

Preliminary Design of an On-Line Vision Based Brick Inspection System

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by

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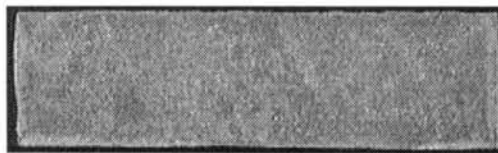
1 Abstract

This project is a cooperative effort between Heath Brewer, and Mike Lipscomb, and myself under the direction of Dr. Mongi Abidi. The objective is to design an on-line vision based inspection system capable of inspecting bricks for structural flaws as they come out of the kiln. A preliminary inspection system was designed and tested. The results of these tests are given along with future work objectives on this continuing project.

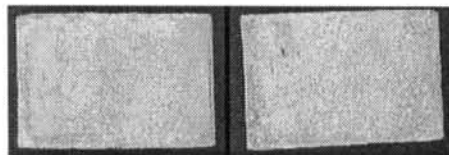
2 Technical Approach/Equipment

The bricks are to be inspected on the four major sides in the following priority (See Figures 1-3):

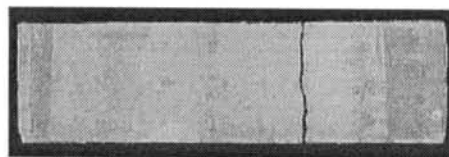
- Fig. 1: Top face (to outside world).



- Fig. 2: Right and left sides.



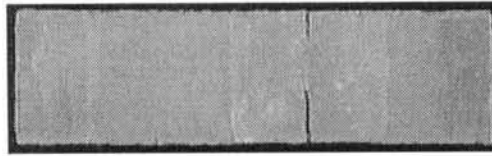
- Fig. 3: Bottom face (to inside world).



The beds, those sides that show the six or eight holes of the brick, are not to be inspected. As we are told by the General Shale executives, the bottom face is most likely to have crack defects because it is facing downward when the bricks are sitting on a bung and fired in the kiln. Also, the bottom two or so layers of bricks are most likely to contain cracked bottom faces caused by the weight of the bung pressing down on them. Preliminary work in the area of dehacking will help move most of these defective bricks to other conveyors where the inspection system will be installed. This will move bricks that are most likely to be cracked to the inspection system.

Because the initial objective concentrates on crack defects only (see Fig. 4), a visual system was used for crack detection utilizing the video camera equipment in our lab. However, a more thorough inspection system would use a laser range device that would adequately map cracks of various orientations and sizes. Another future possibility might include the combination of a laser range scanner and a video camera for full inspection of both physical defects such as cracks, chips, pits (see Fig. 6), as well as "visual" defects such as texture, color, incorrect size (see Fig. 5).

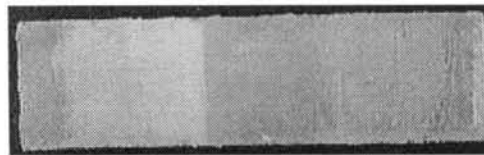
- Fig. 4: Cracked Sample.



- Fig. 5: Pitted Sample.



- Fig. 6: Discolored Sample.



Our objective is based on using our present lab inventory: video camera, conveyor belt, digitizer connected to a Sun workstation, and in-house software. We proposed and tested a system that takes a visual image of bricks on the conveyor belt using the video camera. Then we digitized the image using the video frame grabber. Once we had a computer image (converted into the appropriate format), we manipulated and tested the image using our own lab software.

One problem we discovered was how to inspect the bottom face. We can set up three cameras to inspect the top, left, and right sides. The bottom side sits on the conveyor belt, however, so the brick must be rotated or lifted so that a fourth camera can inspect this side.

One of the most important aspects of this problem is the lighting. If we can control the lighting, we can control how our samples will be acquired. Then all of our results will be consistent and easily tunable. Ultimately this inspection system will be placed in a factory environment where lighting is often insufficient for camera-digitizer work. Lighting must be controlled, as well as some type of hardening of

instruments provided, to survive the harsh conditions, such as airborne dirt and other debris present in the factory, that can damage sensitive computer equipment. We propose to house the entire vision inspection system in an enclosure suitable for the factory that will allow us more control over the lighting. This enclosure would be designed to fit around the existing conveyor belt.

General Shale proposes an unloading system that will unload 22 bricks at a time from the bung using a wide-grip robot arm. As the first 11 are placed on the conveyor belt, a camera underneath a robot arm digitizes an image of the first 11 bottom faces. This process uses software to detect cracked bricks and then track them down the conveyor line to the rejection mechanism. Another pass by the camera over the remaining 11 bricks would repeat the bottom face inspection for this set of bricks. General Shale's method seems a little impractical because

- 1 The speed of the imaging system would require a fast CPU and camera system.
- 2 Blurring might occur that must be corrected either by the software or by tracking the camera system along with the swinging robot arm (see Fig. 7).
- 3 The software tracking of the rejected bricks could be difficult, not only for subsequent motion down the conveyor system to the rejection mechanism, but also because of the possibility of a belt breakdown between the "mark a brick as bad" step and the actual rejection mechanism.

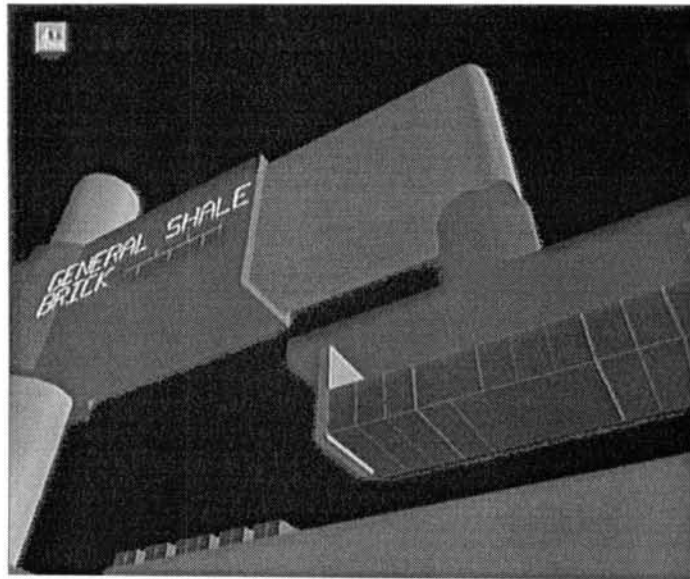


Fig. 7: Computer-generated representation of swinging robot arm.

We do not know if General Shale would like to mark bad bricks with some type of ultraviolet dye or other physical mark so that a simple rejection device could kick out bad bricks. This is an issue that can be further discussed in the future.

There are basically two approaches for detecting cracks. The first approach is to generate a one-dimensional signature that would look like the brick, complete with valleys that represent the crack (see Fig. 8). A classification of the brick is based on the presence or absence of valleys that are considered likely to be cracks in the brick. The second approach is to develop a two-dimensional image that would represent the inspected side (see Fig. 9). This image would undergo several image processing steps, producing a final image from which the computer could make a decision. This image ought to show a white crack clearly on a black brick background.

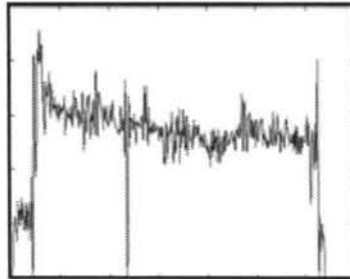


Fig. 8 One-dimensional signature.



Fig. 9 Two-dimensional signature.

Development of the one-dimensional signature is closely tied to the use of a laser range scanner for crack inspection. It is possible to have a laser "sheet" that can scan the entire surface of the inspected brick face and generate a one-dimensional signature (see Fig. 10). This laser sheet can use the natural motion of the conveyor belt to generate a continuous "sampling" of the inspected brick face. Once a collection of samples is generated, operations (averaging, summation, root-mean-square, etc.) can be applied to reduce the collection of samples to a single signature. Since we did not have this type of laser range scanner, we attempted to generate our own collections of signatures from video images. This approach was somewhat crude and we did not spend much time exploring this area in-depth. Perhaps it could be more fully developed in the future.

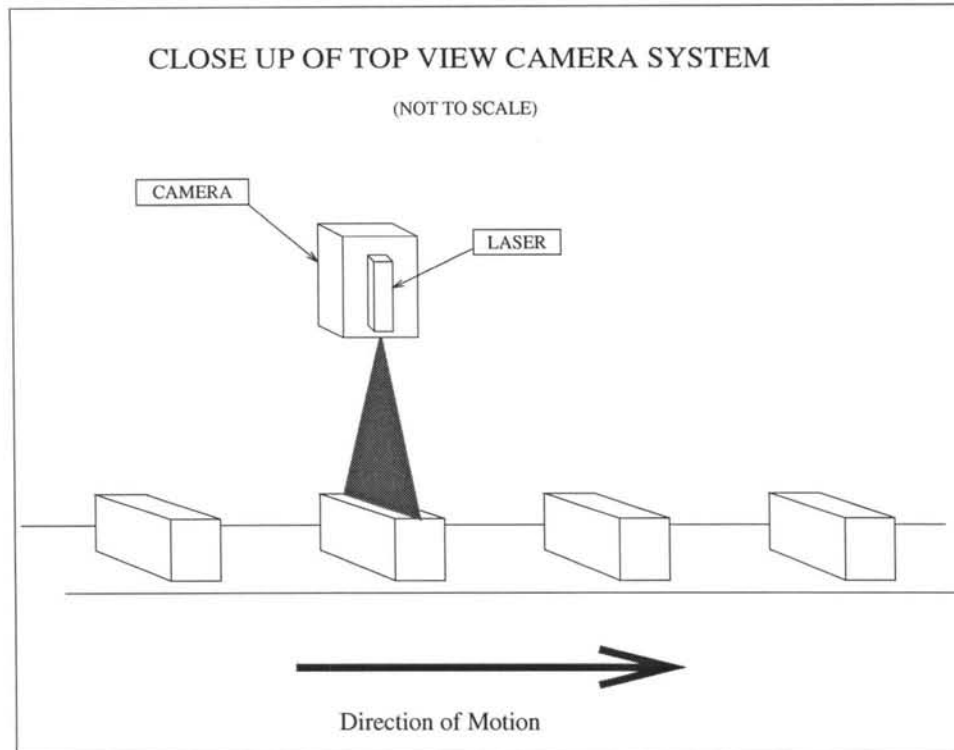


Fig. 10 Laser sheet scanning brick surface on conveyer belt.

The two-dimensional image processing system is what we concentrated on for most of our research work. Since we already had a video camera, all we had to do was generate a library of brick samples and start performing image processing functions on this library in order to test our algorithms.

3 Testing Procedure

- 1 Convert a library file from .gif to .ppm format.
- 2 Convert the .ppm format file into separate red, green, and blue channels to simulate the channels of a video camera.
- 3 Isolate the brick in the image by summing horizontal pixels to obtain a horizontal signature, adding the vertical pixels to obtain a vertical signature. Then bound the brick against the background by comparing the signatures against the background, and output the final image file. (Errors caused by this step are due to the fact that the isolation algorithm is not completely adaptive. The internal values used for the signature brick/background thresholding are constants. To significantly reduce the occurrence of isolation errors, an adaptive

algorithm can be created to generate isolation values unique to each image.)

- 4 Threshold the brick image. Each horizontal line of the brick image is broken into small segments, the size of which is an internal constant. These segments are then thresholded by computing each pixel's deviation from the segment's average intensity. The maximum deviation from the average segment intensity has a constant scale factor. An adaptive generation of the segment size and the deviation scale factor could increase performance significantly.
- 5 Classify the brick as good or bad. We manually classified our library as good bricks or bad bricks based on the presence or absence of cracks. Once a brick was classified, it was noted as falling into one of four categories:
 - 1 NONDEFECTIVE classified as NONDEFECTIVE
 - 2 DEFECTIVE classified as DEFECTIVE
 - 3 NONDEFECTIVE classified as DEFECTIVE
 - 4 DEFECTIVE classified as NONDEFECTIVE

The statistical results are listed in the next section. The vision system classifies a brick by searching the thresholded image for crack segments of a predetermined size. This technique is a type of template matching. If any segments are identified, the brick is considered cracked. Currently, only vertical segments are identified. A vast improvement will be to search for crack segments of any orientation.

The output of the algorithm is shown in Fig. 11. The first image is the grayscale image of the isolated brick. The second is the binary brick image obtained from thresholding. The final brick image is the result of the template matching revealing whether the algorithm detected any cracks or not. The last portion of the output shows two markers. The marker on the left represents the manual classification with that on the right representing the classification given to the brick by the algorithm.

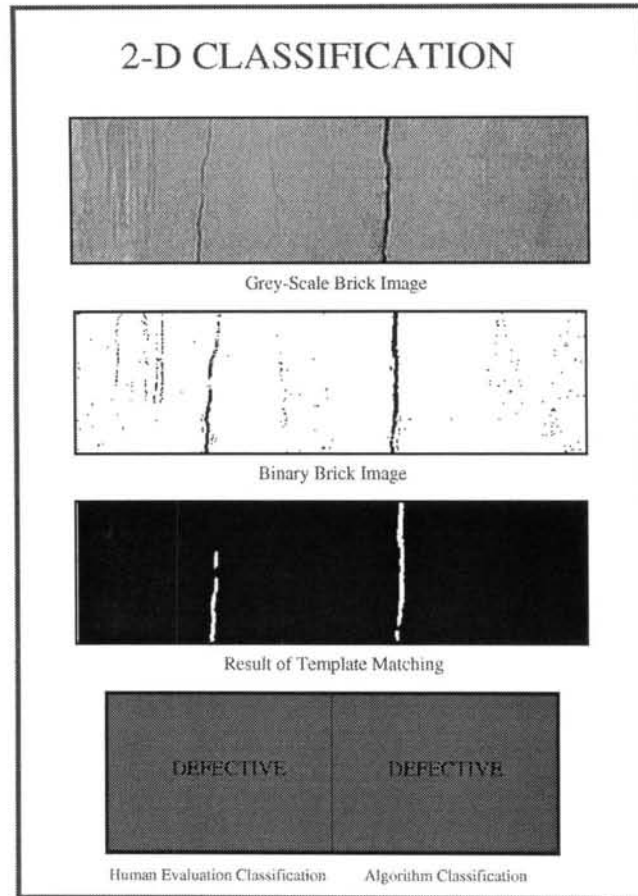


Fig. 11 Graphical Output of Classification Algorithm for a Brick Sample.

4 Conclusion

Out of 92 total sample inspections, (top and bottom faces of 46 bricks), we obtained the following results:

- 63 out of 67 were NONDEFECTIVE classified as NONDEFECTIVE (94%).
- 23 out of 25 were DEFECTIVE classified as DEFECTIVE (92%).
- 4 out of 67 were NONDEFECTIVE classified as DEFECTIVE (6%).
- 2 out of 25 were DEFECTIVE classified as NONDEFECTIVE (8%).

Also, our study shows that it is realistic to design a vision system with the following characteristics:

- Inspection of 5000-6000 bricks per hour per conveyer line.

- Detection of line flaws on the order of 2 mm width (average width of our cracked samples).
- Detection of pits, chips, and color variations of reasonable size and diversity.
- Computer hardware kept to a minimum using components now available.
- Modular image acquisition hardware using off-the-shelf parts to facilitate easy repair and minimize downtime.

As stated previously, this project is an on-going one that calls for changes in parameters as our research continues. Because of this state of change, versatility in the inspection system needs to be offered in order to aid in the continuation of the project. To help offer more versatility, we are currently working on the installation of testing equipment capable of performing sample brick inspections using a laser range scanner to acquire the data. Using the laser range scanner will offer us the advantage of not having to control the surrounding light as the laser will not be affected by that light. This will also allow us to use either 1-D or 2-D processing as a part of the total inspection process. Both the 1-D and 2-D processing approaches offer a great deal to this project and the advantages of both are currently being compared to help us decide which type of system will be best to ultimately implement.