as in apparatus **100**, the transfer function will be exactly the same except for a fixed delay in the output signal.

The horizontal block of apparatus **110** contains m units, each of which performs partial horizontal filtering or convolution. Two adjacent samples in cells **112** and **113** are summed by adder **114** which represent here the boxcar function. The output of the adder is fed into output cell **115**. Cascading many horizontal units performs a 1-dimensional horizontal filtering. The output of the horizontal block is then fed into the vertical block.

The vertical block is made of identical units, each of which performs partial vertical filtering. Apparatus **116** shows one vertical unit. The signal is fed into the input cell **117**. The output of that cell is down shifted along the shift register **118**. Adder **119** adds the output of the shift register and the output of cell **117**. The output of module **116** is fed into the input of the next module. The vertical modules perform a 1-dimensional convolution on the output of the horizontal module, completing in this manner a 2-dimensional convolution on the grey-scale image. All memory cells in the vertical or horizontal units as well as all shift registers are pulsed by a common clock (not shown) feeding the value of each cell into the adjacent cell.

While the above described apparatus performs repeating convolutions with a boxcar function comprised of two adjacent pixels, the convolutions can be achieved using a boxcar function comprising more than two adjacent pixels. This can be achieved, for example, by increasing the number of sampling cells and the number of shift registers, and consequently also increasing the number of inputs entering the adders per module.

As previously indicated, the convolution process requires a 2-dimensional convolution with the differences between Gaussian functions and this can be achieved in the manner indicated in FIGS. **10** and **11**, the size of the boxcar function (i.e., its limits along the line of registers) is empirically selected to produce good correspondence between the bit map eventually produced and the actual board. While a line of data in the example described above is said to consist of 2048 pixels, it should be clear that this number is by way of example only and represents the number of photodetectors used in conventional scanning cameras. Furthermore, the 20-pixels window referred to above should also be Considered as being an example because other windows, or even no window at all, can be used.

Finally, while the invention has been described in detail with reference to optical scanning of printed circuit boards, the inventive concept is applicable to other optical scanning problems, and more generally, to any 2-dimensional convolution problem. For example, the invention can be applied to inspecting hybrid boards as well as integrated circuits.

The advantages and improved results furnished by the method and apparatus of the present invention are apparent from the foregoing description of the preferred embodiment of the invention. Various changes and modifications may be made without departing from the spirit and scope of the invention as described in the claims that follow.

I claim:

1. A process for producing a binary map of an object having edges comprising:

(a) sampling the object to obtain grey level values at discrete sampling points for producing a digital grey scale image of the object with a given resolution; and

(b) processing the grey scale image to produce a digital map of the object having a resolution greater than said given resolution, such that the location of an edge of the object in the higher resolution map is related by a scale factor to the location of the corresponding edge in the object independently of the relative location of said edge with respect to the locations of said discrete sampling points.

2. A process according to claim **1** wherein the processing includes the step of convolving the digital grey scale image with a filter function that approximates the second derivative of a Gaussian function for forming a convolved image having signed values.

3. A process according to claim **2** wherein the processing includes determining the location of edges in the object by finding zero crossings between adjacent oppositely signed values.

4. A process according to claim **2** wherein the increased resolution of the binary map is achieved by interpolation.

5. A process for [producing a binary map of a printed] *inspecting an electrical circuit* [board] having conductive traces on a surface of a substrate, the processing comprising:

a) [linearly] displacing the [printed] *electrical* circuit [board in a direction perpendicular] *relative* to a linear array of photosensitive detectors, each of which produces an output that is functionally related to the brightness of [the field] *an elemental area of the electrical circuit* viewed by the detector*, each elemental area being associated with a measured data point and each said measured data point being mutually spaced apart generally by a predetermined sampling distance*;

b) applying the output of the detectors to a memory having cells for storing, in the cells thereof, a two-dimensional digital [grey] *gray* scale image of the [printed] *electrical* circuit [board], said image having [a predetermined] pixel*s* [size] *corresponding to said measured data points*;

[a) convolving the stored image with a two-dimensional, Laplacian of a Gaussian function for producing a convolved digital image having a signed value for each cell of said memory;

d]*c*) [interpolating between adjacent values of opposite sign for] obtaining *from said two dimensional digital gray scale image* a [binary] bit map of said [printed] *electrical* circuit [board with a pixel size]*, said map formed of digital map elements, wherein at least some non-adjacent digital map elements represent portions of the electrical circuit that are separated by a distance that is* smaller than said predetermined [size] *sampling distance*; and

[e) storing said binary bit map in a memory]*d*) *employing said map to detect defects in said electrical circuit.*

6. A process according to claim **5** wherein said [Gaussian function is empirically selected in accordance with electrical noise generated by the photosensitive detectors and the traces on the printed circuit board such that the bit] *digital map elements are pixels and said* map is representative of the traces on the [printed] *electrical* circuit [board].

7. A process according to claim **5** wherein the convolution is achieved by carrying out a one-dimensional convolution of successive lines of the image to form a one-dimensional convolved image, and carrying out an orthogonal one-dimensional convolution of successive lines of said one-dimensional convolved image to form a two-dimensional convolved image of the printed circuit board.

8. A process according to claim **7** wherein each onedimensional convolved image is formed by multiple convolving with a boxcar function.

9. Apparatus for producing a binary map of an object having edges comprising: