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Low-Cost Vision Systems for Monitoring and Sorting Ceramic Tiles Before Firing

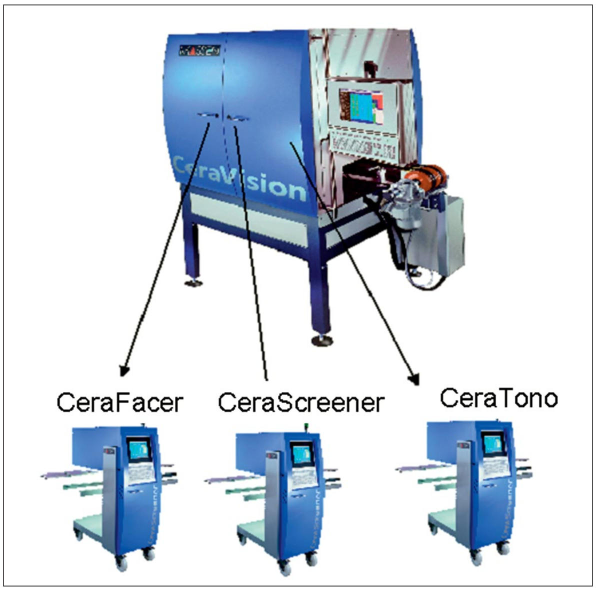


Fig. 1
A family of small, low-cost dedicated vision systems monitoring the tile production before the kiln are derived from the full-blown final automatic sorting system CeraVision

Automatic Inspection of Ceramic Tiles Comes (too) Late

The automation of visual inspection and sorting of ceramic tiles before packaging has now become a no longer questioned technology in modern, highly automated and rationalized factories. The task of replacing the human eye and brain with cameras and intelligent algorithms is a demanding technology which actually is only mastered by just a few machine vision companies. These systems not only reduce the substantial personal costs of manual inspection and sorting. This technology has also become a defacto standard for assuring a constant physical and aesthetical quality of the produced tiles and is therefore also introduced in low labour cost countries eager to compete in terms of tile quality.

Final sorting vision computers do collect a huge number of valuable information on the production process as they do monitor every single tile. This information however comes too late for improving the ongoing production. In continuous, storage-free production lines, the tiles have already spent 30 to 45 minutes in the kiln before beeing checked by the sorting computer. In sorting lines operating on stored, fired tiles, the time delay between production and sorting may encompass days to weeks.

The automatic final inspection and sorting systems therefore are not able to prevent the production of minor quality; they just sort out the already produced bad quality. Every production engineer will tell us, that it is better to prevent bad quality then to sort it out.

So even if we cannot today discard automated inspection and sorting before packaging, there is a dedicated need for automatic visual process monitoring systems which can operate before the kiln, which are able to monitor the most critical production steps such as the press and the decoration. These systems could trigger early alarms and thus prevent the production of large batches of minor quality beeing produced. They also may sort out clearly bad tiles at an early stage of production and thus save precious production capacity from beeing consumed by low quality tiles.

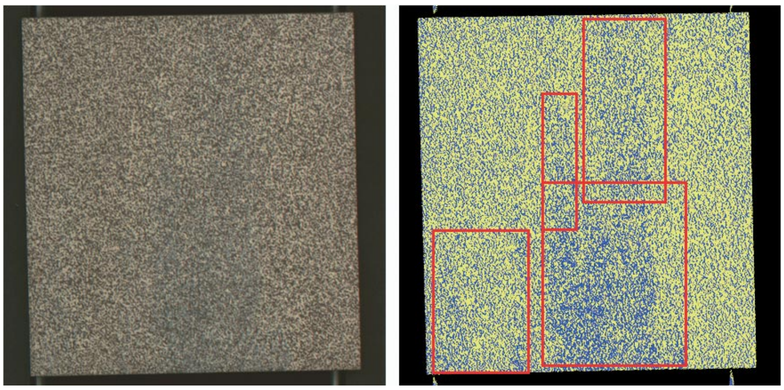


Fig. 2
Problems with the homogeneity of particle distribution of porcellanato tiles are checked with the colour-camera based CeraFacer immediately after the press

Our company, after having established the state-of-the-art CeraVision multisensorial camera technology for automatic inspection and sorting before packaging, has therefore focused on a new family of low-cost visual systems that are able to operate before firing. They are based on sub-sets of the complex CeraVision technology in order to keep development costs low. They are easy to install and to operate and cost typically only 25 % compared to the full-blown CeraVision systems for the final inspection (Fig.1). They do not replace these, but earn their own return-of-investment through their potential to reduce the production of minor quality and to save production capacity by eliminating bad tiles prior to firing.

We discuss three different systems of this new family, all build into the same looking housing and specialised for monitoring the press ("CeraFacer"), the decoration ("CeraScreener") and for predicting colour shade instabilities before firing ("CeraTono").

Monitoring the Press for Particle Homogeneity and Quality of Embossing

A well-known aesthetical defect of porcellanato tiles is the non-homogenous distribution of the coloured particles (Fig. 2). Hard-to-detect by the naked eye, this defect often stays un-noticed for long periods of time, leading to large produced batches of minor quality. We use a colour-camera system and our proprietary ColourBrain technology detects after the press any process drift towards bad homogeneity. An alarm is triggered immediately and the bad tiles can be pushed from the conveyor right a way. This small "Cerafacer" has a slow footprint and does not need any interfacing to the process. It is just positioned over the conveyor and includes all components (illumination, camera, processor, display) in a small water- and dust thight integrated electronic cabinet. It is parametrized via self-learning phase and very easy to operate by the layman.

A second, very common defect occuring during the pressing of embossed tiles are local defects in the embossed pattern (Fig. 3). Small debris sticking to the press matrix can produce single or longer series of visually noticeable defects within the embossed pattern. We use a topological b/w camera to scan the 3D profile image of the pressed tiles and a fuzzy image comparision software to compare the actual 3D image to it one or several previouly learned references. Badly embossed tiles are removed before moving to the subsequent production steps such as (if done) first firing, decoration and final firing.

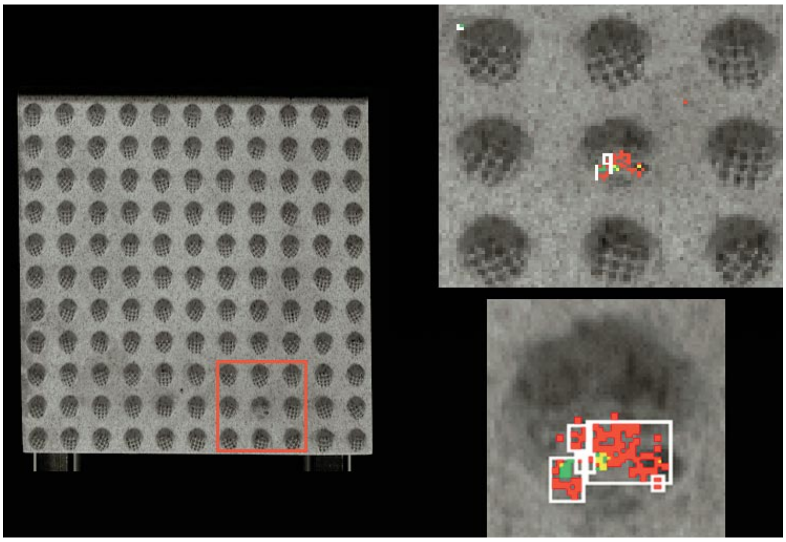


Fig. 3 Even smallest defects in the embossing patterns can be signalled by the CeraFacer using a b/w 3D topology camera and a fuzzy image comparison software

Fig. 4 (bottom) The CeraScreener watches the screen printing process for smallest defects in the decoration by using an advanced colour image comparison technology

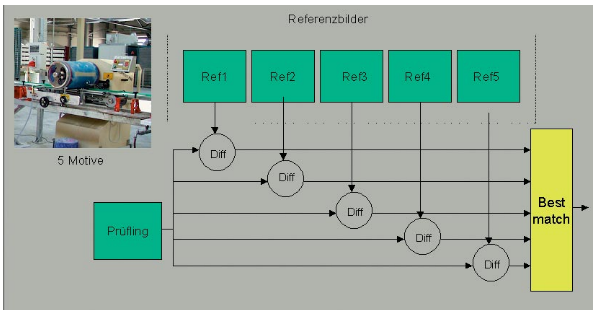
Monitoring the Decoration Process for Quality of Printing

Almost half of all tile defects occur during the decoration process : the flat-screen , rotary screen or Rotocolor decorators all have their specific weaknesses. Defects in the decoration step often are on-going defects: a screen rupture, a loss of glaze rarely heels by itself! In a modern, fully automated and almost unmanned production, the losses due to large batches of on-going production of bad quality significantly undermine the gain of profitability obtained through automation. Our CeraScreener drastically improves this situation by generating immediate alarms if such a defect occurs. It uses high-resolution colour cameras and a proprietry fuzzy image comparison technology to match every decorated tile against a good reference. Even smallest local defects such as missing decoration, misregistration, broken screen or miss of glaze are readily detected (Fig. 4). The system automatically learns all the reference images of one repeat and automatically compares the actual tile to its corresponding reference (Fig. 5). The CeraScreener also operates on transparent, glossy glazes by using a b/w camera observing the surface under an angle of total optical reflection (Fig. 6). It thus detects local smear or small defects in the glossy pattern which are very hard to see at this production stage by the naked eye of the human operator (if any is present at all).

Predicting Colour Shade Problems Before the Kiln

Sorting into batches of same colour shade is one of the most demanding tasks, for the human sorter as well as for an automatic camera-based system. There are (too) many process instabilities which lead to the production of tiles with a slightly different shade, which cannot be sold together. The required sorting into lots of same shade is expensive in terms of labour but also with regard of the many different shade families which must be handled separately.

Some of the processes which lead to a different shade occur within the kiln. It is only after firing that the final colour of the metal-oxide based pigments become visible. A good deal of issues which lead to a different shade are however located before the kiln: non-stable pigment concentration, different pigment absorption due to changing moisture content of the biscuit etc. These effects are so faint before firing, that they are not visible to the human eye.



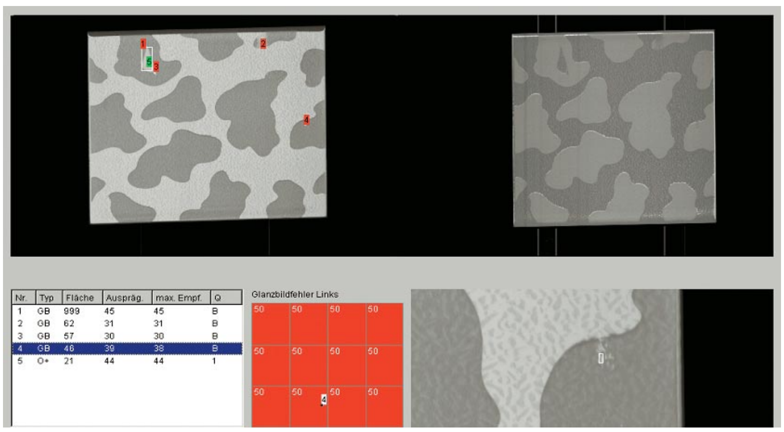


Fig. 5 (top) The CeraScreener matches an inspected tile to all possible reference images of a repeat

Fig. 6 (left) Defects in glossy decoration patterns which are hardly visible by the human eye are readily detected by the CeraSCreener

Fig. 7
A CeraTono system monitors before the kiln the stability of colour shades with a novel "imaging colorimetry" at the Venis plant in Spain

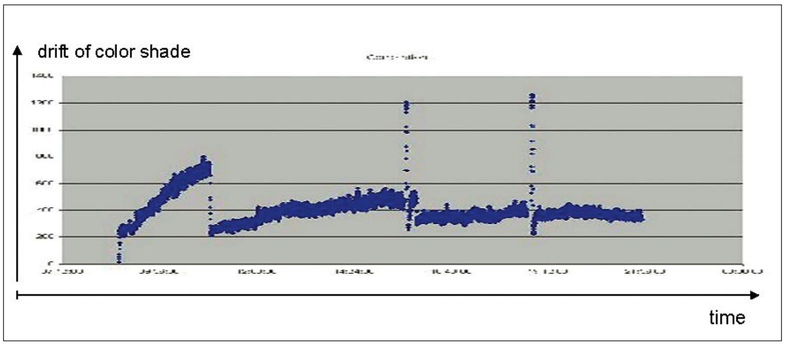


Fig. 8 The stability of the final colour shade is predicted before the tiles are fired using a new colour-camera based vision technlogy

We have investigated into measuring these very faint changes of shade in the not-yet fired glazes using the proprietary colour-camera based "imaging colorimetry"(Fig. 7). We proofed that it is indeed possible to monitor the stability of the final colour by carefully analysing the Hue, Saturation and Intensity statistics immediately after decoration. We use a very stable illumination and digital colour camera set-up together with a sophisticated automatic recalibration scheme to monitor permanently the colour shade stability and to warn the operator in case of process drifts which will lead to a different colour shade (Fig. 8). The "CeraTono" system does not predict the actual new colour shade; it merely warns that something is drifting within the decoration process and thus enables the operator to take counteractions. The CeraTono therefore provides an actual measure of shade stability timely close to the process drift, whereas the after-the-kiln sorter can only see the final shade of the finished tile and has no way to go back for improving the process in view of preventing colour shade variations.

Conclusion

Automatic camera-based inspection and sorting systems which operate at the very end of the tile production line, i.e. before packaging, do a very good job in assuring a constant quality. They are however not able to produce informations which could be used to control the production process in view of preventing low quality tiles and colour shade variations.
We have developped, based on the multi-sensorial vision technology of our full-blown automatic inspection system CeraVision, a new family of small, low-cost and dedicated vision systems able to monitor the critical production steps before firing: the press and the decoration. These easy-to-install and easy-to-operate systems provide continuous information on the process stability, generate immediate warnings and are able to eject bad, semi-finished tiles from the conveyor. They therefore save precious production capacity otherwise consumed by low quality tiles. They prevent due to the automatic immediate alarm generation the production of large batches of low quality common in modern, almost un-manned plants. Their return-of-investment is typically less then one year and they provide a welcome complement to the end-of-the-line automatic inspection.

