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COMPUTER DETECTION OF BENT FINGERS IN LEAD BONDING FRAMES

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ABSTRACT. In the production of logic circuits in dual inline packages, various tedious assembly line tasks are performed by human operators using microscopes or television enlargements. One boring and difficult task is the detection of bent fingers in lead bonding frames to which integrated circuit chips are subsequently bonded. Bent fingers can cause stresses which may eventually lead to the failure of circuits. This paper discusses the inspection problem and presents a computerized bent finger detection method which could be adapted to free human operators from this task. More immediately, it presents a method of examining an object and determining whether or not it is in focus based solely on inspection of the object's digitized light intensity profiles.

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INTRODUCTION

In the production of logic circuits in dual inline packages, various tedious assembly line tasks are performed by human operators using microscopes or television enlargements. These boring and difficult tasks could be performed faster and more reliably by computers. A machine which detects etching defects in printed circuit boards with greater precision and speed than human operators already exists [1]. Current research attacks similar tasks, such as the detection of bad solder joints [2] and the orientation of integrated circuit chips for lead bonding [3]. Another possible task which could be performed advantageously by a computer is the detection of bent fingers in lead bonding frames.

Lead bonding frames, which are stamped out of brass, provide a way of connecting the external circuit to the integrated circuit chip. The actual contact with the integrated circuit chip is made with finger-shaped areas on the lead bonding frame, which are bonded to special ball-contacts on the integrated circuit chip. If such a finger is bent, the bonding with the integrated circuit chip is stressed and may ultimately fail while in service. This paper presents a bent finger detection method which could solve this problem.

This scheme runs on the PDP-11/45 in the Artificial Intelligence Lab at the Massachusetts Institute of Technology. The Micro-Automation system is comprised of a DEC PDP-11/45 with 31K of core, a GT40 display terminal, a Vidicon camera and digitizer, and various other peripherals. The Vidicon, a modified television camera, provides a digitized array of intensities which represent a slow shuttered snapshot of its field of view. Thus, the computer can "see" a lead bonding frame, as well as any bent fingers on it.

Once the data is in the computer, various methods could be used to determine whether or not a lead bonding frame is acceptable. As with the other tasks mentioned in the initial paragraph of this section, template matching, comparing each lead bonding frame against a standard frame, is unsuitable. Not only would this limit the potential inputs to the system and waste core on storage of the standard frame, but the noisiness of the Vidicon would create a reliability problem due to the difficulty of matching a lead bonding frame with the standard. Instead, the method presented here searches out the fingers on a lead bonding frame, and then examines intensity profiles to see whether or not the fingers are in focus, If any of the fingers on a frame are bent significantly, the frame is rejected.

The simple method proposed here works reliably, though as it stands, it may take as much as five minutes to examine a lead bonding frame. However, with the right equipment and some simple changes, this method could be used as a future refinement in the production of integrated circuits. Furthermore, the bent finger detection scheme presented here illustrates a method whereby a machine can verify whether or not an object is in focus based solely on the object's digitized light intensity profiles.

BENT FINGER DETECTION

The major problem in this project was the determination of camera orientation and lighting conditions under which the Vidicon would most successfully detect bent fingers. Although the fingers have freedom to bend in more than one fashion, the bent fingers which are of interest are the ones which are bent out of plane so that their fingertips are no longer flat with respect to the lead-frame. If the fingertips are bent in this way as little as five to ten thousandths of an inch, an insufficient bond with the integrated circuit could later be formed, resulting in a faulty circuit.

Two angles at which the Vidicon can face the lead bonding frame will allow detection of such finger bending. One method is to place the Vidicon at a 45 degree angle above the plane of the lead bonding frame. In this configuration, a bent finger will appear out of place compared to its neighboring fingers; either shorter, longer, bent towards, or away from them depending on the orientation of the lead bonding frame (see Figure 2). A disadvantage of this method is that it relies on comparing neighboring fingers, which obviously requires fingers to have neighbors, potentially limiting the generality of such a method. Furthermore, since an entire neighborhood of fingers may be similarly bent, a more elaborate bent finger detection scheme would in fact be necessary.

A method which eliminates this disadvantage is placing the Vidicon directly above the lead bonding frame. In this configuration, bent fingers appear out of focus when the Vidicon is focused on the plane of the lead bonding frame. Under large enough magnification, (a 10 power objective on the Vidicon,) even fingers bent as little as five to ten thousandths of an inch appear distinctly out of focus. The disadvantages of such magnification are a limited field of view and the detection of ambient mechanical vibrations which could cause a "good" finger, (one which is not bent,) to appear out of focus. However, since this method achieves the required results with accuracy and relative simplicity, it is employed.

With the Vidicon digitizing the lead bonding frame from an overhead position, the bent fingers, which appear out of focus, could be noticed by various manipulations of the data. With overhead, point-source lighting, a good finger will have more detail, or granularity, on its surface than a bent finger. Thus r.m.s. over average intensity would be a measure of focus. I used another method instead.

With either overhead or underneath lighting, a bent finger edge transition will appear wider than a good finger edge transition. This could be detected by counting the number of jumps in intensity to get from the intensity of the background to the intensity of the finger surface. In practice, a subtle variation on the above method, in which the largest inter-point intensity jump moving perpendicularly across a finger edge is determined, yields the most dependable detection of bent fingers. Good fingers always have a few large jumps while bent fingers have many small jump - see Figure 3.

Methods which use overhead, point-source lighting are all subject to large light intensity variations due to the crystalline appearance of metal under high magnification. These effects are sufficiently random that they tend to confuse any simple method which must decide where a finger is compared to its background, or where a finger's edge is. Therefore, back lighting is used. Using a light table underneath the lead bonding frame, the fingers appear black. With unnecessary surface reflections eliminated, representative light intensities of a finger and its background are easily determined, with intensities of the edge region falling between the two. Then, moving through the edge region perpendicularly to a finger, the largest inter-point intensity jump is found. On this basis, a finger is accurately classified as either a good or a bent finger.

THE BENT FINGER DETECTOR

The bent finger detector program consists of five modules: a picture taker, a histogram analyzer, a finger finder, a bent finger detector, and an x-y table mover. These modules respectively read digitized light intensity values into core from the Vidicon; perform a histogram analysis to determine representative point intensities for points on and off the lead bonding frame, as well as determine a cutoff between the two; determine whether or not a finger is in the Vidicon window, (i.e. in its field of view;) determine whether a finger found in the Vidicon window is in or out of focus; and move the x-y table upon which the light table and the lead bonding frame rest.

These modules are integrated as depicted in Figure 5. First, a human operator carefully focuses the Vidicon on the lower leftmost finger of a lead bonding frame. At this time, the program sets a parameter in the bent finger detector in order to compensate for ambient vibrations. Next, the x-y table mover moves the lead bonding frame through the Vidicon window in increments which allow the entire lead bonding frame to be analyzed. At each incremental position, a picture is taken and a histogram analysis of the point intensities performed. On this basis, the finger finder determines whether or not the Vidicon window contains a finger. If it does not, then the x-y table mover is called. If it does, the bent finger detector decides whether or not it is bent. If so, the entire lead bonding frame is rejected, and the process stops. If not, the x-y table mover determines if the entire lead bonding frame has been searched, in which case the frame is accepted, and the process stops. (Note: At this time, the x-y table is suffering from some hardware trouble, so the x-y table mover is not actually implemented.)

The non-trivial subroutines, the histogram analyzer, the finger finder, and the bent finger detector, are discussed below in more detail.

The Histogram Analyzer

In the picture taking routine, the Vidicon associates each point in its window with one of 256 possible intensities. This serves as the input to the histogram analyzer, which creates a buffer in core with 256 locations, each location containing the number of points in the Vidicon window which have any particular intensity value. When looking at a lead bonding frame this histogram will have two peaks: one near the average light intensity of points on the lead bonding frame, and one near the average light intensity of points in the bright background, off the frame. The histogram analyzer determines the finger intensity value cutoff, located mid-way between the peaks, for the use of the finger finder, as well as supplying the two aforementioned peaks representing "on the finger" and "off the finger" intensity values to the bent finger detector for finger edge location purposes. (In addition, the histogram analyzer aids the x-y table mover in case the histogram contains only one peak, which may indicate that the entire lead bonding frame has been moved out of the range of the Vidicon). Note that with overhead lighting, a histogram analysis of this sort would have to be considerably more complicated.

The histogram analyzer is flow charted in more detail in Figure 6.

The Finger Finder

The finger finder uses the finger cutoff supplied by the histogram analyzer to examine the intensity values of the points in the Vidicon window in order to determine whether or not a finger is in there. As it happens, the Vidicon has its best resolution in the vertical direction. Therefore, the lead bonding frame is positioned with its fingers running horizontally across the Vidicon window, so that the finger edges can be determined most accurately. Accordingly, the finger finder first searches along the (vertical) edges of the window for a sequence of point intensities which are first off the finger (i.e. above the finger cutoff,) then on the finger (i.e. below the cutoff,) then back off the finger again. If such a sequence is encountered, and the "on the finger" sequence is suitably long, a finger cross-section may have been located.

Due to the noisy character of the Vidicon, a fingertip will not have sharp right angles or even straight lines when read into core in the form of intensity values. Furthermore, a finger which is out of focus will be even less clear. Therefore, the finger finder uses a simple peninsula finding technique. From the (vertical) window edge which has a potential finger cross-section, points one third and two thirds the way up the hypothesized finger are located. From these points, successive horizontal point intensities are compared with the cutoff. If both searches reveal points at some horizontal displacement which lie off the finger, the finger finding routine returns successfully.

(Note that the above peninsula finding method has the disadvantage of classifying some non-fingers as fingers, resulting in lost time to decide whether such non-fingers are in or out of focus. However, this is the desired default action since it allows for variously shaped fingers and since over-specifying fingers could miss bent fingers). Accurate mechanical positioning in a factory environment would eliminate the need for most of the operations of this function, since one could assume one was looking at a finger in the first place.

The finger finder is flow charted in detail in Figure 7.

The Bent Finger Detector

The bent finger detector is called once the finger finder has found a finger in the Vidicon window. It searches along the window edge starting at a point one third of the way up the finger found by the finger finder, and searches downwards for the lower finger edge. It assumes that the edge region will have intensities which lie between the two representative "on the finger" and "off the finger" values found by the histogram analyzer. While in the edge region, it searches for the largest inter-point intensity jump.

If this jump is sufficiently large, then the lower finger edge is in focus. This is enough to insure a good bond with the integrated circuit, so the finger is accepted, and the x-y table mover is called. Otherwise, the upper finger edge is similarly analyzed. If it is in focus, the x-y table mover is called. Otherwise, the finger is bent, and the entire lead bonding frame must be rejected.

Note that the cutoff between inter-point intensity jumps which correspond to good fingers and those which correspond to bad fingers is not set until the first time the bent finger detector is called. At this time, the Vidicon window contains what can be assumed to be a good finger, so by relating the cutoff to that finger's maximum inter-point intensity jump, a compensation for ambient mechanical vibrations, (which may vary from place to place, from time to time, etc.,) is made.

The bent finger detector is analyzed in detail in Figure 8.

CONCLUSIONS

I have presented a process for computer detection of bent fingers in lead bonding frames. This process uses a Vidicon which digitizes the light intensity of a lead bonding frame with back lighting. The digitized intensity values are processed, and it is determined if any of the fingers in the lead bonding frame are bent, in which case the frame must be rejected.

This method is not unlike some other recent work in printed circuit board assembly tasks. All of the recent advances along this line using computer vision use local analysis rather than template matching to achieve their objectives. The bent finger detection scheme presented here is similar.

The major problem with the scheme as presented, is that of vibration during picture taking. The scheme has various compensations for this effect. However, this problem could be reduced by using a more stable support structure and a slightly reduced magnification of the Vidicon field of view. (Perhaps a seven power microscopic objective would be a good compromise between a three power objective, which does not discriminate clearly between good and bent fingers, and the 10 power microscopic objective employed in the bent finger detection scheme as presented above, which is subject to vibration. The high power objective is also difficult to focus on a lead bonding frame with underneath lighting, given that such a frame is only ten thousandths of an inch thick, and that a worn stamp in the production of such a frame can result in uneven edges of all sorts).

This bent finger detection method takes two or three seconds to analyze any positioning of the Vidicon window, and thus as much as five minutes for an entire lead bonding frame. Therefore, although more accurate than current industrial bent finger detection performed by human operators using microscopes or television enlargements, it is slower. (Given a higher resolution Vidicon, able to inspect a whole frame at once, and perhaps more computer memory, this method could be made to work faster, and could be used in future integrated circuit assembly). With mechanical finger positioning which guarantees that a finger is in the Vidicon window, only one sixtieth of a second, i.e. the time for one Vidicon scan, is needed per finger. This brings the time per lead-frame down to where this process might begin to look competitive to industry.

The bent finger detection method presented here shows how a computer, using digitized intensity values, can determine whether or not an object is in the focus of a given lens. In the future, this technique could be incorporated into a wide variety of automated visual tasks.

ACKNOWLEDGEMENTS

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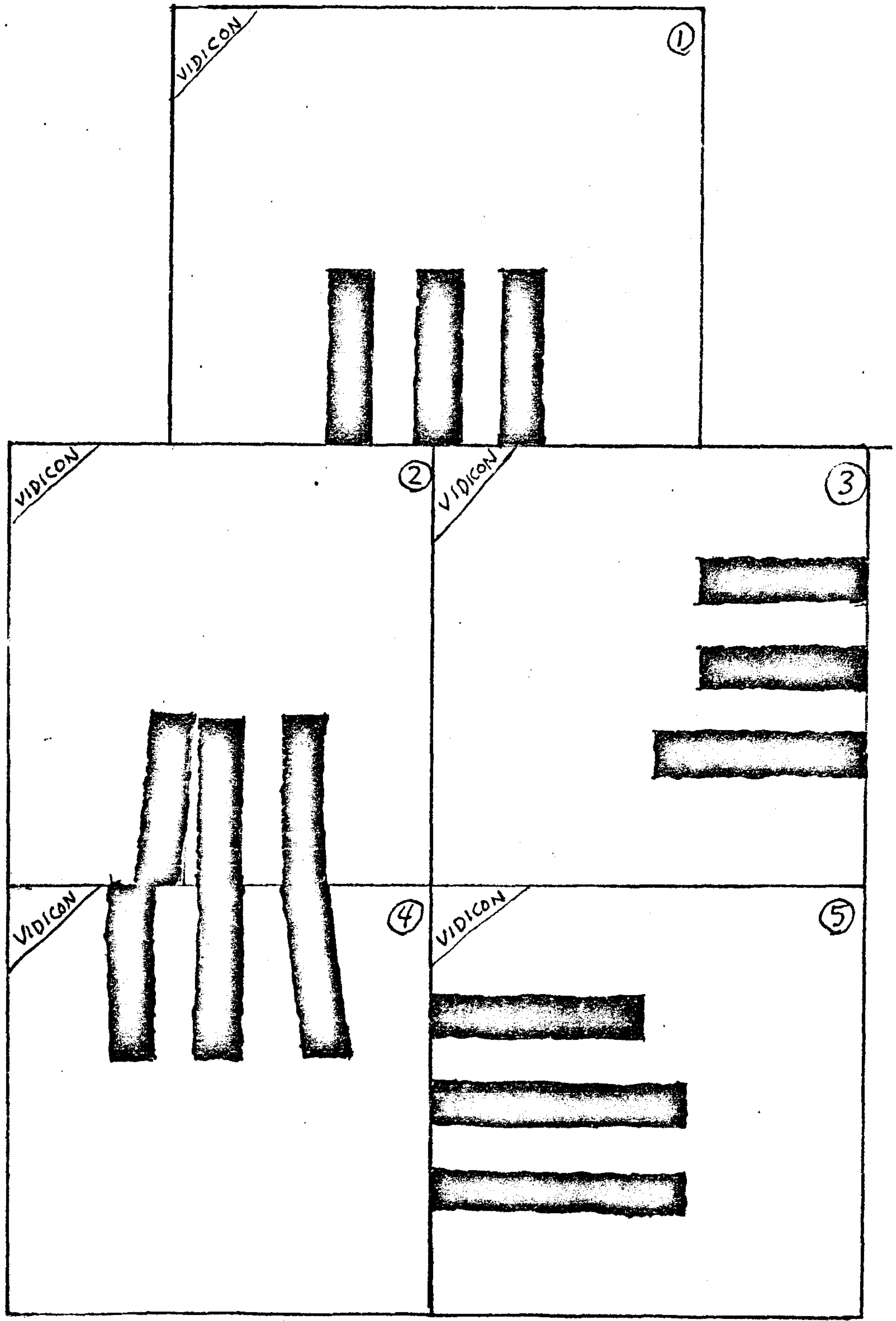
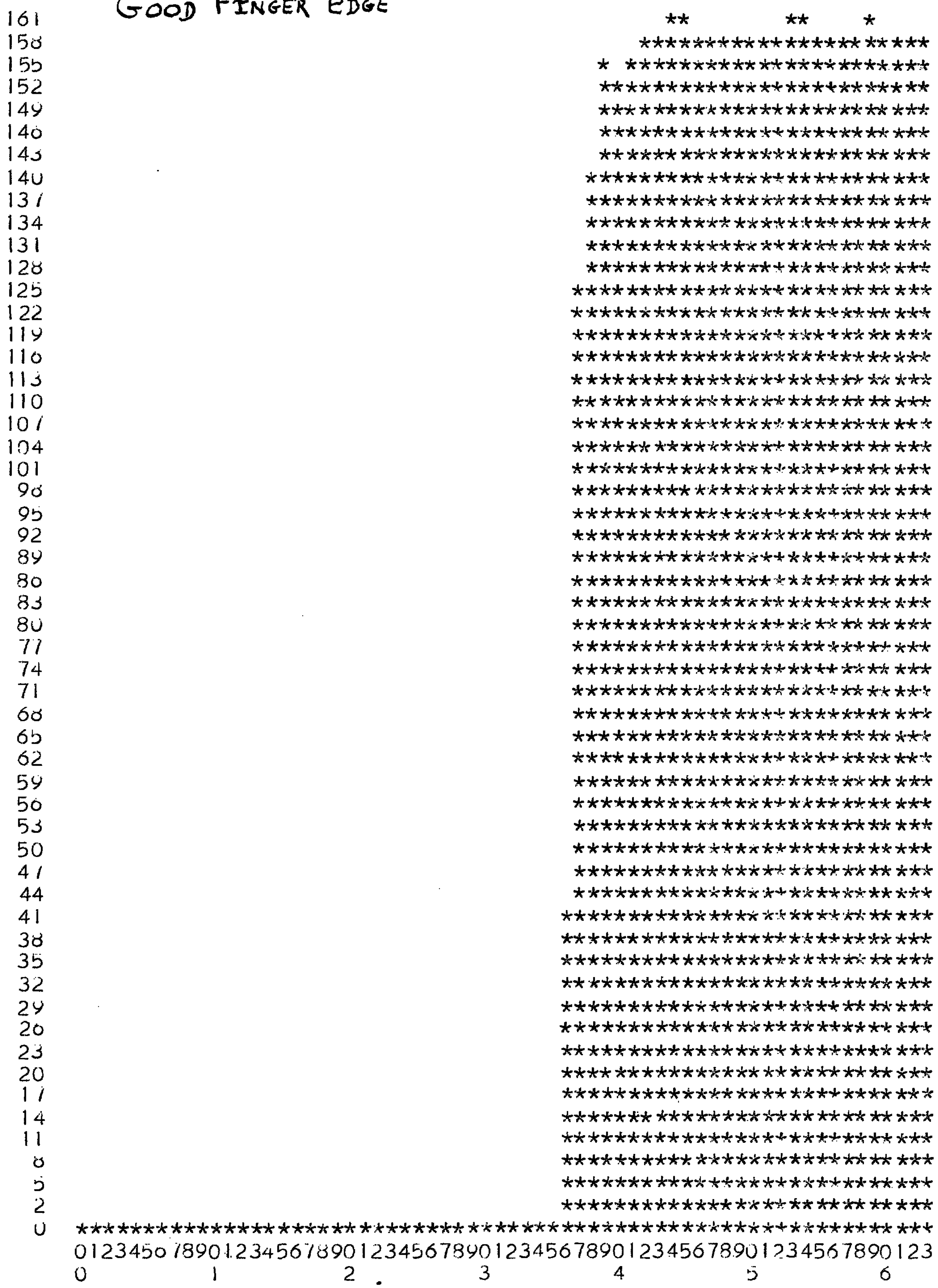
Figure 2: Bent Finger Detection (45 degree angle)



1. GOOD FINGERS 2. BENT FINGER APPEARS BENT TOWARDS NEIGHBORS 3. BENT FINGER APPEARS LONGER THAN NEIGHBORS 4. BENT FINGER APPEARS BENT AWAY FROM NEIGHBORS 5. BENT FINGER APPEARS SHORTER THAN NEIGHBORS

GRADIENT PLOT X = 23 INTENSITY VALUE VS Y COORDINATE



GOOD FINGER EDGE

FIGURE 3A

GRADIENT PLOT X = 23 INTENSITY VALUE VS Y COORDINATE

Bent Finger Edge

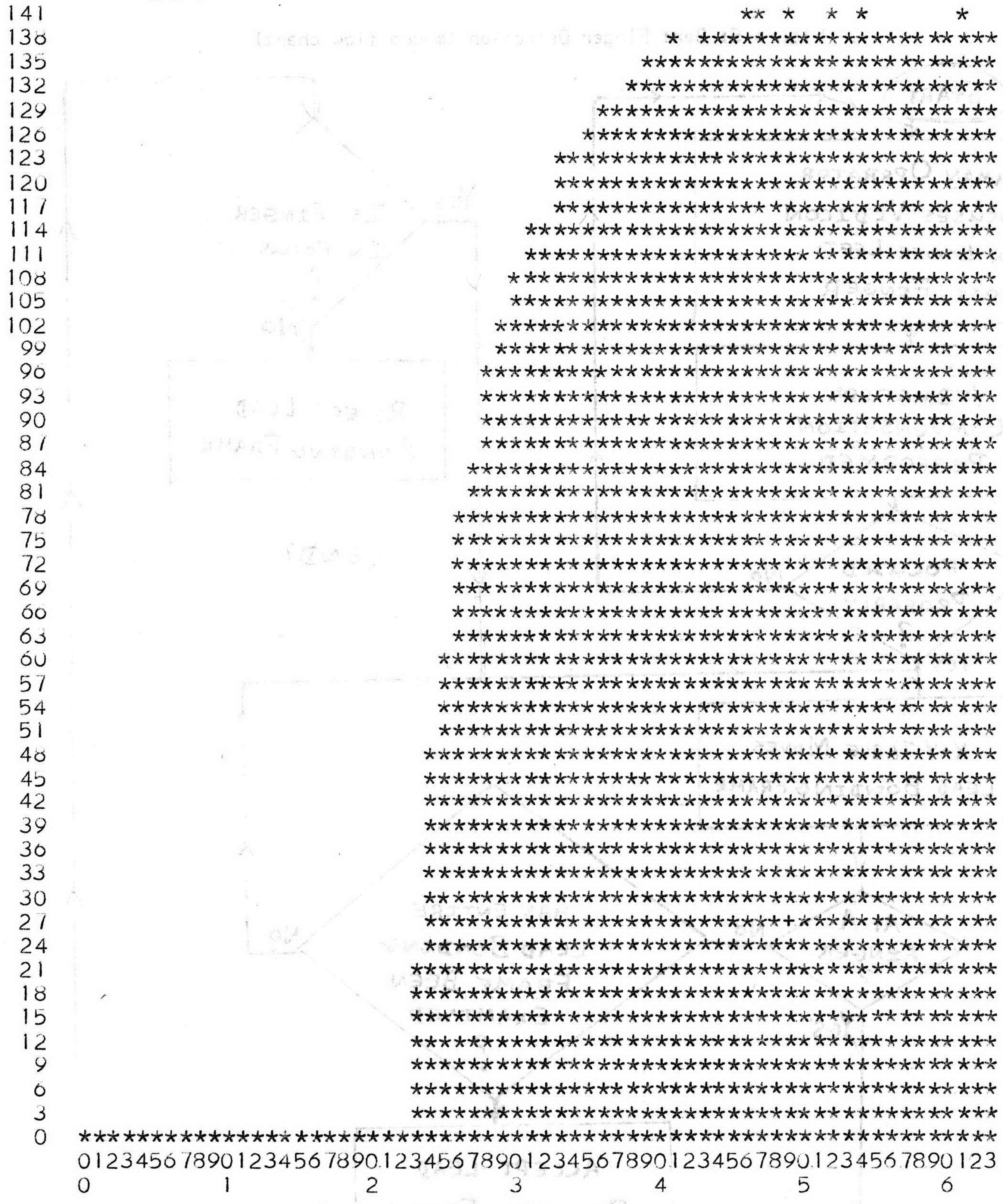


FIGURE 3B

Figure 5: Bent Finger Detection (macro flow chart)

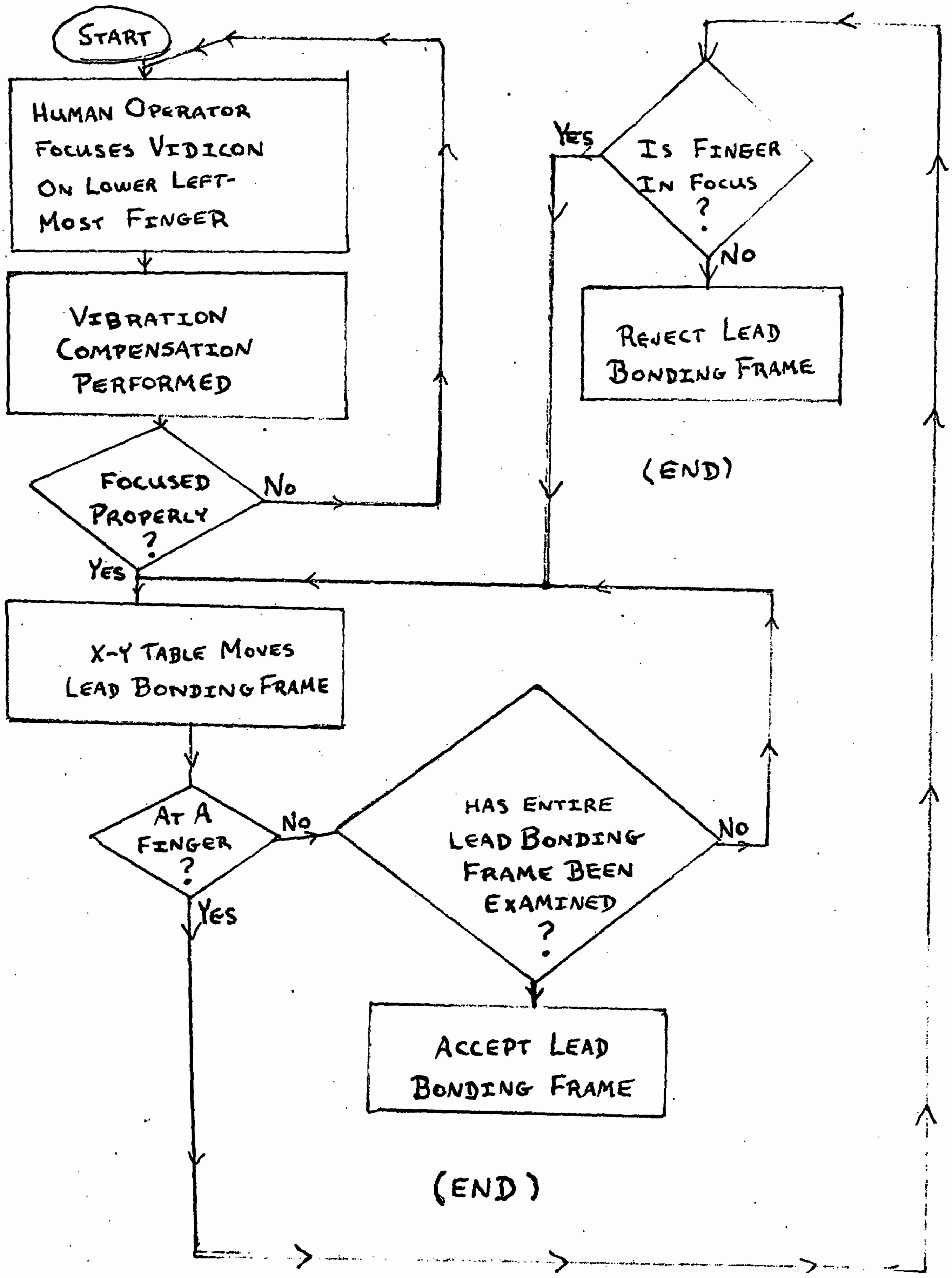


Figure 6: Histogram Analyzer (flow chart)

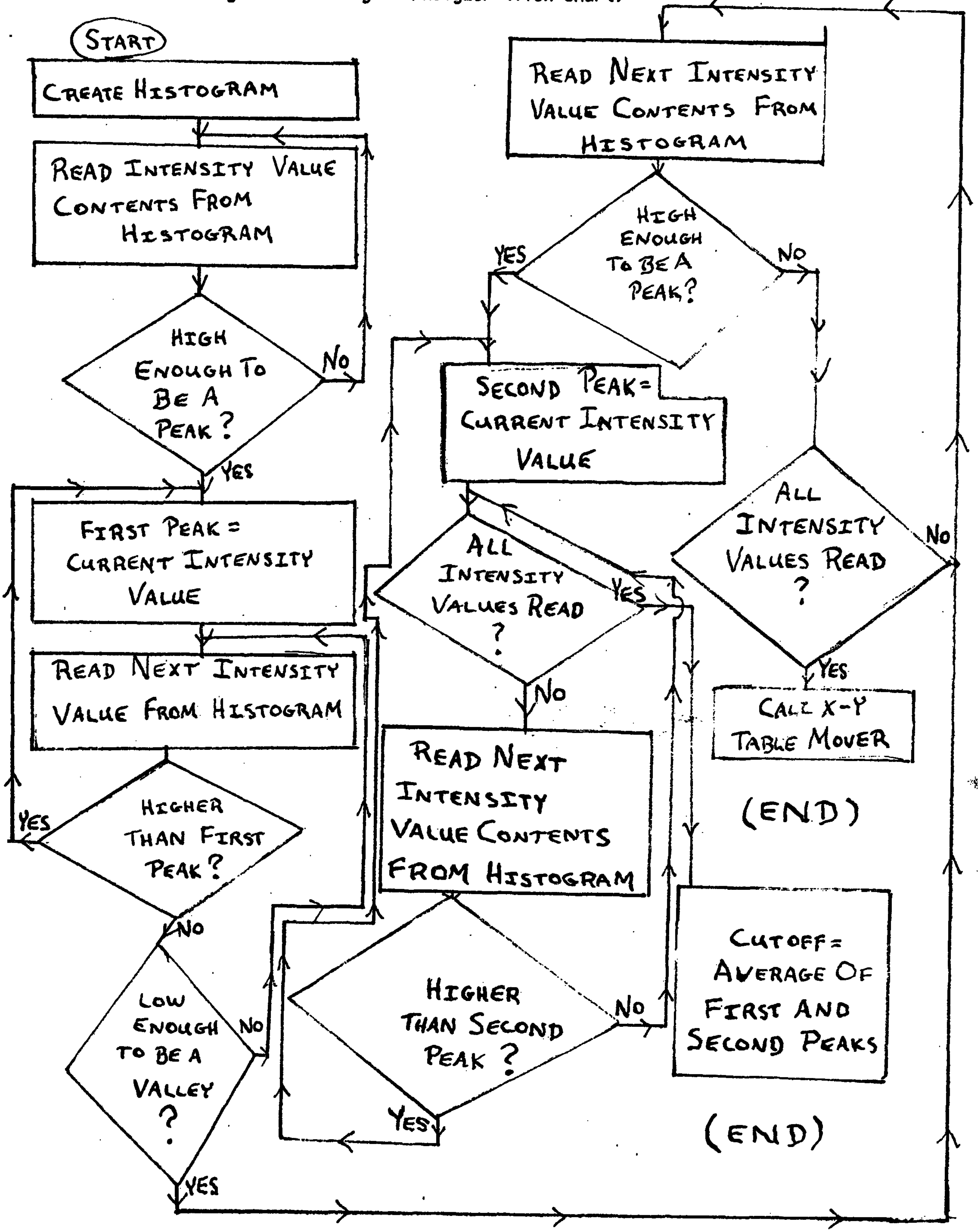


Figure 7: Finger Finder (flow chart)

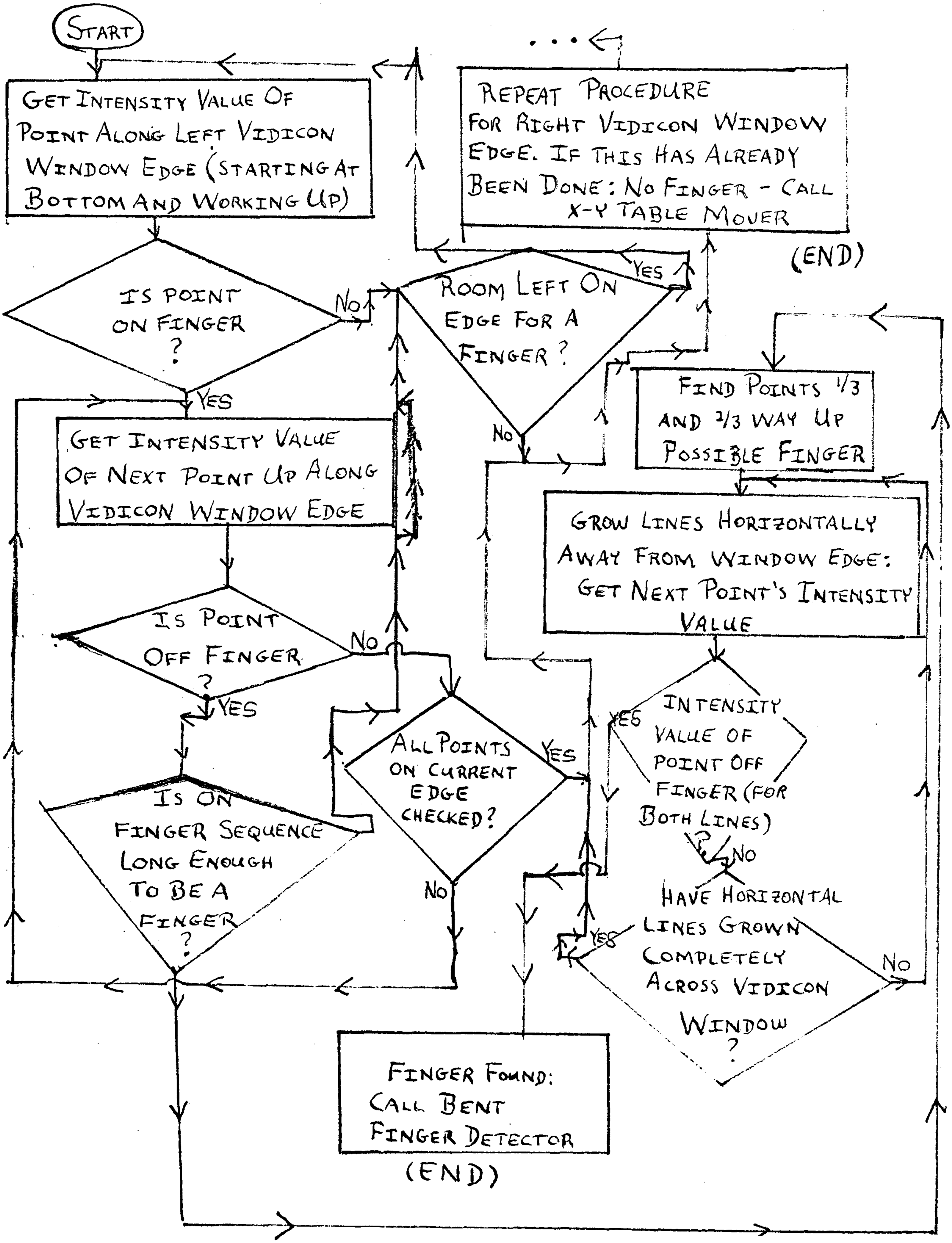


Figure 8: Bent Finger Detector (flow chart)