Flexible Multi-Sensor Inspection System For Solder-Joint Analysis

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ABSTRACT

This paper describes the design and construction of an open, automated, solder bond verification machine for the electronics manufacturing industry. The application domain is the higher end assembly technologies, with an emphasis on fine pitch surface mount components. The system serves a measurement function, quantifying the solder bonds. It interfaces with the manufacturing process to close the manufacturing loop. A geometric model of the solder in a joint, coupled with a finite element analysis of the physical properties of solder, lead to objective measurement of the solder. Principle illumination systems are laser, X-ray and noncoherent lighting. Open, Objected Oriented design and implementation practices enable a forward looking system to be developed.

1 PROJECT OVERVIEW

This paper describes the design and construction of an open, automated, solder bond verification machine for the electronics manufacturing industry, under the auspices of VERBONDS, a project within BRITE/EURAM. It is being under taken by a consortium of partners — Trinity College, Dublin; Lucas Engineering and Systems Ltd.; Digital Electronics Corporation; Liverpool John Moore's University; Sopelem-Sofretec; and LETI (CEA - Technologies Avancees), DSYS-CENG. The prime target area in the industry is fine pitch, surface mount components, with care being taken to address the more advanced technologies of the future. The design goal is to provide the industry with a set of norms for assessing the quality of product by quantitative measurement.

The ultimate objective of the project is to develop a machine capable of 100% inspection of Printed Circuit Board Assemblies (PCBAs). The machine is constrained to operate within the constraints imposed by the production factors such as cycle time and cost. To achieve this goal three different sensor systems are being used, namely coherent light, non-coherent lighting and X-rays. By utilising the inherent benefits of the different sensor modalities a broad spectrum of data can be acquired upon which to base subsequent analysis.

2 APPLICATION DOMAIN

Bonding technologies are developing apace, with decreases in pitch and diversification in functionality. The trends within the industry are to shy away from extremely fine pitch devices, but there is continuing innovation in component types. This will place additional strain on the current inspection processes, and to meet these demands a radical upgrade in inspection techniques is needed. The fundamental problem with current Visual Mechanical Inspection (VMI) standards is their subjective nature. Standards from e.g. the International Tin Research Institute,[1] or MIL-STD-2000 and WS-6536, are undermined by the inability of the subjective inspector to provide objective quality assessments, and thus do not provide quantitative data on the manufacturing process.

The provision of quantitative assessments of solder joint quality is the objective of the VERBONDS project. The final system will both serve as a measurement tool within the electronics industry and contribute to the development of quantitative inspection standards. The ultimate goal of the VERBONDS system is to provide the electronics manufacturing industry with both increased process automation and superior quality control. To provide this improvement, the inspection platform under development will take quantitative measurements in real time enabling *continuous* monitoring of the process to ensure those standards are met.

3 VERBONDS SYSTEM OVERVIEW

To meet the demands of the industry across the full spectrum of today's technologies, the design specifies an open system, fusing multiple sensing systems into an integrated process control instrument. This will facilitate the flexibility of the system, as well as its coverage. Given the range of components currently in use within the electronics industry, the imaging requirements for 100% coverage are complex. These can be met, by providing a comprehensive configuration, but such a solution soon becomes prohibitively expensive. The ability to dynamically configure the inspection routines, and to incrementally upgrade the sensing systems, means that the VERBONDS system can provide flexible solutions sensitive to both the needs and the budget of a broad range of product within the electronics industry.

The VERBONDS System is primarily divided into two sub-systems, the Measurement System and the Supervisory System. The Measurement System's main function is to perform data acquisition and calculate solder joint parameters on the PCBA under inspection. The Supervisory System handles the overall management of the work cell providing such services as the load/unload mechanical handling and the interfaces to users and the on-line production management system.

3.1 The Supervisory System

The Supervisory System is responsible for overall work cell management. The Supervisory System constructs the Inspection Request (IR) by interfacing with the product CAD database and production process requirements. The process requirements can be dynamically determined by the production engineer, or by statistical analysis of past inspections. The inspection request is sent to the Measurement System which returns the parameters which were requested. The Supervisory System reports on the data via a Graphical User Interface (GUI) and also performs data analysis over a period of time identifying statistical trends to aid in the control of the production process.

The Supervisory System is further subdivided into the following modules.

Inspection Request Generator (IRG) This determines the inspection events necessary to fullfil an inspection request. These events constitute an IR that should be carried out for a particular subject PCBA. Possible inspection strategies range from a statistically driven sampling routine to a full 100% inspection of all bonds. The IR is in the form of a file loaded to the Measurement System which details the general board layout i.e. fiducial marks, locations of components and the types of inspection to be carried out on each component.

Material Handling Subsystem (MHS) The Material Handling Subsystem (MHS) identifies PCBA's as they are loaded into the work cell. The identity of the newly loaded PCBA will select between two courses of action. If the PCBA differs from the loaded configuration it is necessary to build a new IR, however if the PCBA matches the configuration the IR requires no modification. When the inspection has completed the MHS is informed and unloads or inverts the PCBA depending on whether bottom side inspection is required.

Data Analysis (DA) This module receives the information from the Measurement System in the form of either parametric measurements or in the form of pass/fail results. For quantitative measurements the DA module processes the information with respect to the current quality criterion to develop an overall strength/reliability measurement for the joint. Selected algorithms to generate the quality measurement from the criteria are being developed within a Finite Element Modelling (FEM) package. The quality measurements are returned, linked with the CAD data for the PCBA, providing precision logging of process performance and product quality.

Process Control Information (PCI) The PCI module is responsible for results dissemination both directly to an on-line Process Control System and to the users of the system via a GUI. There are several interfaces in the GUI for the different types of users, for example a separate interface is necessary for Production Engineers, Machine Operators and Developers. PCI will use the recent information to update process control charts (for variables or attributes) which are being used to monitor the process.

3.2 The Measurement System

The Measurement System is responsible for the production of quantitative information about the product under examination. The Measurement System is itself divided up into four main components, the Inspection Control Module, Acquisition Control, Image Management and Image Processing.

Inspection Control Module The Inspection Control Module's primary function is to drive the Acquisition Module through the requirements of the Inspection Request. It also generates the configuration requirements for the Image Management and Image Processing modules. The Inspection Control module drives the real-time measurement functions of the Measurement system. It drives the acquisition system through a stated pattern of inspection events in order to acquire the necessary images and pass them to the Image Management module. To perform these functions it uses the processed CAD files for the PCBA to generate the routing and sensor configuration information for the sub-systems within Acquisition Control module. Critical issues in synchronisation, timing, and mechanical control are within province of this module.

Acquisition Control Acquisition Control primarily manages the acquisition of the images from the different sensors. It takes the inspection request information from the Inspection Control module and executes the route, moving the PCB and passing the relevant sensor configuration information to the sensor. The resulting images are passed to the Image Management module.

The modular specification of this component of the VERBONDS cell provides for the flexibility of configuration that will guarantee the viability of the project. Each project partner is enabled to develop one or more sensing systems, which can be readily integrated on account of the Sensor Subsystem interface specification. Sensor Subsystem configuration time is projected at 15 minutes, thus rapid configuration and re-configuration are definite targets. The Measurement System may be configured with one or more Sensor Subsystems, allowing minimal, cost effective, solutions to be provided on the one hand, and comprehensive functionality for critical applications on the other.

Image Management The Image Management module manages the system resources and distributes sub-images to the relevant image processing algorithms in the Image Processing module. This provides for the possible parallel operation of sensor systems within the Acquisition Control module and the parallel distribution of the image processing algorithms by the Image Processing module. The complexity of such a system would be encapsulated within the Image Management module removing the need to redesign the other parts of the system.

Image Processing The Image Processing module converts the raw sensor data into parametric solder joint measurements or pass/fail measurements. These measurements are then passed to the Supervisory System. The Image Processing module receives the images from the Image Management module and processes these images into quantitative or pass/fail measurements of solder joints. The site of the processing is not predetermined — specialised hardware, DSP chips or multiprocessing networks may be incorporated to provide for realistic measurement times.

The Image Processing system can provide pass/fail measurements from pre-determined critical bounds on the prime variables of the particular assembly technology. The quality criteria within the industry remain subject to the production process and manufacturer, principally determined by the application demands, and hence the financial constraints imposed on producing cost effective product.

4 FROM SUBJECTIVE TO OBJECTIVE IMAGING

To remedy the lack of quantitative standards for solder joints, a theoretical model of the quality of a solder joint has been developed. The theoretical model of the solder joint, coupled with a sophisticated model of each sensor system's imaging, allows *quantitative measurement of the solder joint.* The validity of the model of the physical properties of the solder joint and the accuracy of the sensor system determine the validity of the quality assessment.

4.1 Theoretical Model of the Solder Joint

The model of a solder joint effectively parameterises the geometry of the solder. Some recent work in this area[2] identifies the prime variable in the SMT process as heel fillet formation (see Figure 1). However, due to imaging difficulties, the heel fillet requires much more expensive sensing equipment, e.g. X-rays, and so to provide a cost effective yet comprehensive solution, several secondary variables are taken into consideration in the model. The surface profile, both longitudinally and laterally, coupled with the fillet curvature, leads to a geometric representation of the solder volume. This, coupled with an finite element model of the solder volume, provides a solid physical reference for the parametric measurements from the Imaging system.

The theoretical model of the solder joint allows the fusion of information from the various sensor modalities. It is precisely the open design of the system, abstracting physical measurements from imaged data, that permits

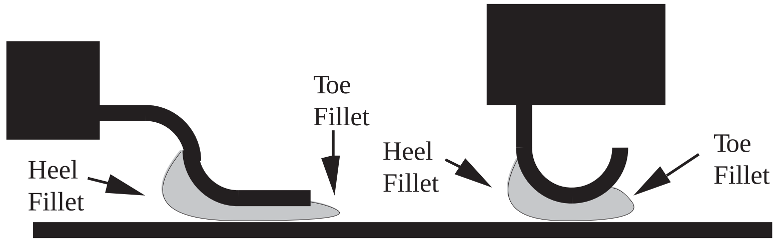

Figure 1: Two joint types are shown, on the left a gull-wing lead and on the right a J lead. Both are dry, indicating the information that is *not* readily detectable by X-ray imaging.

multi-sensor operation. For example, if the ambient manufacturing temperature proved to be a contributing factor to the quality of the process, the adding of a temperature sensor to the system would simply involve an extra physical parameter as input to the FEM model.

4.2 Parameters

The prime variable under consideration is the toe fillet angle. The high resolution structured light system is specifically designed to image the toe fillets. The measurement of width and length of gull wing joints is relatively tractable with any sensor. To measure the surface profile a laser diffraction pattern is projected across the joints. Finally, the X-ray system, using a micro-focus source, is capable of imaging solder features to $\sim 4\mu$. The *thickness* of the solder in the joint is readily calculated from the Radon transform of the absorption function. The principle requirement on sensor fusion is to couple the information from the structured light, laser light and X-ray sensors to provide an integral measure of the geometry of the joint from the separate measurements.

No sensor can measure all the features on it's own. There are some overlaps in the capabilities of the various sensors, in which cases the process criteria are used to decide which sensor system is used. For example if both the laser system and the vision system are able to measure a particular feature and processing speed is critical then the faster sensor will be chosen. If however accuracy is at a premium then the most accurate sensor will be chosen.

4.3 Multi-Sensor Fusion

The sensors being utilised include standard CCIR cameras, and high-specification CCD arrays producing digital output. The optics used in the imaging systems provide for a variety of resolutions, thus enabling the optimum combination of data throughput and analysis speed to be chosen per application. The physical imaging systems are tabulated in Table 1.

The architecture facilitates the use of multiple sensor modalities by allowing the integration of data from the different systems. Although the analysis of the images varies with sensor type, a common basis for the fusion of data is provided by the parametric model of the solder joint and by rigorous calibration of the sensor models.

The parametric model can be expanded to include any measurable features of the solder joint. It ultimately yields a quality measurement, by interfacing with the FEM model of the solder properties.

The use of multi-sensor and multi-processor systems is facilitated by the use of an *Open Object Oriented* design philosophy. The object oriented (OO) features such as encapsulation using inheritance and operator overloading provide a robust and simple method of avoiding many of the complexities common to multi-sensor fusion. Other OO features such as message passing allow the parallel execution of tasks to be facilitated. The open design philosophy involves making the design as independent as possible of both hardware and operating systems. This involves managing the hardware dependencies of the component systems at the lowest possible level within the system. The OO paradigm provides a structure within which alternative implementations of system functions can be dynamically linked into the system.

4.4 Sensor Modalities

The following table depicts the relative capabilities of the differing systems. The physical properties under measurement are indicated in the second column. The specular reflections are used to determine geometric parameters of the solder using a technique based on a model of the joint geometry and the imaging system. X-ray imaging presents a direct measurement of the thickness of the solder. Coherent, laser, light involves imaging of a projected diffraction pattern, from which the height profile can be measured.

The calibration of the sensing system is incomplete, as the mechanical structures of the sensing systems are under redesign. The figures are based on the design trials, and so do not reflect the finished system calibration figures.

Illumination	Physical Property	No. Images	Resolution μ per pixel	Image Size	Pixel Size	Acquisition Time	Memory
Coherent Light	Specular Reflections	4	4μ	1260x1152	8	0.04s	1.3MB
Structured Light	Specular Reflections	4	7μ	768x512	8	0.04s	0.8MB
Structured Light	Intensity	1	14μ	768x512	8	0.04s	0.8MB
Coherent Light	Surface Profile	1	20μ	739x484	32	0.12s	3.2MB
X-ray	Thickness	1	20μ	1024x1024	32	1.5s	12MB

Table 1: Sensing System by Source, Acquisition Time, Resolution and Pixel Size.

4.5 Imaging and Image Analysis

Image analysis occurs in two distinct stages. The different sensors provide different types of information, and encapsulate image data in different ways. For example the X-ray image represents the absorption of the X-rays as they pass through the PCBA. This data is encoded in images with 32 bit pixels. The structured light sensors produce images of the reflection of lighting from the solder on the PCBA in 8 bit pixels.

The physical difference between the data captured by the different sensor systems requires that each individual sensor has a separate model. The models of the imaging system allows calibration of the images, in microns per pixel. This is the essential prerequisite for turning a machine vision system into a measurement device. This does not obviate the need for sensor specific algorithms be used to extract the data from the images to a sensor independent format, but rather guarantees the integrity of the resultant data.

By using the *Object Oriented* features of C++, we can *overload* the processing techniques which require different sensor dependent implementations. This facility simplifies the inclusion of a new sensor type to the implementation of new sensor specific algorithms.

The sensor specific pre-processing generates the sensor independent information which is required to compute the parameters of the solder joint model. Processing of this sensor independent data is now abstracted from the sensor modality from a computational point of view. The sensor independent data will however have tolerances which relate directly to the original sensor modality and to the sensor dependent algorithms. These tolerances will determine the overall accuracy of the inspection.

After the pre-processing of the images several sensor independent algorithms may be shared by the different sensor systems. Typical image processing algorithms at this level will include texture measurement, geometric parameter extraction, and morphological operations to determine connectivity. The subsequent extraction of solder depth, height and surface features in the sensor independent processing provides a rich representation of the quality of the solder joint.

5 NON-COHERENT LIGHTING SENSOR SYSTEM

5.1 Non-coherent Lighting for Solder Joint Analysis

The imaging of reflowed solder joints is an inherently difficult optical and lighting problem due to their extreme specularity. Several approaches to lighting were accessed in a series of lighting trials.

A diffuse source of lighting was used initally. The specularity of the joints made the effective use of this technique difficult. The specularity caused blooming in the cameras and the position of the highlights gave little or no information due to the uniformity of the lighting. A tiered colour lighting system was devised similar that described in Takagi.[4] This approach was reasonably effective but had some significant drawbacks. The light sources used were bulky and had high power requirements. Imaging using single chip colour cameras produced poor resolution and a three chip camera was deemed too expensive and bulky.

A Moiré fringe projection system was evaluated. It proved to be too inflexible and fraught with problems to be considered. The fringes projected onto the solder joints were distorted by specular highlights, the fringes could not be used for J-leaded components, the optical structure proved cumbersome and alignment was difficult to maintain.

The last and most effective method evaluated involved the use of specular highlights similar to Nayar[5] and Sanderson.[6] This technique involves using tiers of point sources distributed above the joints. The position of the specular reflection of a point source on the solder joint is a function of the viewing position, the point source position and the surface of the joint. Thus using a given viewing and point source position the extraction of the shape of the surface is tractable. It was found that for the problem of solder joint analysis the point sources could be grouped into patterns which could extract major surface features with relative ease.

5.2 Algorithm Development for Solder Joint Analysis

The final choice of the multiple point source illumination provides highly controllable, directed lighting which allows the use of structured highlight image processing techniques. There is a major inter-dependence between the lighting system configuration, the optical system and the image processing algorithms. The algorithms utilise the flexibility and precision of the lighting to simplify subsequent image processing, thus providing for high speed operation.

A high precision X–Y table moves the PCBA around beneath the lighting and optical head. There is provision within the system for the PCBA to be in constant velocity motion while images are being captured. The X–Y table provides hardware interrupts to the acquisition control module at specific locations. These locations correspond to components coming into the field of view of the camera system. Acquisition with a CCIR camera of a moving object leaves a shift between the two interlaced fields. The shift in each of the fields is constant due to the uniform motion and is corrected for. The reconstituted image is passed to the image processing module and analysed.

This acquisition strategy produces very high data rates and to allow for this images are passed through an image management module on their way to the image processing module. The image management module allocates memory for each of the images as acquired in a large image buffer. When this buffer reaches a critical high watermark the acquisition control module is informed and the next motion and therefore its corresponding sequence of images is deferred until the low-watermark is reached in the image buffer. By using this strategy the speed of inspection is only limited by system resources, with processing speed and the amount of memory as the limiting factors. Bottle necks in earlier inspection systems have centered around the motion between static image positions, and the VERBONDS system is designed is to eliminate those bottlenecks.

6 COHERENT LIGHTING SENSOR SYSTEM

Coherent optical sensor systems considered for solder joint inspection fall into two main categories, fringe projection systems and diffraction based systems. To date the most successful technique employed has been that of fringe projection, however the diffraction techniques have yielded some promising results for smaller scale components.

6.1 Fringe projection

Various 'structured lighting' approaches may be utilised to enable three dimensional data to be obtained from an essentially two-dimensional image. Examples are single-stripe, multi-stripe and grid pattern illumination. Simple triangulation may be used to calculate three dimensional height, however phase measuring techniques offer a greater degree of accuracy.

Given a surface illuminated by a cosinusoidal multi-stripe fringe pattern when viewed at a normal to the object reference plane, it can be proved[7] that the height of the object is given by

$$\text{height}(h) = \frac{\text{fringe spacing}(x).\text{phase shift}(\phi)}{2\pi \sin(\theta)} \tag{1}$$

When an object is illuminated by a fringe pattern and observed at angle θ, the fringe pattern can be seen to be phase modulated by its surface shape. The resulting phase modulated signal can be recorded by CCD camera and demodulated in order to reconstruct the original surface form of the object. Two phase measuring methods have been investigated, phase stepping and a fourier based approach.

Phase Stepping This involves the capture of several fringe contoured images, each with a different known phase offset present in the projected fringes. Each image represents an equation of the form,

$$I_{(x,y)} = A_{(x,y)} + B_{(x,y)} \cos(\phi_{(x,y)} + \alpha) \tag{2}$$

Where $I_{(x,y)}$ is the intensity at any point, $A_{(x,y)}$ is a D.C. level, $B_{(x,y)}$ is the amplitude of the Cosine envelope, $\phi_{(x,y)}$ is the phase and α is a known phase offset. These equations may be simultaneously solved in order to extract the required phase signal. Since three unknowns are present in the equations at least three images must be used, however four images are more common because they yield a simpler mathematical expression for phase. It can be proved[7] that for a system where four cosinusoidal fringe contoured images are recorded, each having a known phase offset introduced into the illuminating fringe pattern of 0^o, 90^o, 180^o and 270^o respectively, that

$$\text{Phase } \phi_{(x,y)} = \tan^{-1}\left[\frac{I(90^o)_{(x,y)} - I(270^o)_{(x,y)}}{I(180^o)_{(x,y)} - I(0^o)_{(x,y)}}\right] \quad (3)$$

One of the advantages of phase stepping is noise reduction brought about by the averaging effect of processing several frames. This is useful to remove laser speckle effects, which remain constant over each phase stepped frame. However the technique necessitates the capture of a minimum of three images as well as the time associated with the necessary phase movement in the illuminating fringe pattern. The time required for this relatively complex optical 'front end' is countered by a comparatively simple processing task to derive signal phase.

Fourier Approach This method allows a single image to be processed using Fourier transforms to yield the required phase signal. The technique was first developed by Takeda.[8] The Fourier transform of a fringe contoured image is taken, and Fourier domain filtering takes place to remove the negative frequency components. After filtering the Inverse Fourier Transform is applied. The phase signal can then be extracted by taking the inverse tangent of the quotient derived from dividing the imaginary parts by the real parts of the Inverse Fourier signal. Drawbacks include problems arising from the high frequency components present in fringe contoured images of solder joints and that the Fourier technique is not suited to processing small areas of interest such as the pad/solder regions of an image. The time required for image capture is greatly reduced and the optical 'front end' may be much simpler, however processing time is extended with the necessary transformations.

Both the phase stepping and Fourier approaches described above produce a 'wrapped phase map', meaning that the fringe phase lies in the range $+\pi$ to $-\pi$. Both techniques require a further 'unwrapping' stage so that phase progresses from approximately zero and increases by 2π for every fringe crossed. A calculation may then be performed to convert the continuous phase signal to a height signal above a flat reference plane, allowing a full three dimensional surface reconstruction to take place.

Diffraction Based Approach Fringe projection techniques suffer harsh optical limitations when dealing with very small objects, primarily because of severe restrictions in depth of focus at high magnifications. Research is being carried out into an inspection technique designed especially for very small components. If an array of fine pitch leads is illuminated by laser light, it approximates a diffraction grating and a reflected diffraction pattern is produced. A change in the uniform lead structure will bring about a respective change in the diffraction pattern. This diffraction pattern may be analysed to determine the quality of the lead array. Work is being carried out on the application of neural networks to the task of fault detection from diffraction pattern analysis.

The current optical system consists of an fringe projection head which allows the use of either Phase Stepping, the Fourier method, or a combination of both techniques. Processing is carried out using a TMS320C30 based DSP system, however a parallel system using TMS320C40 DSP chips is in the late stages of development.

7 X-RAY SENSOR SYSTEM

7.1 X-Ray Imaging

An X-ray flux going through an object is attenuated according to the density and the thickness of the encountered materials, as expressed in the following equation :

$$I = I_0 \exp\left(-\int_L \mu(l)dl\right) \tag{4}$$

where I and I_0 are respectively the incoming and outgoing flux, L the path of the ray in the object, and μ the attenuation function (strongly correlated to the density function).

For an object composed of n materials of respective attenuation functions $(\mu_i)_{i=1,n}$, this formula becomes :

$$I = I_0 \exp\left(-\sum_{i=1}^{n} \mu_i l_i\right) \tag{5}$$

where l_i is the thickness of material i crossed by the X-ray.

The flux I is then converted to visible light by the use of a X-ray image intensifier and a phosphor screen coupled to a CCD camera. Once the response of the acquisition system is determined, we can access the image of the $\sum_{i=1}^{n} \mu_i l_i$. An X-ray image is in fact a $2\frac{1}{2} - D$ image : each grey level expresses an interpretable quantitative datum.

For the inspection of fine pitch PCBAs we have to reach spatial resolutions of about 300μ to 100μ, this can be reached by setting the X-ray system to reach a magnification of about 10 to 15. Such magnifications can only be reached by the use of a microfocus X-ray source.

Let us now detail how such images can be interpreted.

7.2 PCB X-Ray Images Interpretation

The integration along the X-rays leads to an image with a lot of information of the internal structure of the object, but we have to develop very specific algorithms for its interpretation.

For a double sided PCB we get a superposition of the top and bottom side structures and we cannot directly identify the contribution of the components of each side. To address this problem we have developed at LETI (CEA - Technologies Avancees), DSYS-CENG a separation method based on the use of three radiographs corresponding to three different points of view. We have adopted an algebraic approach and are now speeding it up by a multiresolution approach to keep processing times compatible with an on line inspection.

Once this separation has been completed our problem is then equivalent to that of the inspection of a single sided PCB. On such an image we have still have the superposition of the pads and solder with certain component features (J-leads for example). To extract the solder contribution we are developing a method based on the use of a data base of non soldered component templates.

X-ray based PCB inspection requires very specific image interpretation algorithms, which are computationally expensive compared to those for a visible or laser inspection. But as mentioned in the previous subsection the radiographs contain a lot of '3-D' information about the solder : its volume, its height, its angle, the presence of voids or inclusions. Many of these parameters are not easily, or not accurately reachable by the other inspections modalities, as for the inspection of J-leads where the solder joints are hidden by the PCB case.

Let us also notice that for specific 2-D information, as the detection of lifted pads or of dry joints, X-ray inspection is not well adapted. So X-ray inspection has to be utilised in a cooperative inspection process : to keep a realistic inspection time we have to extract all the possible information by faster inspection methods, and use X-rays for parameters unreachable or not well suited for them (internal structure, hidden joints).

8 CONCEPT PROTOTYPE

The system is still in the prototype phase, with system development scheduled to complete in November 1994. The principle function of the concept prototype is to evaluate the VERBONDS system specification's highest risk elements. The concept prototype design brief set out specific evaluation targets the prototype ought to reach. The brief sets tentative goals for the evaluation of the specification in the risk areas. These include the numbers of component technology and package types to be inspected to be of the order 15, 40 joints per second inspection speed, sensor system reconfiguration time of the order of 1-2 hours, accuracy 1 misclassification in 10000. Issues in industrial acceptance, expandibility and cost constraint are also to be addressed.

Some illustrations of the system with laser and non-coherent sensor systems are included in Figures 8 and 8.

9 Future Vision Systems For Inspection and Control

The trends for the vision systems of the future seem to point to the use of systems with auto calibration, and dynamic configuration. Machine vision is becoming an integral part of the manufacturing process, rather than a separate entity inspecting its production. The VERBONDS system is being developed as an integral part of the production system, providing the information to aid automatic control of the entire process. The flexibility and configurability of the VERBONDS system enables the system to be used in controlling the process rather than as simply an inspection machine.

In closing the process control loop in a quantitative rather than a subjective manner (as is the current practice in the electronics industry) we hope the VERBONDS system will make a significant contribution to the industry. The scalability and flexibility of its hardware and software architectures should allow it to benefit from advances in computer technology and serve a varied application domain for many years.

The provision of a GUI to provide user friendly access to information be it on the manufacturing floor or in a production engineer's office are important features of many new computer applications, with machine vision systems being no different. The VERBONDS system will provide several different types of interface for the many possible users, machine operators, engineers or developers.

The success or failure of any machine vision system still hinges on robustness, repeatability and reliability. The robustness and repeatability of results of each of the individual systems is maximised as in any vision system through vigorous testing. The VERBONDS system also benefits from the ability to compare the measurements of several different sensor systems. This sensor redundancy provides a means of highly accurate tuning of the algorithms of all different sensor systems. However the final configuration will really be decided on the cost/benefit analysis for particular applications.

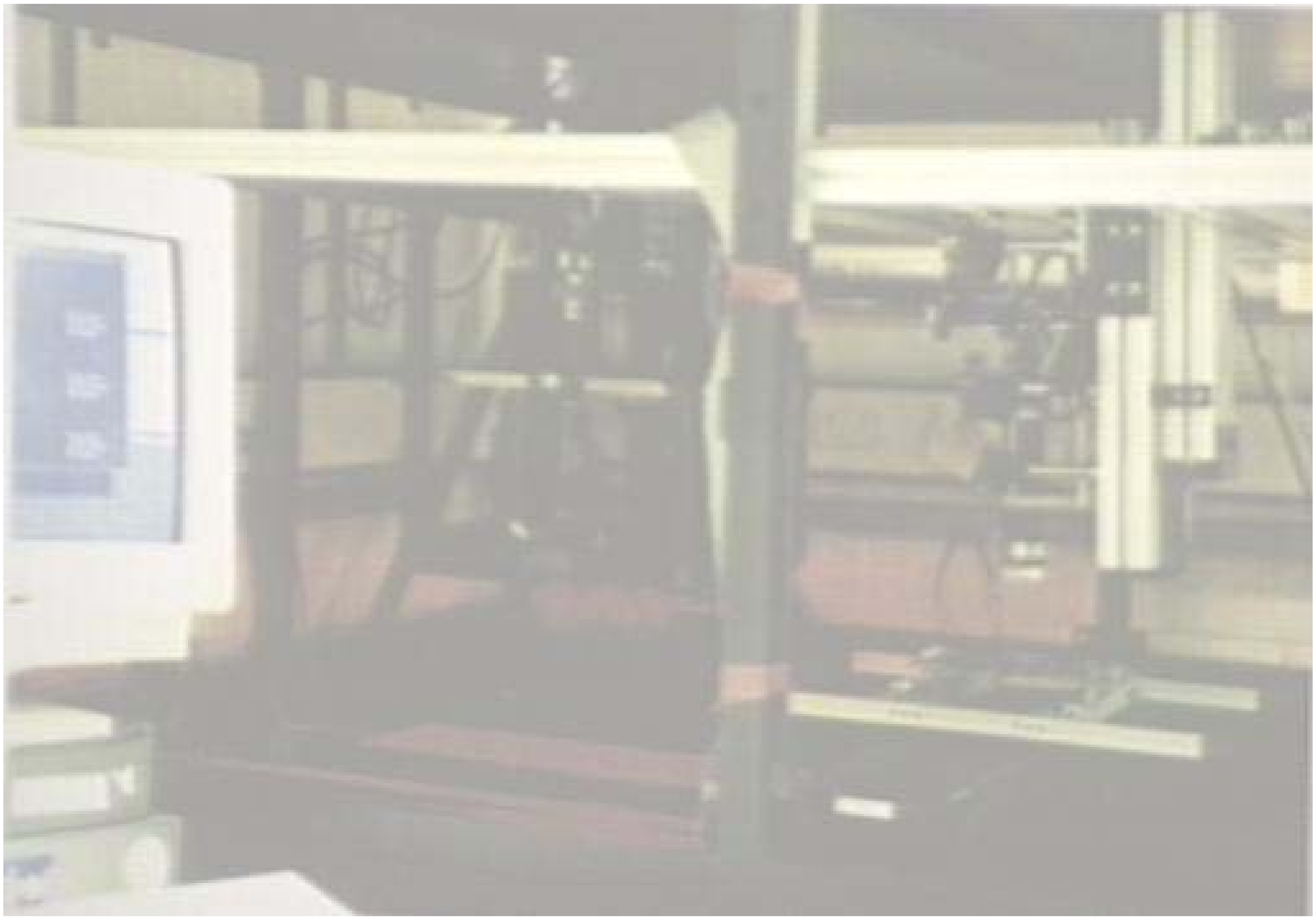

Figure 2: Picture of the integrated coherent and non-coherent lighting systems in operation.

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(a) (b)

Figure 3: Close up of the mounted coherent (a) and non coherent (b) lighting systems.