Improving the Testing Rate of Electronic Circuit Boards

The Acculogic company, based in Markham (Ontario), produces and sells the FLYING PROBE systems, which are used by its clients to test Electronic Circuit Boards (ECBs). Those systems include eight mobile bases called SHUTTLES, to which at most four instrument pods (and especially probes) are attached. In the ECB there is a finite number of points where the probes can make contact with the ECB. Each test is performed when (at least two) probes make contact with points of interest located in the ECB. The overall goal of the system is to carry out a set of tests in sequence, while minimizing the resources consumed during the testing process.

The ECBs are manufactured according to a pattern. The points of interest have theoretical coordinates (called board coordinates) within this pattern. Let us denote by (x_i, y_i) the coordinates of the ith point of interest. In practice, however, each board produced is slightly different from the board pattern and every other concrete board. Let us denote by (x_i^a, y_i^a) the actual coordinates of the ith point of interest within the board being tested.

The actual coordinates of the points of interest on a particular board are not known. We first describe the current method for extrapolating them. The extrapolated points will be denoted by (x_i', y_i'). One considers three fiducial (or reference) points and measures their actual coordinates. Without loss of generality, assume that these points are $f_i = (x_i, y_i)$ for $i = 1, 2, 3$. The measurements will yield $f_i' = (x_i^a, y_i^a) = (x_i', y_i')$ for $i = 1, 2, 3$. One can verify easily that there are unique vectors O, e_x, and e_y such that $f_i' = O + x_i \cdot e_x + y_i \cdot e_y$ for $i = 1, 2, 3$. (Note that e_x and e_y are unit vectors.) Once the vectors O, e_x, and e_y have been determined, one can extrapolate the positions of the other points of interest (i.e., the coordinates (x_i', y_i') for $i > 3$) using $f(x_i, y_i) = O + x_i \cdot e_x + y_i \cdot e_y$. The computed coordinates are called "system coordinates".

This is part of the calibration process of the machine. A calibration board is used to measure the three fiducial points. The process of measuring the points (x_i', y_i') relies on correlating a number of ideal shapes with their real counterparts in the actual board. This is done through connectivity tests: the probe goes up and down on the board repeatedly and the system checks whether electrical contact was made with the calibration board or not.

The method described in the previous paragraph is far from perfect. In particular, when running the FLYING PROBE system, some electrical contact must be made between the tip of a probe and the position (x, y) on the calibration board. This is a binary test, to determine whether there was an electrical contact or not. Also, the imperfections of the calibration board are not taken into account. If the system coordinates (x, y) are different from the actual coordinates (x_a, y_a) in a certain region of the board, the tests involving points of interest in a neighborhood of this region cannot be carried out. In the current setup, the system reports that a certain number of tests are not routable, making it impossible to perform them, or demanding time from a human expert.

It would be highly desirable to improve the accuracy of the (x_i', y_i'), i.e., propose an algorithm that computes coordinates close to the actual coordinates (the (x_i^a, y_i^a)). One way to do this is to use a camera, which is part of the system already, in order to obtain an accurate picture of the actual board. Then compare the information obtained through the image with the known ideal information contained in the ideal board. The primary problem for the team to solve is the following: given a set of ideal images arranged in a region of the ideal board, and a picture of that region in the actual board, find a map $f : (x, y) \mapsto (x_a, y_a)$ from the board coordinates to the actual coordinates.