S A Journal of Industrial Engineering, Vol 5, No 1, June 1991 pp. 27-36

ADVANTAGES AND LIMITATIONS OF AN AUTOMATED VISUAL INSPECTION SYSTEM

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ABSTRACT

An automated visual inspection system is not the panacea that it is made out to be. There are many pitfalls for the unwary company wishing to implement such an inspection system. The major advantages and disadvantages are discussed in this paper. This will increase the probability that anyone installing a visual inspection station will obtain a successful system that meets their needs.

OPSOMMING

'n Outomatiese visuele inspeksiestelsel is nie die wonderwerk wat die industrie verwag het nie. Daar is probleemareas wat goed ondersoek en verstaan moet word. Die vernaamste voordele en nadele word hier bespreek. Dit sal dartoe bydra dat enigeen wat 'n visuele inspeksiesisteem installeer 'n beter kans sal hê om iets te kry wat suksesvol en nuttig sal wees.

1. INTRODUCTION

All physical objects can be easily identified by means of the image signature which they present. The image is, however, only a representation of a limited number of the physical characteristics of the object under observation and does not include any of the non-visual characteristics, such as the mass, sound or vibration, which may be present. A three-dimensional colour image contains a very high level of topographical, chromatic and textural information about the object, while the simple binary image contains considerably less. The first problem then is to decide on the simplest image which will provide the desired information.

The drive towards higher productivity in the manufacturing industry in South Africa and elsewhere has highlighted the need for an improvement in product inspection [Jacobson (1)]. One of the most important elements is the inspection of electronic assemblies [Reynders (2)]. Present inspection methods rely extensively on the use of spring-loaded probes fitted into dedicated test units ("bed-of-nails"), and on human vision.

An automatic visual inspection system can assist the human inspector but cannot replace or duplicate many of the unique abilities which the human being has. In this paper the principal benefits and shortcomings of visual inspection systems in industry are examined with specific reference to the inspection of printed circuit boards.

2. THE HUMAN INSPECTOR

The human inspector cannot maintain a high level of error-trapping for long periods of time. Within 15 minutes of the start of an inspection shift, the error-trapping capability of the inspector can be reduced drastically. The number of errors made will be influenced directly by the complexity of the task and the number of components on the printed circuit board, the time of day and the particular day of the week [Dhillon (3)]. Experience gained in the USA shows that a human being involved in visual inspection can be expected to find approximately 70 % of the total errors on a complex board [DIT (4)].

Major advantages of the human inspector:

a) Is only slightly affected by the lighting of the area.
b) Has very good deductive powers.
c) Is not affected by different-coloured components.
d) Is not affected by disorientation of the board or components on the board.
e) Has very good character recognition.

Major disadvantages of the human inspector:

a) Is affected by fatigue, time of day and day of the week.
b) Cannot maintain long-term consistency.
c) Needs breaks and rest periods from the task.
d) Can be slower than a machine.
e) Inconsistency between different inspectors.

3. TEST JIGS

Possibly the most common form of test jig is the bed-of-nails unit consisting of a specially designed and manufactured test device with many spring-loaded test probes. These probes make contact with strategic points on the device under test. A bed-of-nails inspection unit can only be used on boards which have been specially designed with this form of inspection in mind.

The very close tolerances required between the bed-of-nails test points (typically 0,01 mm at 0,5 mm spacing between centres) make this a difficult method to apply to the new breed of dense boards which now often include many surface-mounted devices (SMDs) [Smith (5)]. The modern trend is to continue increasing the number of SMDs on a printed circuit board, with an ever-increasing component density.

Major advantages of a test jig:

a) Is faster than a human being.
b) Can be cost-effective on simple products.
c) Can perform a functional test.

Major disadvantages of a test jig:

a) Is dedicated to a specific product design.
b) Can be impossible to implement on small products.
c) Requires a very stable and accurate product placement.
d) Can be very expensive for a complex product.
e) Cannot inspect all the components as can a human being.

4. VISUAL INSPECTION SYSTEMS

The visual inspection system makes use of a video camera for data collection, and a computer and software for data analysis. The video camera captures an image of the object under test. This is sent to a computer via a frame grabber card for processing. The software in the computer then analyses the image and makes a decision as to whether the object passes or fails the inspection.

The conditions under which the video system works must be well controlled and must be easy to maintain in factory conditions. Depending on the level of automation, a video system can considerably reduce the task of the inspector.

Major advantages of the visual system:

a) Is easily adaptable to inspect different products.
b) Can be reprogrammed off-line on another machine.
c) Does not get tired and can work 24 hours per day.
d) Maintains consistency of inspection.
e) Has an average speed which is higher than that of a human being.

Major disadvantages of the visual system:

a) The lighting conditions must be well designed and implemented.
b) Software must be carefully selected and implemented.
c) Is intolerant of component variations on products.
d) Does not emulate the human inspector.
e) Has no real intelligence: follows rules.

5. IMPLICATIONS

Inspection must be regarded as an overhead expense because it adds no direct value to the product. The product must, however, be inspected to ensure that the quality remains as high as possible. A faulty product which is sold to a customer can do irreparable harm to the company's reputation. In extreme cases, low quality of product inspection can lead to a company closing down.

A fully automated video inspection system, on the other hand, will be very expensive and is beyond the means of all but the largest companies. The system will maintain a consistently high level of fault-trapping, but cannot easily be adapted to detect alternative components from different suppliers being used at different times during any production shift.

The human inspector is not infallible and can make two types of incorrect decisions:

1 He may accept a faulty item as being in order and allow the product to pass through the inspection station.

2 He may reject a good item and return it for repair, causing delays and unnecessary expense.

No inspection system is totally foolproof, but an automated system can be fine-tuned to produce better results than a human inspector on routine tasks.

6. CHOICE OF INSPECTION SYSTEM

A vision system can be of assistance to the inspector, by highlighting the visual characteristics of the device under test. This can reduce human inspection errors. Although the combination of a vision system plus a human being will not be infallible, it will improve the overall level of fault-trapping.

An efficient low-cost inspection system can significantly improve productivity by reducing the possibility of errors on the products being overlooked, and by minimising the time spent on inspecting the product during manufacture.

The inspector can be provided with an enlarged and enhanced image of the device under test, allowing the major part of the decision-making process to remain directly under his control. The amount of human intervention allowed during inspection may be set at any one of a number of different levels. The inspection station may use a low, medium or high level of automation, with the ultimate being a fully automated device requiring no human intervention or supervision.

The inspection station must be as close as possible to the point where the fault may occur so that the error can be trapped at the earliest possible opportunity and diverted for correction. It is preferable to divert a board for correction after component insertion but before soldering takes place rather than after the components have been soldered. A typical flow diagram of the production line in a small electronic assembly plant is given in Figure 1, with suggested points at which inspection could be implemented.

Human inspectors become more unreliable as the task becomes more complex [Connel, Harris (6,7)]. The level of unreliability increases in direct proportion to the time the inspector spends at the same task [Dhillon (3)]. This problem arises in the field of printed circuit inspection both with unpopulated boards and during the population of the boards with components.

Philips of Eindhoven claim to have reduced the passage of assembly errors from 5 % to less than 0,04 % by using a proprietary vision-assisted inspection station on a production line [Kane (8)].

In an analysis undertaken in 1987 by ETP of Saratoga, they found that automated inspection systems were effective in capturing 97 % of all faults, whereas under the best conditions a human inspector without any extra aid was only capable of capturing 78 % of the faults [Rettig (9)].

The principal components of an image-based inspection system are shown in Figure 2. The system must be configured for the particular task being undertaken, but will always contain at least those items shown in the diagram.

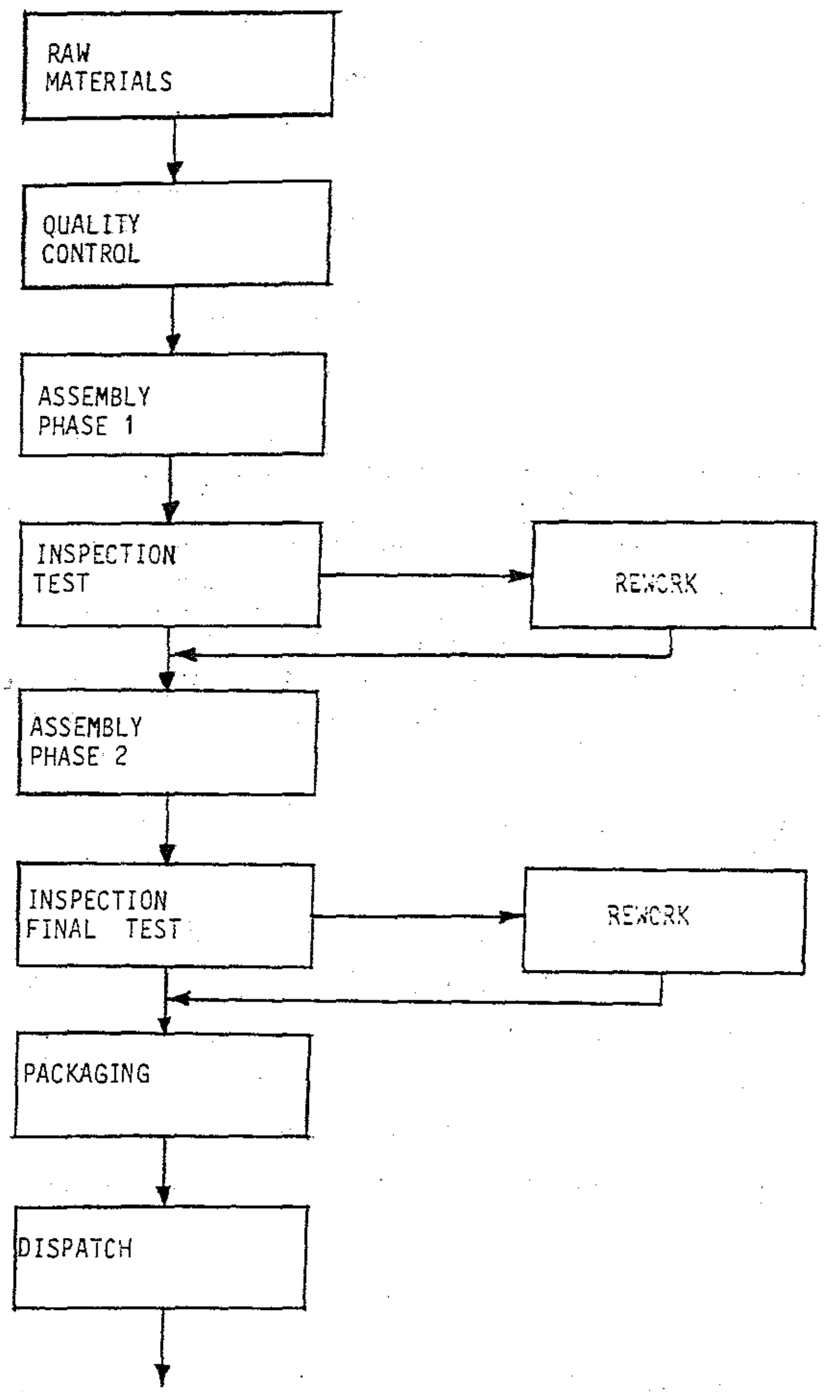

FIGURE 1: Product Flow Along an Assembly Line
The figure presents a simplified diagram of the material flow along a typical printed circuit assembly line. Two inspection stations are shown where rework may be required and where image processing can be of use in isolating errors.

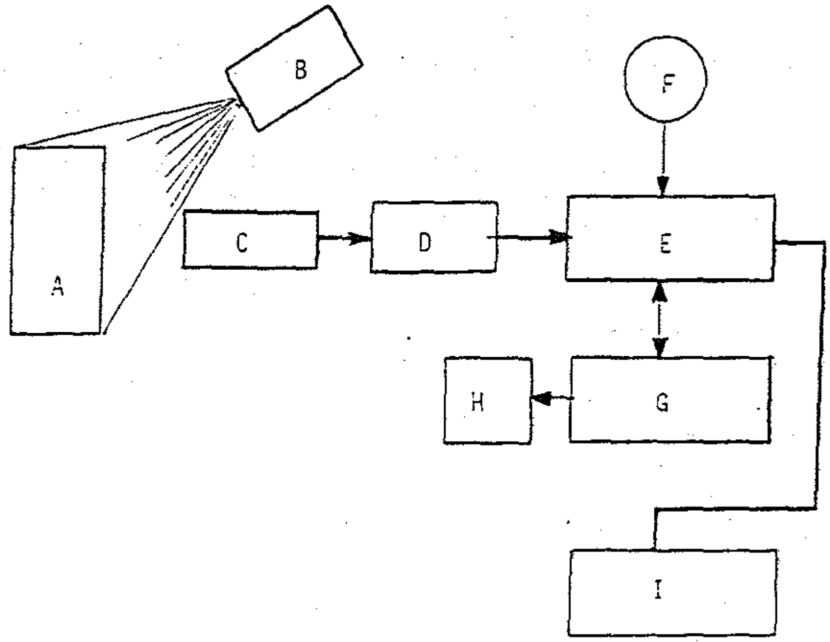

FIGURE 2: **Diagram of an Image-based Inspection Station**
This figure shows the principal components of an image-based inspection system. A is the device under test illuminated by the lamp B. The camera C feeds the image via the frame grabber D to the computer E. The software F performs the desired inspection functions. The system is controlled by means of the keyboard G and the image is viewed on the monitor H. An alarm or rejection unit I is activated when an error is detected.

7. THE IMAGE-BASED INSPECTION SYSTEM

An image-based inspection system can be considered to be useful even if it only partially alleviates the task of the inspector. Machine vision and automated inspection systems cannot be compared directly with a human inspector. The level of human perception and intelligence involved in normal vision and the differences between the methods of analysis of the two make the human and machine systems each unique in their particular application areas.

A skilled inspector is able to draw on a vast amount of knowledge and experience gained in the field, which allows him to pick up cues which are not possible to program into a computer at present. Machine intelligence is nearly faultless in maintaining a constant level of detection for a well-described fault, but is still very much in its infancy in being able to make deductive inferences requiring a medium level of true deductive skill.

The cost of procuring and installing a single small image-based inspection station can very quickly prove to be a worthwhile economic proposition in a small electronics factory, instead of having a small number of dedicated electro-mechanical bed-of-nails test units. With the currently available technology, it is feasible for even a low-volume producer to consider an image-based inspection station. An image-based inspection system is also ideal for use with the new smaller PCB-based electronic products being manufactured, such as calculators and wristwatches.

The survival of a viable modern electronics company can be positively affected by the successful implementation of a good image-based inspection system.

8. CONCLUSION

The use of an image-based inspection system can improve the quality of the work performed by inspectors in the electronics industry. The implementation of such a system must, however, be done only after careful evaluation of the company's needs. A careful design and feasibility study must be made first, taking into account the advantages and disadvantages of the various options. If this approach is used, the chances of success and of a reasonably trouble-free introduction of the system can almost be guaranteed.

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