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BGA 焊点气孔缺陷的特殊结构光质量检测

袁肇飞 曹其新 杨扬

摘要: 为了解决球栅阵列 (BGA) 焊点气孔缺陷的在线检测问题, 开发了一种特殊的结构光检测技术。同时用环形红光和十字形绿光发射二极管 (LED) 照明 BGA 芯片, 通过环形和十字形的中心, 布置一个带有远心透镜的电荷耦合器 (CCD) 摄像机记录小球上红色圆环和绿色十字的图像。根据图像半径方向上的纹理频谱分布特征, 引入人工神经网络 (ANN) 算法对 BGA 芯片的气孔缺陷进行检测。采用真实的 BGA 焊点进行实验, 结果验证了方法的精度和可行性。

关键词: 球栅阵列 (BGA); 焊点; 气孔; 反光表面; 检测

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文献标识码: A

随着电子产品的小型化及功能的复杂化, 对电子组装技术提出了更高的要求, 新的高密度组装技术不断涌现。其中 BGA (Ball Grid Array 球栅阵列封装) 就是一项已经进入实用化阶段的高密度组装技术, 现在在很多新产品设计时大量使用这种器件, 由于非常复杂的原因, 气孔很容易出现在 BGA 焊点中。作为常见的工艺缺陷之一, 气孔缺陷会降低焊点的机械强度和导电性能, 因此非常有必要对它进行检测^[1]。传统的检测方法主要有目测、电子测试和 X 射线测试。目测法很难判断焊点内部是否有气孔缺陷, 费时, 费力, 并且会受主观判断的影响; 电子测试法会将很多好的焊点误判; X 射线测试虽然有较高的准确率, 但成本太高^[2]。

为此, 本文提出一种用于检测 BGA 焊点气孔缺陷的特殊结构光投影技术。同时用环形红色光和十字形绿色光发射二极管 (LED) 照明 BGA 芯片由小球表面成像后产生一个红色圆环和一个绿色十字。通过环形和十字形的中心, 布置一个带有远心透镜的电荷耦合器 (CCD) 摄像机记录小球上红色圆环和绿色十字的图像。通过对图像纹理进行频谱分析, 引入人工神经网络 (ANN, artificial neural network) 最终实现对 BGA 气孔缺陷的高精度检测。

1 BGA 焊点气孔缺陷的特殊结构光投影检测方法

1.1 通过小球表面形成圆环和十字像

当一个特制的 LED 红色环形光源和一个 LED 绿色十字形光源照射 BGA 小球时, 由于小球表面的反光性质, 从小球的上方会观察到一个红色圆环和一个绿色十字。如果将小球的表面视为一个球面镜, 这个圆环和十字便是通过球面镜成的像^[3], 如图 1 所示。



图 1 特殊结构光下实际 BGA 焊点

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1.2 对结构光下 BGA 图片的特征提取

由于气孔位置、大小和频率对焊点好坏都有着影响, 所以判定焊点好坏的标准涉及到很多方面故可操作性差^[4], 又在只有一幅图片的情况下, 很难直接得出气孔大小、位置等重要信息。因此我们通过提取图像的特征并引入神经网络训练的方法使问题得到解决, 检测流程图见图 2。首先将 RGB 颜色空间转化为 LAB 空间, 进而分离出 A 通道, 然后对 A 通道进行特征提取并进行网络训练, 最终根据训练好的网络来判别 BGA 焊点是否合格。

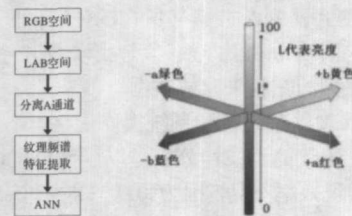


图 2 焊点缺陷检测流程图

图 3 LAB 颜色空间示意图

1.2.1 RGB 空间转换为 LAB 空间

采用红色和绿色光源, 目标图像主要为红色和绿色。由于 RGB 空间在绿色到红色之间缺少黄色和其他色彩。而 LAB 空间中 A 通道是从绿色逐渐变为红色, 如图 3 所示。故为了最大限度的利用图片信息, 首先将 RGB 通道转换为 LAB 通道, 进而分离出 A 通道。此时, 图片由 $77 \times 77 \times 3$ 变换为 77×77 像素大小。见图 4, (a) 焊点 RGB 图像, (b) LAB 图像, (c) LAB 中 A 通道。

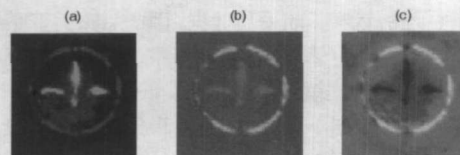


图 4 提取 Lab 空间中 A 通道

1.2.2 纹理频谱特征提取

一个理想的焊点, 得到的图片应该是一个规则的红色圆

环和绿色十字,但是由于气孔的存在会使得圆环和十字发生扩散和飘移,如图1所示。为了捕捉这种变化,我们提取纹理的频谱特征,即半径方向上光谱的能量分布。纹理的频谱度量是基于傅里叶频谱得到的。傅里叶频谱的极坐标表示形式为 $S(r, \theta)$, 其中 S 是频谱函数, r 和 θ 是极坐标系中的变量, θ 为定值时,分析 $S_{\theta}(r)$ 即得到从原点出发沿半径方向的频谱特性[5]。如式(1)所示:

$$S(r) = \sum_{\theta=0}^{\pi} S_{\theta}(r) \quad (1)$$

图5为光谱能量在半径方向上的分布图。因为半径大小为37,所以对每个BGA图片,我们得到一个37×1维的列向量。

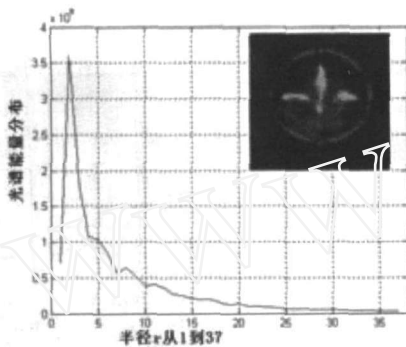


图5 半径方向上光谱能量分布

1.3 应用人工神经网络

我们引入人工神经网络(ANN)来检测有气孔缺陷BGA焊点在特殊结构光下的图片。人工神经网络经常被用来解决传统方法很难处理的问题[6][7]。针对焊点的检测问题,我们引入前馈神经网络,见图6。

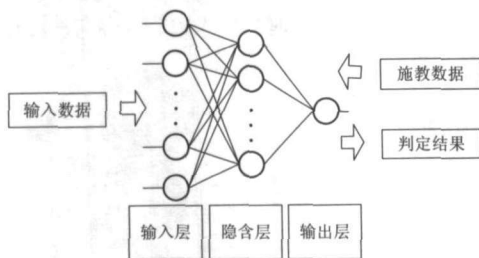


图6 人工神经网络结构图

神经网络包括一个输入层,一个隐含层和一个输出层。输入层的节点数 n_i 等于纹理频谱特征的维数为37,输出层节点数为 $n_o=1$ 。当焊点OK时结果为0,焊点NG时结果为1。根据经验公式(2)得到隐含层的节点数。

$$n = \sqrt{n_i + n_o} + a \quad (2)$$

其中 n 为隐含层节点数; n_i 为输入层节点数; n_o 为输出层节点数; a 为1~10之间的常数[8]。

通过试验对比,当 $n=11$ 时效果最优。在检测前首先对利用提取到的图像纹理频谱特征对网络进行训练,我们采用的是拟牛顿(quasi-Newton)法。在检测的过程中,将提取

的纹理频谱特征向量提供给神经网络输入层,当输出结果小于0.5时判定为OK,大于0.5时判定为NG[7]。

2 实验结果

2.1 样本图片

296幅样本图片是由欧姆龙公司在特殊结构光下拍摄得到的,每一幅图片为77×77×3像素大小。全部296幅图片由专家人为分出238幅OK图片和58幅有气孔缺陷的图片。在296幅图片中随机选出200幅进行网络训练,剩余的96幅用来测试。

2.2 测试结果

训练完成后,用剩余的96幅图片对训练好的网络进行测试,这96幅图片在训练的过程中没有被用到。输出结果的直方图如图7所示。横坐标为神经网络检测输出结果,范围从0到1,纵坐标为分布在各个范围间的焊点个数。可以看到,有3幅图片被误判,其中将OK误判NG的2幅,NG误判OK的1幅。因此准确率为96.9%。

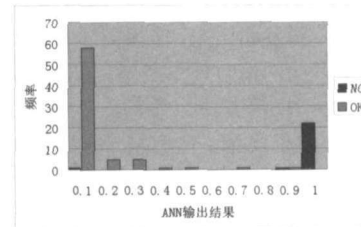


图7 神经网络输出结果

3 结论与展望

本文提出了一种用于BGA气孔缺陷检测的特殊结构光投影方法,引入了人工神经网络,通过实验验证了方法的可行性和优越性。本文的检测方法结构精巧、方法简单、可实现产品在线检测。

特别感谢欧姆龙(Omron)公司提供资料图片。

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GInput 类是对外设输入的抽象。其成员函数 GetInputInfor()负责读取输入信息。在系统设计中创建了与输入设备数目相当的类。本系统设计了两个输入设备: 键盘和触摸屏, 因此 GInput 派生了 GTS 和 GKey 两个子类, 它们的成员变量 TS_Coordinate 和 Key_Value 分别用来存放触摸屏点击处坐标值和键盘按键值。

GWinProcess 为窗口处理类, 对当前窗口的输入信息进行处理。

GOutput 类是窗口显示类, 负责将当前窗口内容显示出来。* mem 为指向内存显示缓冲区的指针。

GControl 类是本 GUI 系统中所有可视化组件的基类, 定义它们的相同特性和公共接口。其成员变量 title、position、size 分别为图形的标题、位置、大小属性; 其成员函数 Text() 用于设置 title, Draw() 用于设置 position 和 size, 它们作为 API 供用户调用。GControl 派生了窗口框架类 GWinFrame、菜单类 GMenu、按钮类 GButton 和对话框类 Gdialogue, 由它们组成本系统的高级图形库。

3.2 窗口管理

在本 GUI 系统中, 窗口系统的设计采用合成模式。合成模式是一种对象的结构模式, 亦称为个别-整体模式, 它把多个对象合成为树状结构用以表现个别与整体的层次结构^[7]。GWinframe 对象相当于一个容器, 持有对其所有子对象如 GMenu、GButton、GDialogue 对象的引用, 负责对这些对象的管理。本设计采用 List 来管理子对象, 即类 GWinFrame 中定义的 GFraControls。GWinFrame 中定义的成员函数 Add()、Delete() 用于向窗口中添加和删除子对象。

系统将用户创建的所有窗口组织成一个双向链表进行管理, 当用户新创建一个窗口对象时, 就会把该窗口加入到窗口链表的尾部; 当用户删除一个窗口时, 就会把该窗口从链表中删除。

窗口内容采用虚屏技术。即通过嵌入式操作系统调用获得一块连续分配的内存, 该内存和物理视频缓冲区一样大。写屏幕直接写到这个缓冲区而不是写到显示设备的物理视频缓冲区。当需要刷新屏幕时, 再将虚屏缓冲区中的内容拷

贝到显示设备的物理视频缓冲区。当不需要虚屏缓冲区时, 通过系统调用将该块内存释放掉, 节省系统资源。采用虚屏技术使对屏幕显示内容的控制更加直观, 且能从全局把握显示效果。

结束语

随着嵌入式应用的发展, 嵌入式软件规模也变得越来越庞大, 各种软件开发方法和设计模式也逐渐被引入到嵌入式软件开发中, 同时硬件性能的飞速发展也为复杂的软件设计提供了支持条件, 但嵌入式系统有自己独特的应用特点, 如实时性要求高、资源还是相对有限等。本文充分考虑嵌入式系统的这些特点, 在保证系统实时性和轻量性的前提下采用各种开发方法和设计模式, 实现了一个性能完善的工控领域的 GUI 系统。因此, 本系统的设计思想也可被其他嵌入式软件设计所借鉴。另外, 本 GUI 还是以 API 的形式提供给用户调用, 今后可向图形化开发方向做进一步研究。

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Abstract: The quick universality of the Internet makes the network transfer much more sensitive data, just like the credit card account needs to be ensured the security of information, the request for ensuring the security of the network data is urgently proposed. Aiming at this problem, we composed a complete information security program and developed an information security system possessing the functions of encryption, decryption and digital signature by using of CryptoAPI provided by Microsoft. Though tests and practical use, this system was testified to be of convenient encryption/decryption capability, which has high and practical value.

Keywords: CryptoAPI; CSP; Digital signature; Secure communication

Design and Implementation of an Industrial Control-oriented GUI (24)
WU Shu, MA Wei-hua, XIE Shu-gang, WANG Qing-yu (College of Information Science & Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China)

Abstract: This paper investigated and designed a kind of embedded GUI for industrial control field which was short of resource and desired serious real-time performance. The system used hierarchy structure and object-oriented design method. RTOS (Real Time Operation System) was also adopted in the GUI. The GUI system designed by this idea has characteristics such as convenient-use, light-duty, transplantable and extensible. It is proved that the GUI is totally competent for this field and has great application value.

Keywords: GUI; Embedded system; Industrial control; Object-oriented

Design of a Sun-tracking System Based on ARM (27)
BI Yu-qing, XIANG Ping (Institute of Electromechanical Engineering, Northwestern Polytechnical University, Xi'an 710072, China)

Abstract: In this paper, the tracking system uses a 32 ARM (Advanced RISC Machines) embedded microprocessor as a controller. It achieves whole process tracking to sun by controlling two directions of level and pitching. And on this basis, the tracking system can timely correct errors to improve the accuracy of tracking by the angle sensor installed on the tracking device. The tracking accuracy of this design can meet the needs of solar thermal power generation with stable system performance, cheap cost and high expansion of functions. It shows high practical value.

Keywords: ARM; Solar thermal power generation; Solar tracking

Design of a Kind of Real-time Voice Acquisition System (30)
HAI Shen, ZHOU Yanyan (Department of Computer, Tongling College, Tongling 244000, China)

Abstract: With the continuous development of real-time voice acquisition systems, to store the data in the storage in format of a usual file system has been widely used. In order to meet the requirements of the real-time system, it is necessary to improve the performance of the system. Based on LPC2210 and CF card, this paper implements a real-time voice acquisition system based on FAT16, and improves the performance from the aspects of the buffer design and the system operation.

Keywords: Real-time; File system; Performance improvement

Structured Light Projection Technique for BGA Void Inspection (32)
Yuan Zhao-fei, CAO Qi-xin, YANG Yang (Research Institute of Robotics, Shanghai Jiaotong University, Shanghai 200240, China)

Abstract: A novel structural light technique was developed for ball grid array (BGA) void on-line inspection. A light emitting diode (LED) ring light and a LED cross light were used to illuminate the BGA package with a charge-coupled device (CCD) to capture the image through the center hole of the ring light and the cross light. By extracting the spectral energy distribution features as a function of radius from the center of the spectrum using artificial neural network (ANN), we evaluated these techniques using actual BGA bumps. As a result, the correct rate of judgment reached 96.9%, which clearly showed that our method could be useful in the practice.

Keywords: Ball grid array (BGA); Bump; Void; Specular surface; Inspection

An institute information Management System Based on B/S Model (34)
JIU Lei, ZHANG Ze-ming (1. School of Information Science & Engineering, Fudan University, Shanghai 200433, China)

Abstract: Now more and more institute organizations need informationization, and it can be achieved by an information management system based on B/S mode. The institute can use the system to get better drumbeating and academic exchanges. System operation results show that the system can meet the institute's day-to-day needs, and expand the visibility of the society, and additionally, the institute can communicate with the users quickly and effectively to disseminate information.

Keywords: B/S model; ASP; Access database; Web server; ADO

Design of Data Disaster Tolerance System Based on SAN Infrastructure (36)
XIN Hai-long (School of Online Learning, Shanghai Jiaotong University, Shanghai 200030, China)

Abstract: A remote data disaster tolerance system based on enterprise IT SAN infrastructure is presented. According to the characteristics of SAN infrastructure, enterprise data were classified into static data and dynamic data. This system was designed based on the electronic vaulting theory. The paper presents the remote disaster tolerance of static data by using virtual tape library to run data backup, transfer and restore, combining with the method of changing process control, and it presents the remote disaster tolerance of dynamic data by innovating and improving current standard data asynchronous replicating method. The results show that it improves the replicating efficiency, reduces the MAX bandwidth of data link, and represents the reliability and cost-saving capability of the system.

Keywords: Remote disaster tolerance; Electronic vaulting; Static data; Dynamic data; Data asynchronous replicating

Technical Communication

Research on the Design of Signal Acquisition Software about Border Patrol Vehicle Power System (40)
ZHANG Chang-gong, ZHOU Jie-min (College of Civil Aviation, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China)

Abstract: Based on the ActiveX control in Visual C++, the method of the serial communication programming with the MSComm control was discussed. The applications of the signal acquisition in the border patrol vehicle power system have been realized by RS-485 serial communication.

Keywords: Serial communication; MSComm control; OnComm information event

Design and Application of Authority Authentication Based on RBAC (43)
TIAN Bao-jun¹, Qin Gang² (1. Institute of Information Engineering, Inner Mongolia University of Technology, Huhhot 010051, China; 2. Huhhot Triones Software Co., Ltd., Huhhot 010050, China)

Abstract: As an important part of information system, authority authentication should not only provide secure, reliable and efficient authority management, but also have adaptability and flexibility to meet the needs of different application systems. Through comparing and analyzing shortcomings of ordinary authority authentications, we designed the authority authentication based on RBAC, which has been proved to be well applied in enterprise