resolution of the equations, but it can produce infinite gain as infrared approaches dust gray. The singularity that exists as visible and infrared approach the dust gray level is ameliorated by the average over the entire block; however, as a further refinement, the formula can be made less subject to such artifacts by moving the singularity to a pure black infrared number by substituting the formula x=G+(V−G)/IR in function block **724**.

The operation of the gain and specific formulas given above are given further intuitive foundation in FIG. **11**. FIG. **11***a* illustrates how the visible record is affected by different degrees of defects. When infrared=unity, there is no defect, and so visible=x. A small defect may attenuate infrared to 0.8, and visible will therefore also be the same 0.8 when x=white. However, the visible line **1102** will pivot on the dust gray point **1104**. The extreme refractive defect will pull infrared, and the visible level when x=white, all the way down to dust gray, which will pivot on dust gray **1104** to give the horizontal line **1106**. The horizontal line implies no image is seen, whether x=black or x=white, only the dust gray of the defect will be seen.

To undo the effects of a defect, the visible record will need to be amplified to overcome the masking effect of the defect. The amplification should be relative to dust gray. FIG. **11***b* illustrates how a gain is chosen to multiply the visible record such that visible times gain is an estimate of x. Note that when infrared=dust gray, gain goes to infinity in an attempt to see through an opaque defect. Although theoretically correct, this singularity creates gross artifacts in actual systems with deviations from perfection, and is avoided by the offset method taught above.

The concept of a correction range was already presented in connection with FIG. **4** in range blocks **450** and **452** acting with the smart subtraction block **460** as defined. This concept of a correction range will now be applied to the method of FIG. **7**.

In FIG. **7**, let the gain block **730** go to zero, thereby eliminating it from the operation. In its place let the upper bound gain block **770** follow the line **1022** of FIG. **10**, such line defining the relationship of input x to output gain, and further let the lower bound gain block **772** follow the line **1020** of FIG. **10**. The upper bound gain **770** multiplies each element of the infrared transform block **712** at multiplier **774** to give the upper bound limit transform **776**, and similarly the lower bound gain **772** multiplies block **712** at multiplier **778** to give the lower bound block **780**. The upper and lower bounds are subtracted from the image transform **710** by the smart subtraction function **744**, in effect using whichever bound brings the result closest to zero, and outputting zero when zero is in between the result of both bounds, thereby totally nulling defects that are within the crosshatched uncertainty range **1024** of FIG. **10**.

A further refinement makes the nulling range frequency sensitive to accommodate a greater uncertainty range at higher spatial frequencies, as mentioned above. To practice this frequency dependence, the upper and lower gain blocks **770** and **772** are made frequency dependent. In particular, a low frequency element **722** in the infrared transform may be multiplied by upper and lower bound numbers defined by center line **1010** of FIG. **10**, whereas a higher frequency element **788** located a distance **790** from the low frequency element **722** would be multiplied by upper and lower bound lines **1022** and **1020** respectively of FIG. **10**. Finally, a very high frequency term **792** would be multiplied by upper and lower bound lines **1002** and **1004** respectively. This method enables more aggressive removal of defects at the higher frequencies.

The examples discussed so far have input a single visible image for processing. It should be understood that a full color image could be processed by repeating the described process with a red visible image, a green visible image, and a blue visible image.

The preferred embodiment disclosed with reference to FIG. **7** used a block transform structure; however, the use of such a structure is not a limitation in the practice of the present invention. Other structures permit the multiplication of infrared defect detail by a gain that is determined as a function of visible image brightness in such a way that defects can be corrected from highlights to shadows. As an example, FIG. **12** presents an alternate embodiment of the invention that uses neither blocks nor a frequency transform space.

In FIG. **12**, a visible image **1202** is received along with a registered infrared image **1204**. The specific mathematics of this example will assume these images are in linear space, but as explained above, other gamma corrected spaces may be used. At function block **1206** a small amount of the visible image **1202** is subtracted from the infrared image **1204** to yield an infrared image **1208** free of visible traces **1210**. In practice, a small amount of the cyan record, as seen in the red visible scan, will appear in the infrared scan **1204** as a smudge **1210**. This can be eliminated by moving the wavelength of the infrared scan farther from the visible spectrum, but high wavelength infrared can stress the optics and sensors used in the scanner. In practice, as an expedient, the infrared scan is kept rather close to the visible spectrum under a wavelength around 850 nm, and the residual effect of the visible image is removed by subtracting about 10% of the red visible record. This step could also be applied to any of the examples previously described if needed.

In the example of FIG. **7**, the details of the infrared defect scan were separated in frequency as is the nature of a DCT or DFT transform. That is, where there is no defect detail, the film is clear in infrared, and all elements of the infrared transform, except the average term, are zero, and any multiplication of the zero terms by a gain will have no effect on the zero value in that term. Conversely, where there are defects, the transform terms will be nonzero, and will be affected by a multiplication in proportion to the level of the defect. In the present example of FIG. **12**, defect details are separated by grayscale. Assuming the image has been normalized such that image **1208** is unity for a section of the image with no defects, function block **1214** subtracts unity from image **1208** to result in an image **1216** that is zero at points with no defect, and as image **1208** drops below unity, image **1216** goes negative in proportion to the depth of the defect. Thus the detail of the defect record has been isolated in image **1216** in such a way that only detail; i.e., nonzero points of the image, will be affected by any multiplication of pixels in the image **1216**.

While the defect details are being isolated in image **1216**, the gain that will be applied to those defect details is being calculated for each pixel. The visible image is blurred by function block **1220** to form blurred visible image **1222**, and the infrared image is blurred by function block **1224** to form blurred infrared image **1226**. This blurring reduces artifacts in the calculation of gain caused by irregularities and noise in the image. A typical blur is to average a 9×9 pixel box around each pixel in image **1202** or **1204** to assign the corresponding pixel in blurred image **1222** or **1226**.

Next, for each pixel in the blurred visible image **1222**, x is estimated in conjunction with the corresponding pixel in the blurred infrared image **1226** by estimator **1228**. The