed, or whether ink has printed through a rip in a silk screen. Many patterned tiles include pseudo-randomly textured areas, typically the background is textured in this way. It will be necessary to segment the tile into parts: applying textural analysis to textured parts, and pattern analysis to patterned parts.

The computer design system is expected to pass all design information to the quality control system. This includes segmentation information, which should be added

by the designer during the design phase, and half tone screening information, added during the separation process.

4 Traditional ceramic tile design

The traditional method of design is to produce a paper version of the design using conventional tools: pens, brushes, air brushes, and so on. When the designer is happy with this, separations are traced onto a transparent medium using the same tools and black ink. One separation is made for each colour used in the design showing where that colour should print on the tile. The separations are used to make silk screens and a small run of tiles is hand made to check for colour and viability of design. Changes may then be made to the design and this cycle may be traversed again until the designers, and the customer, are happy. The separations of the final design are then made into silk screens ready for full scale production on the factory floor.

5 Comparison of graphic design for paper and for ceramic

While being distinct media, the initial steps in graphic design are very similar for both paper and ceramic. Designers in both fields have, in the past, used similar tools and materials to produce their initial designs. It is therefore not unreasonable to expect the computer design tools developed for paper to be equally applicable to ceramic.

The difference at this stage is in the mass of accumulated knowledge about what is and is not good design practice. A graphic designer, working on paper publications, has an excellent knowledge of, for example, the uses and limitations of CMYK separations. Graphic designers working on ceramic tiles have historically required little knowledge of CMYK separation, but have needed a large body of lore on the capabilities and limitations of their medium. There is also a degree of experimentation in tile manufacture. Sometimes no-one can predict in advance the effects of mixing two glazes without firing test pieces in a kiln.

Greater differences arise between paper and ceramic design when it comes to making separations. For paper products, CMYK separations tend to be used. This allows for the reproduction of practically any artwork, and specifically colour photographs. One or two spot colours may be used in addition to CMYK, increasing production costs. Alternatively one or two spot colours may be used in place of CMYK, usually in addition to black. This decreases the cost but does not have the ability to reproduce arbitrary artwork.

Computer based separation tools will produce either just CMYK separations (e.g. Adobe Photoshop's separator) or CMYK and/or spot colour separations (e.g. Adobe Separator, which processes Adobe Illustrator files). These tools can be used to produce automatic separations for ceramic tiles. However CMYK separation is of little use in ceramic tile manufacture, as explained below, and so spot colour separations must be made.

6 Constraints on separations

A ceramic tile designer does not have as much freedom in design as a paper product designer for the following reasons:

1. Ceramics require coarser half-tone screening than paper. Paper half-toning tends to be just fine enough that it is not obviously visible to the naked eye. Ceramic half toning, on the other hand, tends to be easily visible to the naked eye. The coarser half-tone screen is necessary because a relatively coarse silk screen must be used. 73 threads/cm is a typical silk screen pitch. At this pitch a silk screen can be expected to last up to eight hours in production. The nature of ceramic ink, essentially fine glass powder in solution, means that screens can be rendered unusable after only a couple of hours. A finer half tone screen can be used at the expense of a finer and hence more easily damaged silk screen.

2. Magenta and red inks are difficult to make for ceramics, owing to the fact that the chemicals which could be used to make these colours tend to be toxic.

3. There are no standards for ceramic inks, each manufacturer makes his or her own. H & R Johnson, for example, have recipes for several thousand colours, and considerable proprietary knowledge is tied up in the colour mixing process.

4. Colours can mix in unwanted or unpredictable ways. This is due to the reactions which occur inside the kiln between the chemicals used to pigment the ceramic. Care must be taken over which colours are allowed to overlap.

   On the positive side there are a number of reactive glazes which produce predictable and attractive reactions in the kiln. These allow the designer to produce special effects, such as a rippled surface to the tile.

These limitations mean that conventional CMYK separation is of little use in ceramic tile design. Some experiments have been carried out with CMYK separations [1]. The results, while attractive in their own right and hence potentially marketable, show that CMYK separation will not supplant the conventional spot colour separation used in tile manufacture.

7 Computer based design system

A computer is required which is acceptable and readily available to designers. It thus needs a fairly wide support base and a good range of software. It should also be easy for a non-computer literate person to use. Obvious choices are the IBM PC, which has a large share of the personal computer market, and the Apple Macintosh which dominates the design and publishing market. There are other potential alternatives, but the Apple Macintosh was chosen as the hardware platform for the design package because of its dominance of the design and publishing market, its excellent user interface, and its large software base.

Given the choice of an Apple Macintosh computer, there is a wide range of commercially available design packages which could potentially be used to design ceramic tiles. Output from the chosen design package will need to be converted into a form suitable for use by the tile manufacturer, and for use by the quality control system.

Surveying the available software it is apparent that, amongst the plethora of drawing and painting packages, the two most widely used and accepted professional drawing packages on the Macintosh are *Illustrator* from Adobe Systems [2] and *Freehand* from Aldus Corporation [3] (Aldus recently amalgamated with Adobe, and *Freehand* is now being sold by Altsys).

Evaluation of Freehand 3 and Illustrator 5 led us to conclude that Adobe Illustrator 5 was the best candidate for the purposes of the project. Two features are of particular note:

a. *Modifiability* — Illustrator allows us to provide plug-in filters which can be programmed to do anything necessary to the structure of the design document [4]. For example, a filter could be provided that generates a blank tile of the size required by the designer, with any appropriate guide marks already inserted. Another could be used to manipulate the textural annotations required by the quality control system. There is also the capability to store libraries of colours, allowing a tile manufacturer to tie his database of colour information directly into the design package.

b. *Availability of output format specifications* — Illustrator's native output format is a PostScript file. It is human readable, fairly easy to understand, and documented. It has proved straightforward to process the output from Illustrator in a variety of useful ways, and work is in progress to take an Illustrator output file and transform it to produce the various inputs required by the quality control system.

Interface to quality control system

The interface between the design system and the quality control system will be the Adobe Illustrator design file. This is a highly structured PostScript document. Colour and tinting information is provided automatically in the file. We make use of the inbuilt annotation mechanism to permit the designer to specify that a set of design objects make up some texture or other design element. The quality control system can use this information to segment the design, and apply the appropriate type of analysis to each segment.

The Illustrator design file contains a resolution-independent object based description of the tile design. The quality control system requires a set of image masks, each showing where one particular feature (texture, colour, etc) occurs in an image. We are currently constructing a filtering system that will take a resolution-independent design file and a feature specification as input and produce a resolution-independent description of a mask. This can be rendered at a suitable resolution into an image mask by a commercially available PostScript renderer (GhostScript, from Aladdin Enterprises, is suitable). This mechanism will also be able to generate the separations required for silk-screening, if required, independently of any commercially available utility software.

Separations for silk screening

These can be produced from the Illustrator output file by the Adobe Separator utility which is provided with Illustrator. Alternatively they can be produced by our own software tools, described above. The advantage of the latter route is that the separations are produced by the same code as that used by the quality control systems, hence ensuring compatible results. The product of either route is a set of resolution-independent

PostScript files, one for each separation, which can then be printed on a high resolution printer (600 dpi or higher is suitable) or on an image setter. These hard copies can then be converted into silk screen masks in the conventional way.

We have experimented with producing separations and have shown that the separations that can be automatically produced are acceptable for silk-screen manufacture. This is a great advantage over the tedious manual methods currently in use and will free designers to spend more time designing.

Figure 1 illustrates the stages involved in taking a finished design to production.

Plug-in filters for Illustrator

The most important plug-in, from the point of view of quality control, is that which provides an interface to the textural annotation mechanism. The designer is able to specify arbitrary texture identifiers which can be attached to any graphical objects within the design. These are stored in the file, and are used by the quality control system for segmenting the design.

Three other plug-in filters are being added to Illustrator to aid the designer in her work:

1. a filter to create a tile background, with appropriate annotations for the vision system. This will make a background of a chosen colour, representing the background glaze that will be placed on the tile. The designer will use this filter once to create a blank tile on which to design from scratch, or onto which to copy existing design elements.

2. a filter to highlight illegal design constructs, so that the designer can remove or correct them. This will be used periodically during the design of the tile to ensure that the design can actually be printed on ceramic.

3. a filter to remove extraneous information from the design, immediately prior to producing separations for production or prototyping. This will allow the designer to store personal comments and partial picture elements in the design document outside the bounds of the tile, which this filter will remove at the appropriate time.

   The use of each of these filters is illustrated in figure 2.

Example designs

We have used Illustrator to produce a variety of tile designs, some are attempts at mimicking existing H & R Johnson tiles, while others are experiments.

Figure 3 shows six example tile designs, made in Illustrator, and conforming to the design constraints which we have agreed with Axiom. The constraints on reproduction for this conference mean that Figure 3 contains only a black and white representation of what are in practice multi-coloured tiles.

Examples (d) and (e) are attempts to mimic existing H & R Johnson tiles, while (a) and (c) are based on parts of existing tiles. (b) and (f) are new designs, generated by ourselves. This set of six tiles illustrate various points.

Simplest to create was example (f), a geometric design. This was created in a matter of minutes, and consists solely of areas of solid colour. Example (e) is copied from an existing tile supplied by H & R Johnson. Colour-wise it again consists only of areas of solid colour.

Examples (c) and (d) are more complex designs. (d) requires three colour separations (flower, leaf, and highlight colours). (c) requires these three plus a fourth separation to print the background texture which is just visible in reality, but has been artificially enhanced in Figure 3.

Examples (a) and (b) introduce colour tints and gradients into the design. Tinting is the use of a colour at less than its full intensity, achieved on the tile by half-toning. (b) requires a single, green colour separation, while (c) requires two: a grey and a red-brown.

(b), (e), and (f) have only simple separations, as they involve no overlapping colours. Similarly there is little about these patterns that requires any complex analysis to be provided for the vision system. (a), (c), and (d) present more difficulties.

Figure 4 shows separations and masks for example (c), demonstrating the need for textural segmentation. (i) through (iv) show the four colour separations that must be printed on top of the background glaze to produce the tile. The background pattern separation, (iv), is quite complex. In practice it will be analysed by the quality control system as a "random" texture, rather than as a large combination of small graphical objects. Thus the texture mask, (v) will be generated for the quality control system so that it knows where to apply the appropriate textural analysis. Figure 4(vi) simply shows where the background glaze is visible (i.e. not printed on). Like (iv) this would probably not be used by the quality control system in practice.

8 Existing tile designs

While this design system will be used in the design of future tiles, there is the problem that the existing design stock of tile manufacturers tends to be on paper, rather than on computer. We believe that there is little point in forcing a tile manufacturer to redesign all of their products on a computer solely to provide design input for the quality control system. In these cases we propose that the existing separations could be scanned in and registered electronically with one another to provide templates for the quality control system to work from. This involves far less effort than redesign of the tile.

Further, not all future designs will be made using Adobe Illustrator. One estimate is that as few as 40% of designs could use the Illustrator route [1]. We believe that an image manipulation tool, such as Adobe Photoshop [5], could be used for some of the remainder, while the rest will continue to be designed on paper. Future work should include consideration of an automatic separation utility for arbitrarily coloured images generated in, say, Photoshop, or scanned in from a paper design.

9 Summary

We have described the tile design, manufacture and quality control processes, and a computer based design system for ceramic tiles that can pass *a priori* information to an automated quality control system. This graphic design system utilises an existing software product, with plug-in modifications appropriate to the task at hand.

Such a computer based design system has several advantages over manual design: (1) it allows the quality control system access to the design data, incorporating annotations provided by the designer specifically for quality control; (2) it allows separations to be produced automatically, freeing the designer to spend more time designing; and (3) it allows easier previewing of different colourways, and to some extent, aids in experimenting with various design elements. Weighed against this are the disadvantages that

(1) the designer must learn a new tool which replaces rather than augments her existing repertoire of tools; and (2) no computer design package is yet capable of achieving the wide range of effects possible with traditional tools.

10 References

[**1**] H & R Johnson, *private communication.*

[**2**] *Adobe Illustrator 5.0*, Adobe Systems Incorporated, 1993.

[**3**] *Aldus Freehand 3.0*, Aldus Corporation, 1991.

[**4**] *Adobe Illustrator Plug-In Architecture*, Joe Holt, Adobe Systems Incorporated, 1994.

[**5**] *Adobe Photoshop 3.0*, Adobe Systems Incorporated, 1994.

11 Acknowledgements

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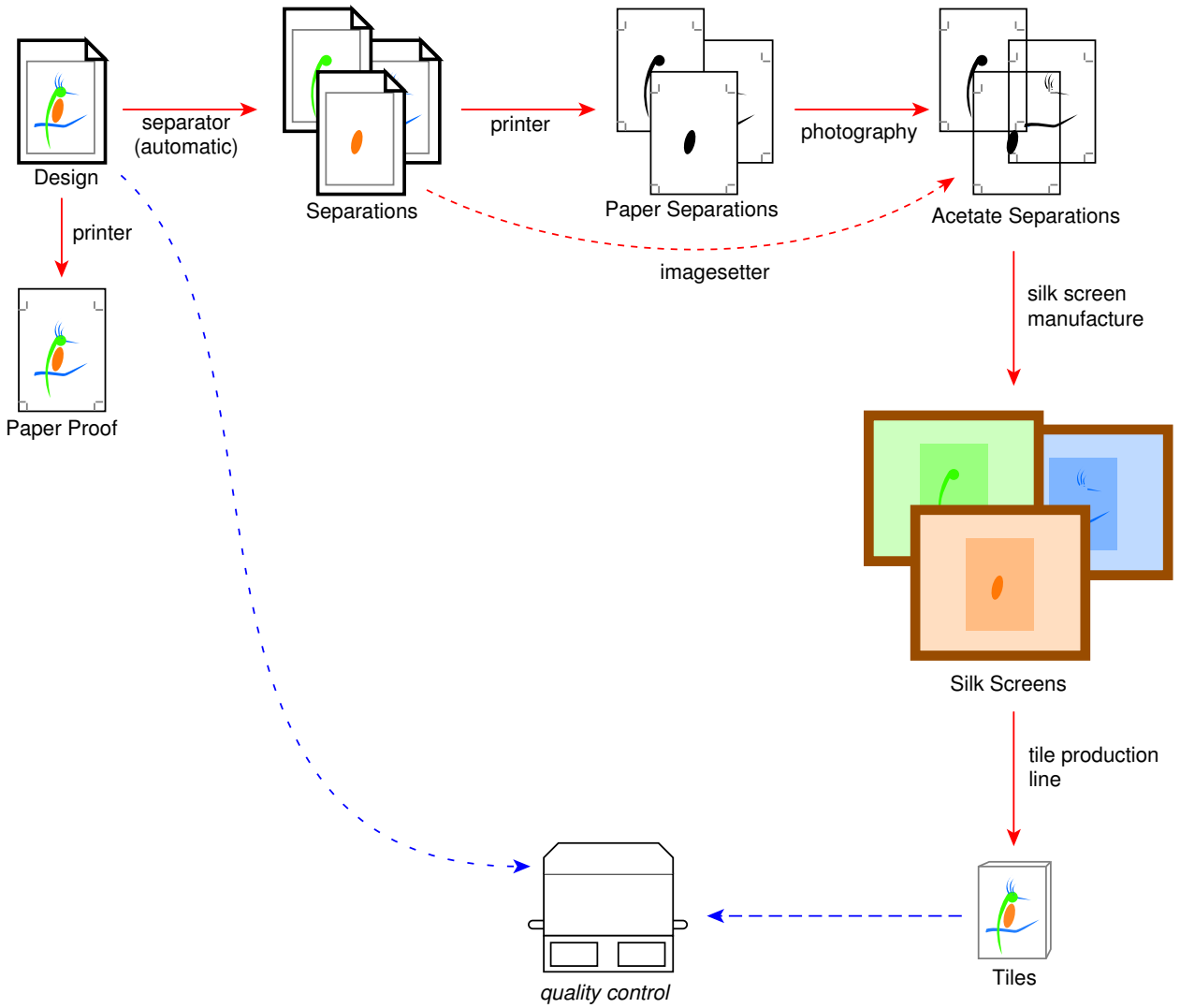

Figure 1: The stages involved in taking a finished (valid) tile design to production.

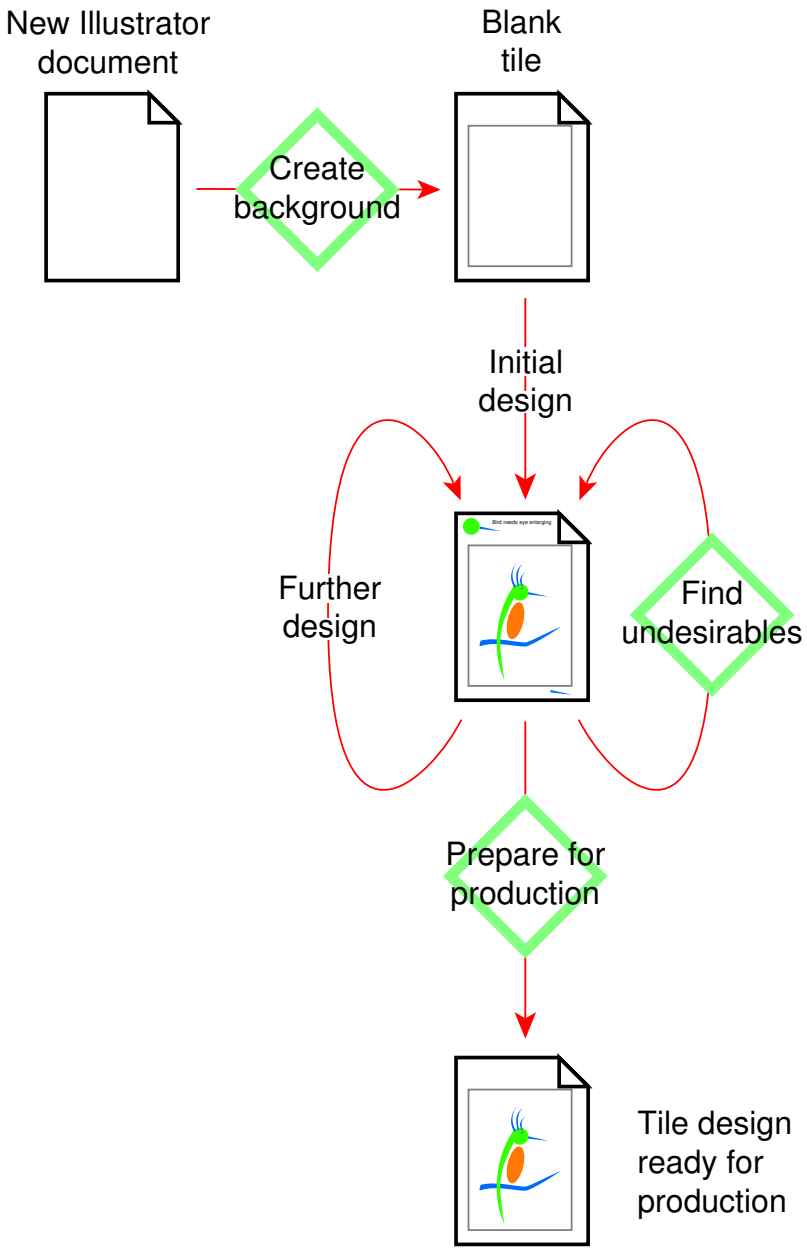

Figure 2: The position of the three proposed plug-in filters in the design cycle. One is used to create a blank tile, one is used during the design process to find undesirable features, and the third is used to remove extraneous information from the file and perform a final check on the design before the tile is sent into production.