本文研究的目的是通过目检和基于知识的计算机视觉自动识别电子部件。这便于为新部件配置高速表面贴装生产线。使用智能算法可使计算机识别部件的属性并同预先存在的数据库交叉对照，有助于确保这些属性的精确报告。独特的里程碑包括：设计目检部件的设备；设计能够自动识别这些部件的属性的智能算法；为便于使用上述算法而设计软件；为交叉对照而实现数据库接口；并为商业化而改进整个系统。

Automatic Recognition of Electronic Components

Gallagher Donovan Pryor, Alex Goldstein, Allen Tannenbaum

Automatic recognition of electronic components can reduce rejected components and increase placement accuracy, yields and surface-mount line throughput.

The goal of the research presented here is to automatically recognize electronic components by visual inspection and knowledge-based computer vision. This recognition would facilitate a high-speed surface-mount assembly line configuration for new components. In the past production engineers have had to manually measure components for width, height and contact layout. But this practice should become obsolete by employing intelligent algorithms that will enable computers to recognize these attributes and cross reference a pre-existing database, thereby ensuring the accurate reporting of these attributes.

The individual milestones of this undertaking include the following: designing an apparatus for visual inspection of components; designing intelligent algorithms capable of automated recognition of these components' attributes; constructing software to facilitate the use of such algorithms; implementing a database interface for cross reference and a brushing up of the total system for commercialization.

Approach

Visual Inspection Apparatus

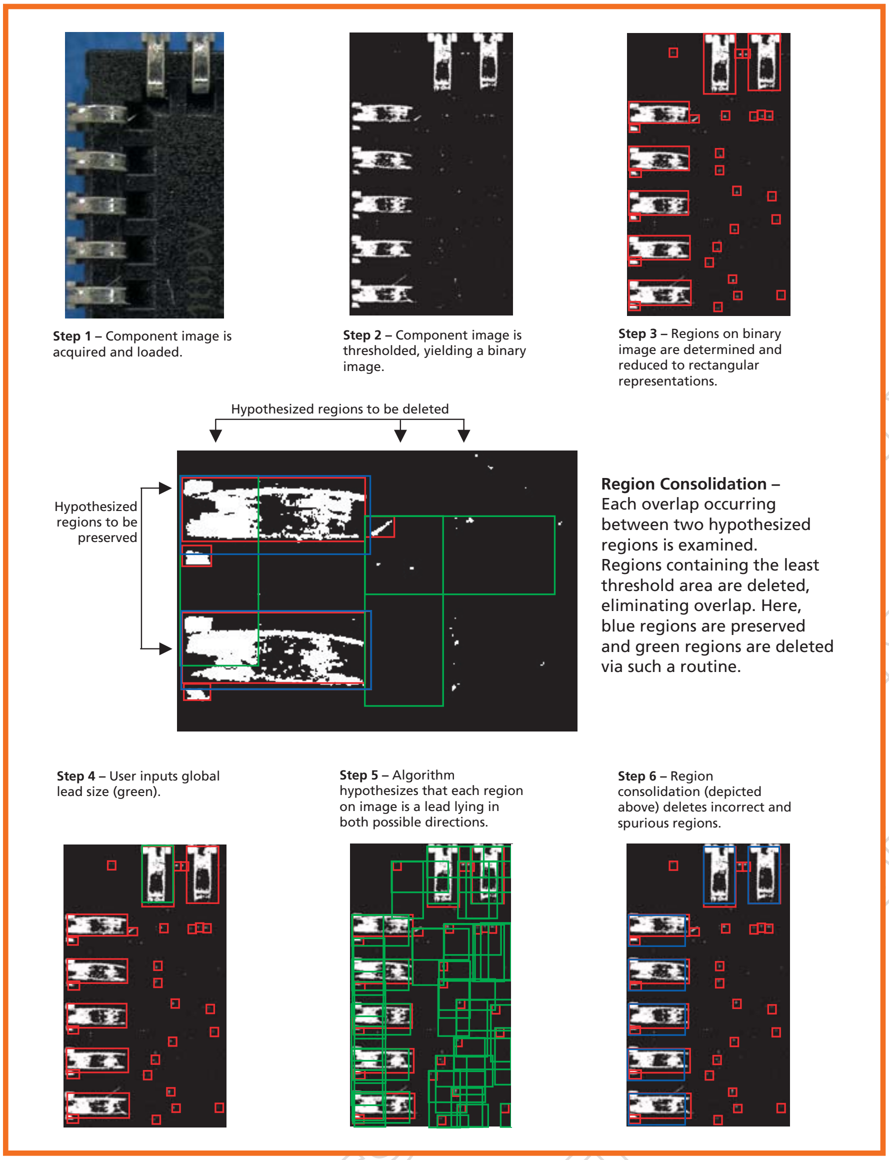
The goal of the visual inspection apparatus in this research was simple: To take a single picture of a given component at a very high resolution and quality, while at the same time minimizing the amount of user intervention required for its operation. This goal, however, was a difficult one, given the subjects under scrutiny. Electronic components are quite reflective, and, as a result, their visual characteristics are unpredictable under the light levels necessary to obtain high quality, high-resolution images of them.

The final inspection apparatus consisted of an elevated, circular ring of diodes that provided right, concentrated light on the subject being photographed; a blue backdrop; and a high quality, tripod-mounted digital camera. Most of the time building this setup was spent fine-tuning the light source and camera to enable the production of images of high enough quality for use with computer vision algorithms. The auto focus feature of the camera became a key issue during this stage. The reflectivity of the components made such a feature almost useless, yet, without it, the photography took considerably longer than when the camera was manually focused.

Fortunately, the auto focus feature could be kept in the final design after a combination of camera settings and light levels were determined through heavy experimentation. With these parameters, sufficient images could be produced for analysis by simply positioning the subject component, adjusting the distance of the camera away from the subject and taking the photo.

Algorithm Design

The actual computer vision algorithm design was the key component of this work. The goal for this stage was to design an algorithm that could recognize components photographed with the visual



Step 1 – Component image is acquired and loaded.

Step 2 – Component image is thresholded, yielding a binary image.

Step 3 – Regions on binary image are determined and reduced to rectangular representations.

Region Consolidation – Each overlap occurring between two hypothesized regions is examined. Regions containing the least threshold area are deleted, eliminating overlap. Here, blue regions are preserved and green regions are deleted via such a routine.

Step 4 – User inputs global lead size (green).

Step 5 – Algorithm hypothesizes that each region on image is a lead lying in both possible directions.

Step 6 – Region consolidation (depicted above) deletes incorrect and spurious regions.

FIGURE 1: Step-by-step depiction of phase one analysis.

inspection apparatus described above and identify features of those components such as contacts or terminals. This task proved to be quite difficult.

As was previously stated, due to their reflective nature, electronic components have very unpredictable visual characteristics under bright, concentrated light. In addition, the contacts to be identified on the components varied greatly from subject to subject as a result of deformities, different materials and perspective effects brought about by high magnification. Each of these problems was formidable in its own right, but reflection played a particularly important role—in most computer vision applications, the first assumption put forth to alleviate the problem is that there are no reflections.

The beginning of this stage was spent experimenting with algorithms that used no domain knowledge of the problem to identify the whole electronic component and its contacts. The identification of the component itself was quite easy. A simple hue threshold routine was run to separate the background of the images from the foreground component. However, identifying contacts was a challenging task due to the reasons described above. In attempting to identify these features accurately, a plethora of computer vision routines were brought to bear, including active contours, adaptive thresholding,

Step 1 - Phase one analysis yields possible contact regions.

Step 2 - Each region is hypothesized to have its own bank. These banks are consolidated by the elimination of parallel conflicts on two different domains: vertical regions and horizontal regions.

Step 3 - Vertical and horizontal banks are matched to vertical and horizontal regions, allowing merging of the two domains.

Step 4 - Perpendicular conflicts are eliminated by the rule of longest bank first.

Step 5 - Outlying regions that do not conform to bank geometry are deleted.

FIGURE 2: Step-by-step depiction of phase two analysis: bank finding and pruning.

morphological operators, Fourier descriptors and statistical pattern matching. All of these methods proved inadequate.

During this experimentation phase, some assumptions were made based upon domain knowledge of the subjects under the following three criteria:

1. Contacts lie in straight lines: These lines were aligned either parallel or perpendicular to the component itself.

2. Contacts occur at constant intervals, spaced out equally from each other in their linear arrangements.

3. A group of contacts arranged in a linear manner constitutes a bank; banks themselves occur in a geometric fashion on components.

With these assumptions in hand, a simple, yet successful, algorithm was developed to take advantage of this domain knowledge.

The component is segmented from the image using the hue thresholding method as previously presented. A Hough Transform is then run on the segmented component's outline. This transform extracts the rotational alignment of the component. Using this measurement, the image of the component is rotated so that the edges of the subject are brought to line up with the edges of the image. This process has the critical advantage of bringing all the contacts into alignment with the edges of the image as well, per assumption number one. This operation also rotates the contacts—which are typically circular or rectangular—in such a way that they are efficiently and cleanly described by a simple rectangle scheme, instead of by a complex shape description scheme.

At this point, the user inputs the expected size of one contact on the component. This step is an unfortunate limitation of the current algorithm, but most likely it can be eliminated fairly rapidly with continued development. In this case, contact size is only needed to distinguish true contacts from various patterns on the components or noise in the image.

The image is then thresholded to identify reflections on the component; ironically, the same reflections that caused so much difficulty in the first place. The resulting binary image is then analyzed to locate collections of connected, positive feedback pixels from the threshold. The result is a set of disjointed regions over the image, each identified via horizontal and vertical extremes to form simple rectangles. Due to the method by which regions are deduced, these areas naturally overlap. At the same time, many small regions exist that are brought on by noise. Both of these occurrences need to be eliminated.

To accomplish this goal, the algorithm then hypothesizes that each region is in fact a contact. Contacts, per assumption number one, may be aligned either vertically or horizontally. At each region's position, the algorithm places a contact marker for both possible alignments. When all placements are made, the algorithm removes overlapping contact markers, deleting those markers encapsulating the smallest region area. The algorithm then deletes contacts encapsulating an amount of region area beneath a set threshold. Figure 1 depicts this algorithm during operation.

Once all removals are completed, all that is left to do is to brush up the analysis for a final result. Lines of contacts are identified as banks, per assumption number three. These banks are then analyzed for spacing consistency and relative alignment based upon assumption number two. These measurements are then used to further delete unwanted regions and determine the correct alignment of remaining contacts. This process of bank identification and final pruning of the segmentation results is quite complex (Figure 2). The algorithm responsible for carrying out this process deserves special attention and is described as follows.

After the first phase of analysis is complete, a set of regions marking possible component features is identified. These regions are considered to have a high confidence level, and they are most likely all correct except for a few outliers. Based on this assumption, the algorithm first hypothesizes that each region at hand constitutes its own bank. Recall that banks are defined as lines of leads. Given that leads lie only perpendicular to the sides of the component, only two possible types of banks exist: vertical and horizontal. Therefore, for each contact region, both types of banks are created—containing both that specific contact region and as many other contact regions as possible. Note that two types of contact regions exist as well: vertical and horizontal. For continued discussion, assume that banks only contain component regions of the same type and that all further operations are carried out on two separate domains with no effect on each other: vertical regions and horizontal regions.

With bank creation complete, we are left with a large collection of banks that overlap each other. This situation is not satisfactory for the pruning task at hand; so many banks must be either deleted or modified. Upon examination of the problem, overlaps between banks may be classified into two categories: parallel conflicts and perpendicular conflicts. A parallel conflict is an overlap occurring between two banks of the same direction. Similarly, perpendicular conflicts occur between two banks of the opposite direction.

The algorithm first deals with the elimination of parallel conflicts. For each parallel conflict detected, the algorithm simply deletes the offending bank with the least number of contact regions. With parallel conflicts eliminated on each separate domain, the algorithm must match the most plausible region type (vertical or horizontal) to the correct bank type (vertical or horizontal). The algorithm chooses the match based on which one yields the longest banks. After a match has been chosen, the two domains of vertical regions and horizontal regions are merged.

With parallel conflicts eliminated, perpendicular conflicts then need to be addressed. The algorithm resolves such conflicts by a process dubbed *bank splitting*, whereby a region is removed from a bank and the remaining regions are grouped into two separate banks. For each perpendicular conflict, the shortest bank in the conflict is split. Eventually, all perpendicular conflicts are resolved, resulting in a bank arrangement with no overlaps. At the same time, any spuriously laid regions of incorrect alignment are removed. Finally, possible false regions are removed by deleting regions that do not conform to bank geometry—in other words, those that do not lie in a proper spacing with the rest of the regions in a bank or do not line up perpendicularly with the rest of the bank.

With a plausible bank layout achieved, pruning of the original image analysis is complete. All regions that reside in the bank layout are considered to be indicative of true contacts, and those that were removed from the layout during processing are simply thrown out.

Conclusion

The opportunity exists for enhancing the robustness of the pick-and-place equipment vision system and reducing programming time by using automatic recognition of electronic components. A specific goal of on-going work is to show that automatic recognition of electronic components described in this article can reduce the percent of rejected components and increase placement accuracy, yields and surface-mount line throughput. ■

Acknowledgement

The authors wish to thank Siemens Dematic for funding this research, and Tom Foley of Siemens Dematic for his input relating to automatic recognition of electronic components.

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