



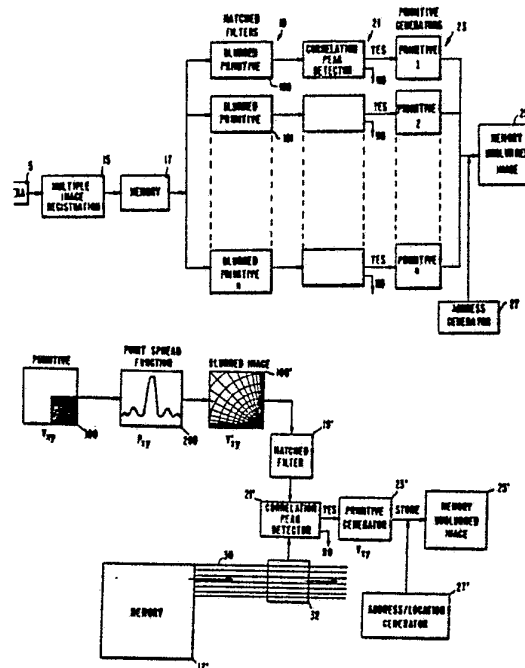
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(54) Title: RESOLUTION ENHANCEMENT AND ZOOM

(57) Abstract

The resolution is enhanced first by effectively decreasing the scan angle subtended between adjacent samples significantly below that of the Rayleigh limit to obtain an image blurred by the point spread function (or diffraction pattern) of the aperture. The next step is to process this blurred image at least to partially remove the blur. The unblurring process consists of correlating each small segment of the blurred image with blurred images of pre-constructed image primitives and then synthesizing a new image comprising a mosaic of spatially correlated original (unblurred) primitives. The blurred images of the primitives are obtained from a complete set of image primitives comprising, ideally, all possible unblurred primitive shapes. These primitives are then blurred by convolution with the point spread function of the imager.



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## RESOLUTION ENHANCEMENT AND ZOOM

1                    BACKGROUND OF THE INVENTION

Image systems including television cameras,  
charge coupled device imagers, forward looking infrared  
sensors, and infrared charge coupled device detectors  
5 produce a video image having a resolution limited by  
the sampling rate of the imager. Designers of such  
systems typically limit the sampling rate to slightly  
more than two samples between the first zeros of the  
diffraction blur in accordance with the Nyquist  
10 criteria. The Rayleigh resolution limit (computed  
from the size of the aperture and the wavelength of  
the scene energy) describes the limits of what the  
eye can see. A discussion of the Rayleigh limit is  
given in Jenkins and White, Fundamentals of Optics,  
15 McGraw-Hill, 1957, at page 304. Specifically, a minimum  
angle of resolution between two points, for an imager  
having a circular aperture of diameter D sensing light  
wavelength  $\lambda$ , is  $\frac{0.244\lambda}{D}$  radians. Accordingly,  
20 scanning imager systems are typically designed so that  
the scan angle subtended between adjacent samples is  
less than  $\frac{0.122\lambda}{D}$  radians.





1 may be accomplished using a correlation tracker, or  
image motion compensating servo error or camera platform  
stabilizing gyro error. The subpixel displacement is  
determined in this way.

5 In another embodiment of the invention, the number  
of samples in a given angle of scan in a conventional  
imager may be increased by using image interpolation  
and zoom. Image interpolation and zoom is useful when  
there is not enough time to process a plurality of  
10 video frames to construct a multiple-registered video  
frame. Another technique is to use smaller sized  
detectors in order to achieve dense sampling in a single  
frame.

15

#### DESCRIPTION OF THE FIGURES

The invention may be understood by reference to  
the accompanying drawings, of which:

FIG. 1a illustrates a typical aperture and sensor  
receiving light from two point sources;

20

FIG. 1b illustrates the diffraction pattern or  
point spread function corresponding to FIG. 1a;

FIG. 2a illustrates four multiple-registered  
video frames;

25

FIG. 2b illustrates a sub-pixel mosaic synthesized  
from the four multiple-registered video frames of FIG.  
2a;

FIG. 2c illustrates an imaging device suitable  
for generating multiple-registered video frames;

30

FIG. 3 illustrates a scheme for fast acquisition  
of multiple-registered video frames;



1           FIG. 4 illustrates an image interpolation technique which may be used in this invention in lieu of the multiple-registration technique of FIGS. 2a, 2b and 2c;

5           FIG. 5 illustrates an exemplary set of image primitives;

          FIG. 6a illustrates the image primitive matched filter correlation technique for synthesizing an enhanced resolution image;

10          FIG. 6b illustrates the implementation of the technique of FIG. 6a for a single image primitive matched filter, as a simplified example; and

          FIG. 6c illustrates a point spread function of the same function shown in FIG. 6b.

15

#### DETAILED DESCRIPTION OF THE INVENTION

          FIG. 1a is a simplified schematic diagram illustrating two points A, B viewed through a circular aperture 1 (shown in cross-section) of diameter  $D \cdot A$  lens 3 of a camera 5 senses the radiation of wavelength  $\lambda$  emitted or reflected from the two points A and B. The angle  $\theta$ , subtended between the two points A and B at the lens 3, is equal to the Rayleigh limit  $0.244\lambda/D$ .

25          FIG. 1b is a diagram illustrating the corresponding diffraction patterns produced at the lens 3 by the radiation from point A (solid line) and from point B (dashed line) in which the ordinate corresponds the photon intensity and the abscissa corresponds the position along the X axis of FIG. 1a. Such diffraction patterns of point source images are uniquely characteristic of the aperture, and are termed "Point Spread Functions".

35



1           The Rayleigh criterion establishes the resolution  
limit of two points viewed through an aperture. Specifi-  
cally, the Rayleigh criterion states that the minimum  
perceptible separation between the two points A and B  
5 occurs where the peak  $P(A)$  of the diffraction blur of  
one point corresponds to the first zero  $Z(B)$  of the  
diffraction blur of the other point. This is exactly  
the condition illustrated in FIG. 1b. This criterion  
is based upon the fact that, below this separation,  
10 there is no longer a discernable diffraction valley  
between the peaks. However, it is a principle of this  
invention that the Rayleigh criterion relates to the  
behavior of the human eye and is not a fundamental  
limit on the resolution of an image viewed through a  
15 particular aperture and, in fact, a greater resolution  
is possible if processing is used. Specifically, the  
shape of the blurred image of two points, whose  
separation is precisely at the Rayleigh limit, is  
different from that of a single point. Furthermore,  
20 the blurred image of the two points continues to go  
through subtle changes below the Rayleigh limit  
until the two points actually coincide in the scene.  
(Of course, upon coincidence they are definitely  
unresolvable.) Accordingly, there is realizable  
25 information contained in a blurred image of two  
points separated by a distance below that of the  
Rayleigh criterion. Extraction of this information  
is accomplished in the present invention.

### 30 Multiple Image Registration

FIGS. 2a and 2b illustrate the multiple image  
registration used in this invention with the simple  
example of a video frame having only sixteen pixels,  
four on each side. In FIG. 2a, a video frame "a",  
35 bounded by the solid line whose corners are denoted



1  $a_{11}$ ,  $a_{14}$ ,  $a_{41}$  and  $a_{44}$ , comprises sixteen pixels each  
centered around sixteen respective points symbolized  
as  $a_{ij}$ . The location of each of the center points  
 $a_{ij}$  of the sixteen pixels is illustrated in FIG. 2a  
5 while the mosaic of the corresponding pixels themselves  
is illustrated in FIG. 2b in solid line.

Multiple image registration is achieved by sampling  
and storing the sixteen pixels of data comprising the  
video frame a of FIG. 2a illustrated in solid line.  
10 Then the camera 5 is displaced in the x direction so as  
to sample a second video frame b illustrated in dashed  
line comprising sixteen pixels  $b_{ij}$  and bounded by pixels  
 $b_{11}$ ,  $b_{14}$ ,  $b_{41}$  and  $b_{44}$ . The displacement in the x direc-  
tion between the video frames a and b is equal to half  
15 the distance between the center points  $a_{11}$  and  $a_{12}$ . The  
sixteen pixels of data corresponding to the sixteen  
center points  $b_{ij}$  are sampled and stored. The camera  
5 is again displaced to sample a third video frame c  
bounded by pixels  $c_{11}$ ,  $c_{14}$ ,  $c_{41}$  and  $c_{44}$  in FIG. 2a. The  
20 video frame c is displaced from the original video  
frame a in the y direction by half the distance between  
the center points  $a_{11}$  and  $a_{21}$ . The sixteen pixels  
corresponding to the sixteen center points  $c_{ij}$  are then  
sampled and stored. The camera 5 is then displaced  
25 from the location corresponding to the video frame c  
in the x direction by a distance corresponding to half  
the pixel spacing to sense a fourth video frame d  
illustrated in FIG. 2a in dashed-dotted line whose  
corner pixels bear indicea  $d_{11}$ ,  $d_{14}$ ,  $d_{41}$  and  $d_{44}$ . The  
30 sixteen pixels corresponding to the sixteen center  
points  $d_{ij}$  of the video frame d are then sampled and  
stored.

1           A composite of the stored data from the video  
frames a, b, c and d is then formed by reorganizing the  
data in the order illustrated in FIG. 2b. Specifically,  
FIG. 2b illustates the data corresponding to the pixel  
5 center points  $a_{11}$ ,  $b_{11}$ ,  $c_{11}$  and  $d_{11}$  in a multiple-  
registered or composite video frame indicated in dashed  
line in FIG. 2b. Each of the points  $a_{11}$ ,  $b_{11}$ ,  $c_{11}$   
and  $d_{11}$  is now the center of a corresponding subpixel  
illustrated in dashed line in FIG. 2b. The number of  
10 subpixels in the resulting composite mosaic is equal  
to the square of the sampling improvement multiplied by  
the number of pixels in any one of the original video  
frames (in our example  $2^2 \times 16 = 64$  subpixels). The  
dashed line subpixels of FIG. 2b are of smaller  
15 dimension than the solid line pixels by a factor of 2.

As a general rule, in a multiple registration of  
n video frames, the video frames are displaced from one  
another by a fraction  $(1/n)^{1/2}$  of the pixel spacing.  
Thus, while FIG. 2b illustrates a multiple image regis-  
20 tration of four video frames in which the pixel dimension  
is reduced by a factor of two, other reduction factors  
may be achieved by multiple image registration.

Even though the granularity of the video data has  
been reduced by the multiple image registration, the  
25 image represented by the data is nevertheless blurred  
in accordance with the point spread function of the  
aperture through which the image was viewed.

In practice, correlation of the spatial displace-  
ment between video frames with the reorganization of  
30 the stored video data may be made by means of a camera  
or sensor 5 mounted on a controller 7 as indicated in  
FIG. 2c. The controller may be a camera gyroscopic  
stabilization platform whose gyro error may be auto-  
matically sensed and used as the video frame displace-  
35 ment. Alternatively, the platform 7 may be an image



1 motion compensator using gyro stabilization. Again,  
the gyro error would define the displacement between  
the subsequent video frames. Finally, a correlation  
tracker may be used to track the actual displacement  
5 due to camera jitter between video frames. Data from  
the correlation tracker would define the displacement  
between subsequent video frames. Each of these  
techniques is compatible with existing systems.

Referring to FIG. 3, a video frame 10 is synthesized  
10 by the multiple image registration of sixteen standard  
video frames of about 500 lines each, could not be  
entirely displayed on a standard video screen. Instead,  
the screen could accommodate only a small fraction 10'  
of the multiple-registered video image. Accordingly,  
15 the data residing in those portions 10a, 10c, and 10d  
of the video frame of FIG. 3 correspond to unnecessary  
scan excursions by the imager 5 in the Y direction. It  
is preferable in this invention to restrict the scan of  
the imager 5 of FIG. 2c in the Y direction to cover  
20 only the portion of 10 illustrated in FIG. 3 as 10',  
10e, and 10b. In this way, data comprising the multiple-  
registered image 10' which is actually displayed on a  
television screen may be acquired about four times  
faster than otherwise for a 4-fold multiple registration.

25 Referring again to FIG. 2b, it should be recognized  
that each of the points  $a_{ij}$ ,  $b_{ij}$ ,  $c_{ij}$ ,  $d_{ij}$  corresponds  
to a word of video data which may be stored in the  
memory of a computer. The word corresponding to each  
of the points  $a_{ij}$ ,  $b_{ij}$ ,  $c_{ij}$ ,  $d_{ij}$  may take on any number  
30 in a range of values corresponding to an analog value  
of the radiation intensity sensed at that point by the  
camera 5. Alternatively, in a low performance system,  
each word may simply be a binary value (black or white,



1 on or off). However, it is contemplated in this invention  
that each word represents an analog value corresponding  
to the intensity of radiation sensed by the imager at  
the corresponding center point  $a_{ij}$ ,  $b_{ij}$ , etc.

5

#### Image Interpolation and Zoom

It may not be possible to use multiple image  
registration to generate subpixel video data. This may  
occur, for example, when objects to be viewed in the  
10 scene are moving so fast in comparison with the rate at  
which subsequent video frames are generated, that there  
is insufficient correlation of the fast moving objects  
between subsequent video frames. In this special  
situation, image interpolation and zoom may be used to  
15 generate the subpixels, instead of multiple image  
registration.

Referring to FIG. 4, a subpixel of video data is  
generated from a single video frame. The exemplary  
portion of the video frame a of FIG. 4 comprises a  
20 plurality of stored words of video data in which only  
the words corresponding to pixel center points  $a_{12}$ ,  
 $a_{21}$  and  $a_{32}$  represent a non-zero intensity, corresponding  
to the shaded areas of the video frame a of FIG. 4.

Image interpolation is achieved by estimating the  
25 value of a point located between pixels. The image  
data is interpolated between the pixels to achieve a  
linear transition between the three points  $a_{12}$ ,  $a_{21}$   
and  $a_{32}$ , as illustrated in FIG. 4 in the heavier solid  
line. The resulting interpolated image is represented  
30 in cross hatching in FIG. 4. The new interpolated  
image, corresponding to the crossed-hatched area, con-  
tains more information than the old image corresponding  
to the shaded or stippled area.

35



1 Interpolation of the analog intensity values  
among the subpixels in the shaded area is made in  
accordance with the following equations defining the  
intensity value of the data word representing a  
5 subpixel  $a'_{ij}$ :

$a'_{ij} = a_{ij}$  if  $a_{ij}$  is the center point of  
a sample pixel in the original video frame  $a$ .

Otherwise:

10  $a'_{ij} = a$  linear interpolation between the  
analog values of adjacent  $a_{ij}$  from the original video  
frame  $a$ .

Data from sampled video frames can update the  
estimates from previously interpolated subpixels if  
combined by a suitable weighting factor. The foregoing  
15 image interpolation and zoom techniques are well known  
and are described in various publications including,  
for example: Pratt, Digital Image Processing, Wiley &  
Sons, New York, pages 110-116. Accordingly, the image  
interpolation and zoom technique will not be described  
20 in greater detail here.

In summary, by the use of either multiple image  
registration or image interpolation and zoom, a video  
image comprising a plurality of fine subpixels may be  
constructed from a plurality of video frames comprising  
25 a plurality of normally sized pixels. A larger number  
of small detectors could also be used to improve  
sampling density. However, the information contained  
in the subpixel composite video frame is still blurred  
in accordance with the diffraction point spread function  
30 of the aperture through which the image was viewed.  
Accordingly, there remains the task of removing the  
blur, at least partially, from the image, and recon-  
structing an unblurred image from the information  
contained in the highly sampled video frame of  
35 subpixels.



1 Unblurring by Matched Filters

The composite image comprising a plurality of subpixels may be substantially unblurred by correlating each small segment of the composite blurred image with a complete set of equally small blurred image primitives. An exemplary set of 25 image primitives is illustrated in FIG. 5. Whenever a peak correlation is detected between a particular image primitive and a particular segment of the composite image, an equivalent unblurred image primitive is substituted in place of the blurred segment. In this manner, a synthesized reconstructed silhouette image is formed from a spatially correlated set of image primitives substituted in place of the original blurred image segments to which they correspond.

Before correlating the set of basic image primitives with the various segments of the blurred composite image, the image primitives themselves are first blurred by convolving them with the sensor degradation consisting of both the point spread function of the aperture, through which the original scene was viewed, and the detector shape, which samples the diffraction limited image. Accordingly, both the blurred composite image and the image primitives to which its segments are compared, are blurred by the same point spread function, thus enhancing correlation. This point spread function is a Bessel function defined by wavelength and the configuration of the aperture through which the scene is viewed, and may be computed in a deterministic manner in accordance with well known principles of classical optics. Blurring of the image primitives, such as those illustrated in FIG. 5 with the sensor degradation, is performed in accordance with well known principles of convolution theory.

1           The foregoing process is illustrated schematically  
in FIG. 6a. The camera 5 generates video data which is  
fed to a multiple image generator 15 which functions in  
accordance with either the multiple image registration  
5           previously described in connection with FIGS. 2a, 2b,  
2c or the image interpolation described in connection  
with FIG. 4. The generator 15 then feeds video data  
corresponding to a composite image of subpixels into a  
cumulative memory 17 which stores the combined video  
10          frame of subpixels. Segments of the video frame data  
stored in the memory 17 are then continuously fed  
to a set of parallel matched filters 19. Each of the  
matched filters 19 corresponds to a blurred version of  
one primitive of a complete set of image primitives  
15          such as those illustrated in FIG. 5. Correlation  
between each segment of the video frame and each of the  
matched filters is detected by a corresponding one of  
the correlation peak detectors 21.

          If a particular one of the blurred primitives  
20          matches a particular segment of the video data read  
out from the memory 17, the corresponding one of the  
peak detectors 21 will enable the corresponding one of  
a plurality of primitive generators 23. The enabled  
primitive generator feeds the corresponding original  
25          (or unblurred) image primitive to a memory 25, the  
selected image primitive being stored in a location  
determined by an address generator 27. This location  
corresponds to the location of the matching segment of  
the original video frame stored in the memory 17. As a  
30          result, feeding a continuum of blurred image segments  
from the memory 17 through the matched filter 19  
causes a new silhouette image to be synthesized in  
the memory 25 comprising a plurality of matching  
image primitives.

35



1           It is contemplated that the correlation process  
of FIG. 6a may be carried out using a memory and a  
charge coupled device transversal filter system such  
as that illustrated in FIG. 6b. In FIG. 6b, memory 17'  
5 contains a plurality of pixels representing one frame  
of video data corresponding to the composite blurred  
image. The pixels are organized by row and column.  
Matched filter correlation of the type illustrated in  
FIG. 6a is implemented by the use of a charge coupled  
10 device transversal filter comprising a plurality of  
n-parallel charge coupled device serial registers 30.  
In the example of FIG. 6b,  $n = 6$ .

The top six rows of the CCD memory 17' are  
transferred serially from left to right out of the  
15 memory 17', through the parallel CCD registers 30 and  
beneath a planar array 32 of charge sensing gate  
electrodes organized by n-rows and n-columns. This  
defines the dimensions of each of the segments of the  
video frame to be compared or matched as n pixels by n  
20 pixels. The n-rows of sensing gate electrodes in the  
array 32 are in vertical registration with the n-rows  
of the stored image 30. The spacing in the x direction  
in the gate electrodes in the array 32 corresponds to  
the serial spacing of charge packets in each of the  
25 image registers 30.

As the top six rows of data from the memory 17'  
are clocked from left to right through the CCD  
registers 30, successive segments of the video data  
comprising six rows and six columns are read out.  
30 Specifically, the magnitude of each charge packet in  
each six-by-six segment of data passing beneath the  
array 32 is sensed by sensing the electrical potential  
of each individual sensing gate electrode in the  
array 32. Each time data is clocked sequentially from  
35 left to right by one pixel through the register 32, a

1 new segment of video data is read out from the array 32  
and fed to a corresponding one of 21' of the correlation  
peak detectors 21. This occurs once each CCD clock  
cycle. The process continues, pixel by pixel, until  
5 the entire image has been processed. Operation of  
charge coupled device transversal filters of this sort  
is well known in the art and will not be described  
further. Charge coupled device image processing with  
transversal filters and CCD sense electrode arrays is  
10 described, for example, in: Nudd et al, "A CCD Image  
Processor for Smart Sensor Applications", Proceedings  
of the Society of Photo-Optical Instrumentation  
Engineers, San Diego, California, 1978, Vol. 155,  
pages 15-22.

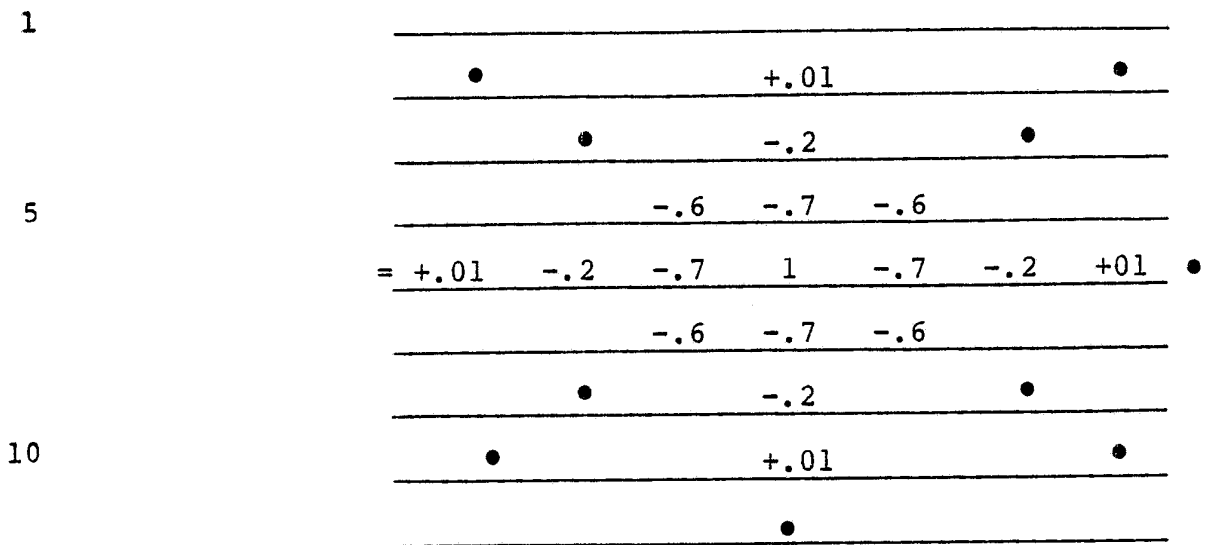
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#### Convolution and Correlation

A simplified description of the convolution and  
correlation processes for a particular one of the image  
primitives of FIG. 6a will now be given with reference  
20 to FIG. 6b. Each image primitive of FIG. 5 is quantized  
into an array of  $n$  columns and  $n$  rows of data words,  
 $V_{ij}$ . A graphic representation of the array corresponding  
to the image primitive 100 of FIG. 5 is illustrated in  
FIG. 6b. An exemplary aperture point spread function  
25  $P_{xy}$  is illustrated in FIG. 6c. It may be digitized  
into an array of  $m$  rows and  $m$  columns of data words  
corresponding to the number of rows and columns of  
subpixels in a complete multiple-registered frame.  
The result is a matrix  $P_{ij}$  of  $m$  columns and  $m$  rows of  
30 data words, comprising the point spread function matrix  
200 indicated in FIG. 6b. The following is a partial  
representation of an exemplary point spread function  
matrix:

35





15 In order to generate a blurred "version" of each image primitive, such as the primitive 100 in FIG. 6b, the primitive 100 is convolved with the point spread function matrix 200, yielding the blurred primitive 100', as indicated in FIG. 6b. Each data word  $V'_{ij}$  in the  $i^{th}$  row and the  $j^{th}$  column of the blurred primitive 100' is computed from the point spread function data words  $P_{ij}$  and the unblurred primitive data words  $V_{ij}$  as follows:

25 
$$V'_{i,j} = \sum_k \sum_l P_{k-i,l-j} V_{kl}.$$

The blurred primitive 100' is then used as an array or matched filter 19' of  $n \times n$  subpixels of data words. The plurality of matched filters 19 comprises, for example, each of the image primitives of FIG. 5 convolved with the point spread function 200, in accordance with FIG. 6b.



1           The  $n \times n$  matched filter 19' is correlated with  
each  $n \times n$  image segment sensed by the array 32, the  
correlation surface is operated on by the two-dimensional  
correlation peak detector 21'. If the detector 21'  
5 senses a peak correlation, the primitive generator 23'  
is enabled by the detector 21' to generate a block of  
 $n$ -rows and  $n$ -columns of data words corresponding to the  
unblurred image primitive 100. The data from the  
generator 23' is stored in the memory 25' in an address  
10 specified by the address generator 27'. The address  
generator 27' directs the image primitive block of  
data in the memory 25' to the location corresponding  
to the original location of the correlated data segment  
of the blurred video frame stored in the memory 17'.

15           Computation of the correlation by the detector 21'  
is performed in accordance with well-known correlation  
techniques in signal processing theory and, therefore,  
will not be described herein in detail.

          The synthesized image stored in the memory 25  
20 comprises a mosaic of selected image primitives and  
has a better resolution than any one of the video  
frames originally generated by the camera 5. It is  
contemplated that the performance may be enhanced by  
the use of a more complete set of image primitives than  
25 that illustrated in FIG. 5.

CLAIMSWhat is Claimed is:

- 1           1. In an imaging system comprising an imager  
which may view a scene through an aperture characterized  
by a point spread function and means responding to said  
imager for generating successive frames of video data  
5 words characterized by a first sampling rate, a system  
for enhancing image resolution, comprising:
- means for converting said video data words  
into a synthesized video frame of video data words,  
said synthesized video frame characterized by a second  
10 higher sampling rate;
- a plurality of image primitives, each of said  
image primitives comprising a matrix of video data  
words;
- means for convolving each of said image  
15 primitives with said point spread function to generate  
a set of blurred image primitives;
- means for computing the correlation between  
each of said blurred image primitives and each  
small segment of said synthesized video frame and  
20 detecting a peak correlation therefrom;
- a memory for storing a mosaic of selected  
image primitives; and
- means, responsive whenever said correlation  
means detects a two-dimensional peak correlation between  
25 a particular one of said blurred image primitives and  
one of said segments of said synthesized video frame,  
for writing a particular one of the unblurred ones of  
said image primitives into said image primitive mosaic  
storage memory at a location corresponding to the  
30 original location of said particular synthesized video  
frame segment in said synthesized video frame.

1           2. The system of Claim 1 wherein said means for  
converting into a synthesized video frame comprises  
multiple image registration means for forming a mosaic  
of displaced ones of said subsequent video frames  
5 generated by said imager.

1           3. The system of Claim 1 wherein said means for  
converting into a synthesized video frame comprises means  
for performing image interpolation in a single one of  
said subsequent video frames.

1           4. The system of Claim 1 further comprising an  
array of detectors having a detector-to-detector sampling  
rate greater than the Nyquist rate.

1           5. The image system of Claim 1 wherein each said  
small segment comprises  $n$  rows and  $n$  columns of said  
data words and said means for generating a synthesized  
video frame comprises a memory device for storing  
5 said synthesized video frame data words, and wherein  
said correlation means comprises a charge coupled  
device transversal filter including  $n$ -parallel  
registers receiving data from said charge coupled  
device memory, said correlation means comprising the  
10 equivalent of a planar array of  $n$  rows and  $n$  columns  
of sense electrodes overlying said parallel registers,  
said electrode array further comprising means for  
detecting each segment of video data words transferred  
through said parallel registers, and transmitting  
15 said detected video data words to a correlation  
computator, wherein said correlation computator  
computes a correlation between said detected segment  
of video data words and said digitized version of a  
corresponding one of said blurred image primitives.



1           6. In an imaging system, a method for employing  
a set of primitives to enhance an image whose resolution  
is degraded by system limitations including blurring  
caused by focus, diffraction and sampling, said method  
5    comprising:

          generating a set of degraded primitives by  
degrading said primitives in the same manner as the  
image is degraded by said system limitations;

          correlating the intensity distribution of a  
10   sampled segment of said degraded image with the intensity  
distributions of said degraded primitives and selecting  
the most correlated degraded primitive;

          synthesizing an enhanced image by displaying  
the undegraded version of said selected degraded  
15   primitive at the image location where the best match  
occurs between said sampled degraded image segment and  
said selected degraded primitive.

1           7. The method of Claim 6 further comprising the  
additional step of:

          increasing the sampling density of the degraded  
image and the degraded primitives prior to comparing  
5    the intensity distributions of degraded primitives and  
sampled segments of said degraded image.

1           8. The method of Claim 6 wherein said degraded  
primitives are generated by viewing said primitives  
through said imaging system so that the degrading  
effects of said system limitations are imparted to said  
5    primitives at the output of said system.

- 1           9. The method of Claim 6 wherein the correlation of intensity distributions is made between sampled degraded image segments and degraded primitives of similar size to each other.
- 1           10. The method of Claim 6 wherein said degraded primitives are generated mathematically by convolving said primitives with a function representing said system limitations.
- 1           11. The method of Claim 6 wherein said sampled segments of said degraded image have overlapping portions.



Fig. 1a.

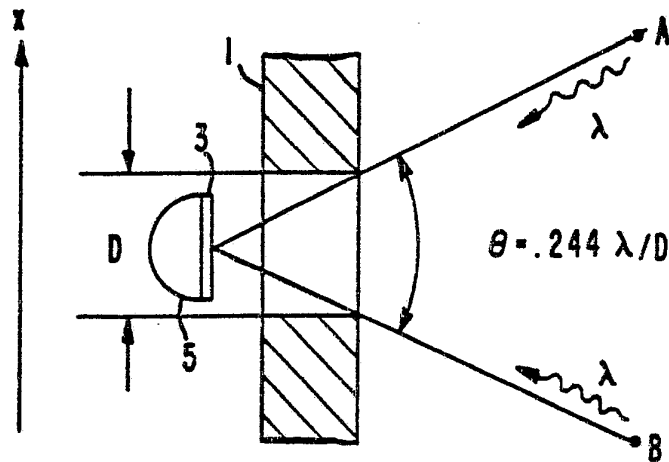


Fig. 1b.

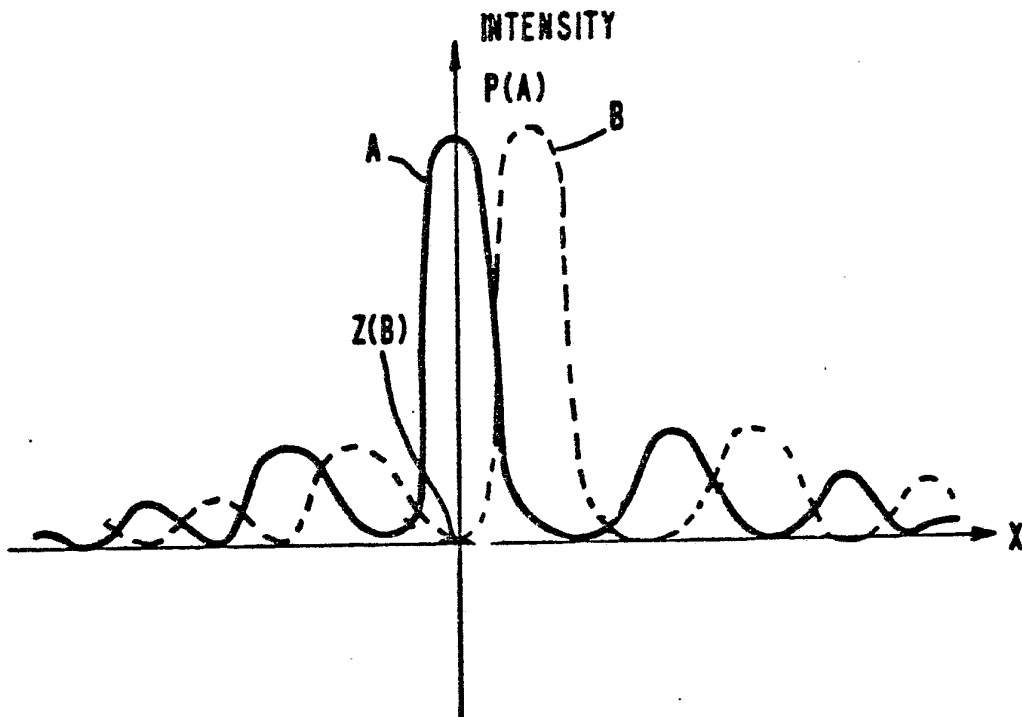


Fig. 2a.

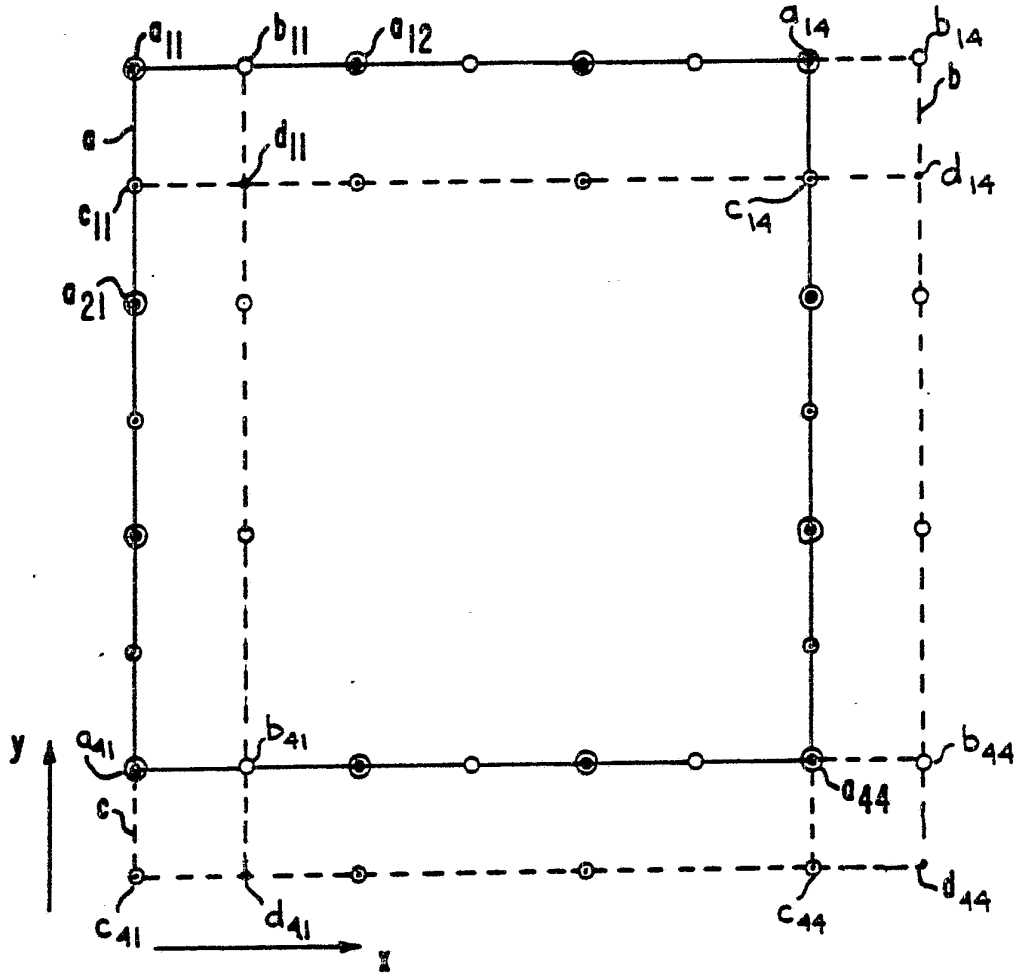


Fig. 6c.

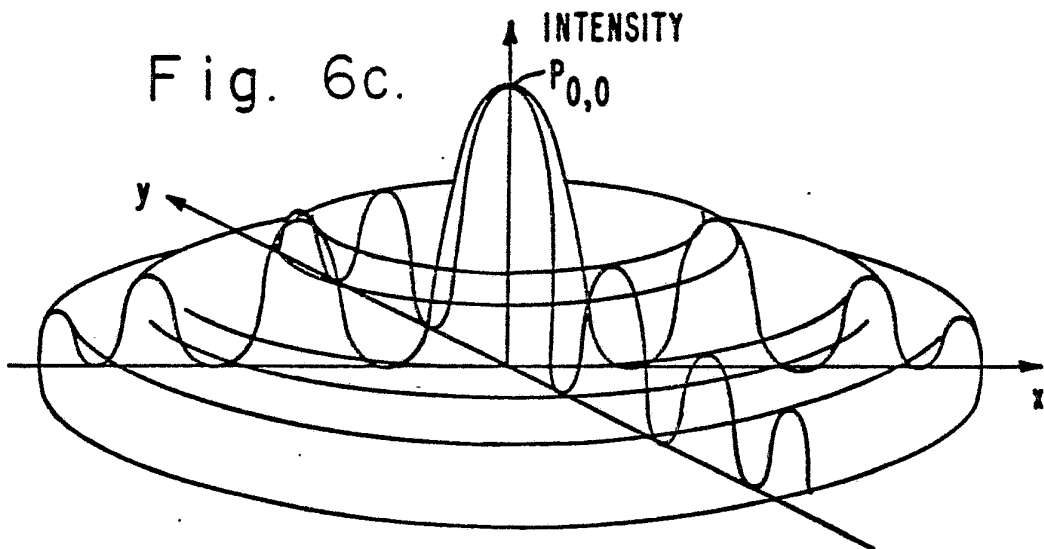


Fig. 2b.

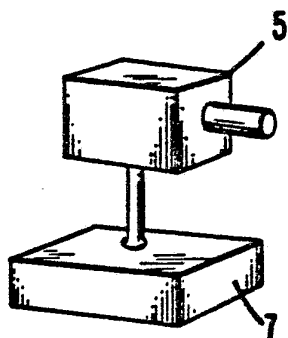
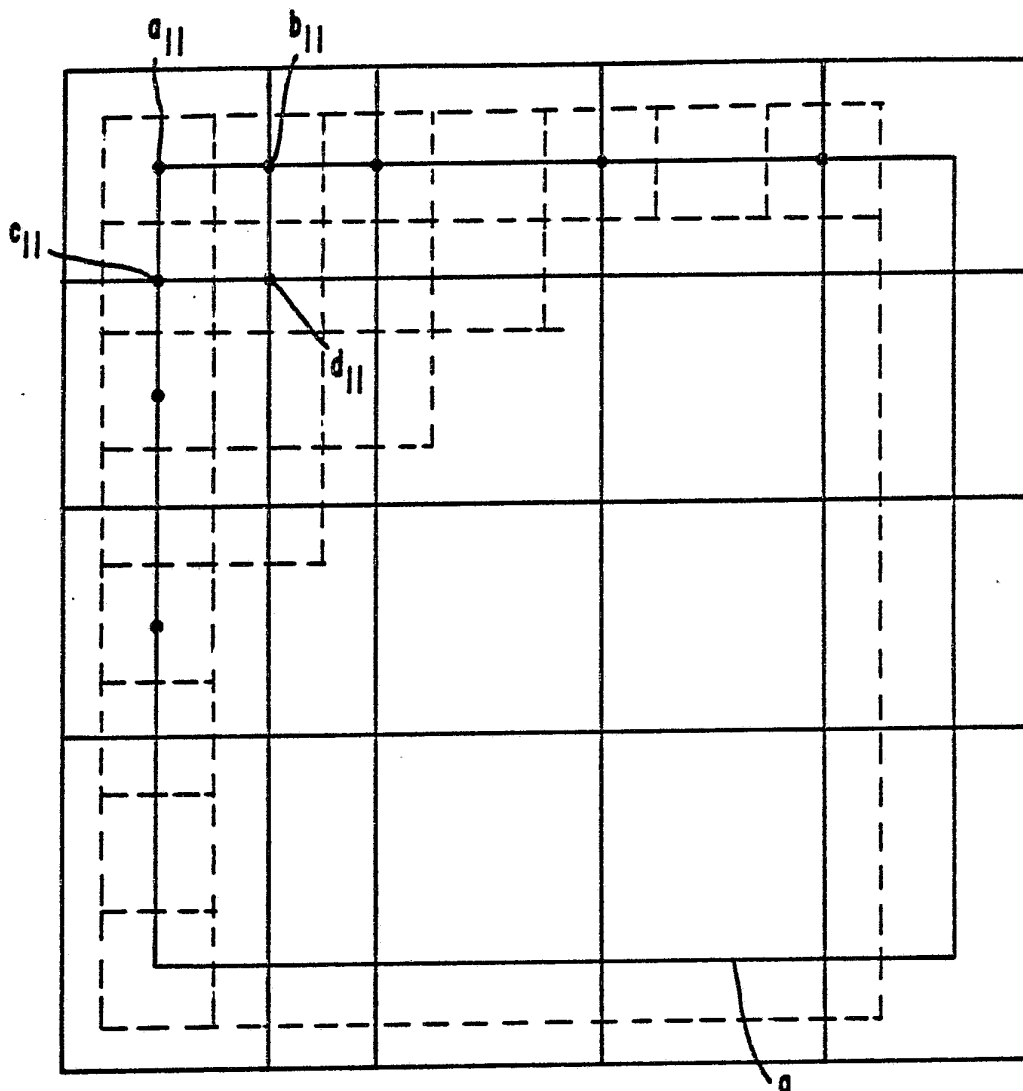


Fig. 2c.

Fig. 5.

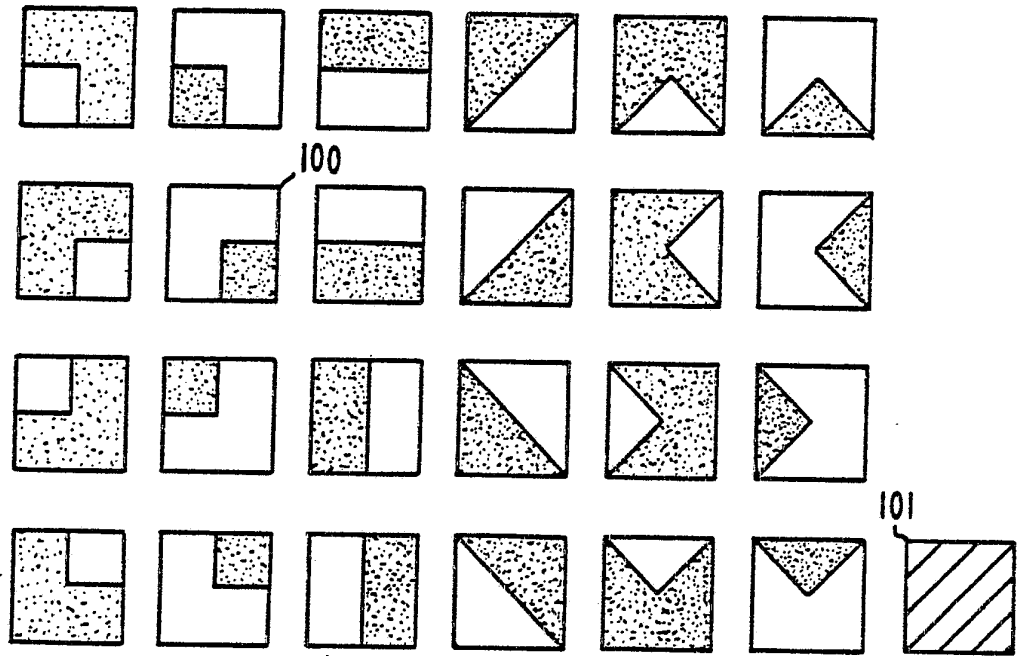


Fig. 3.

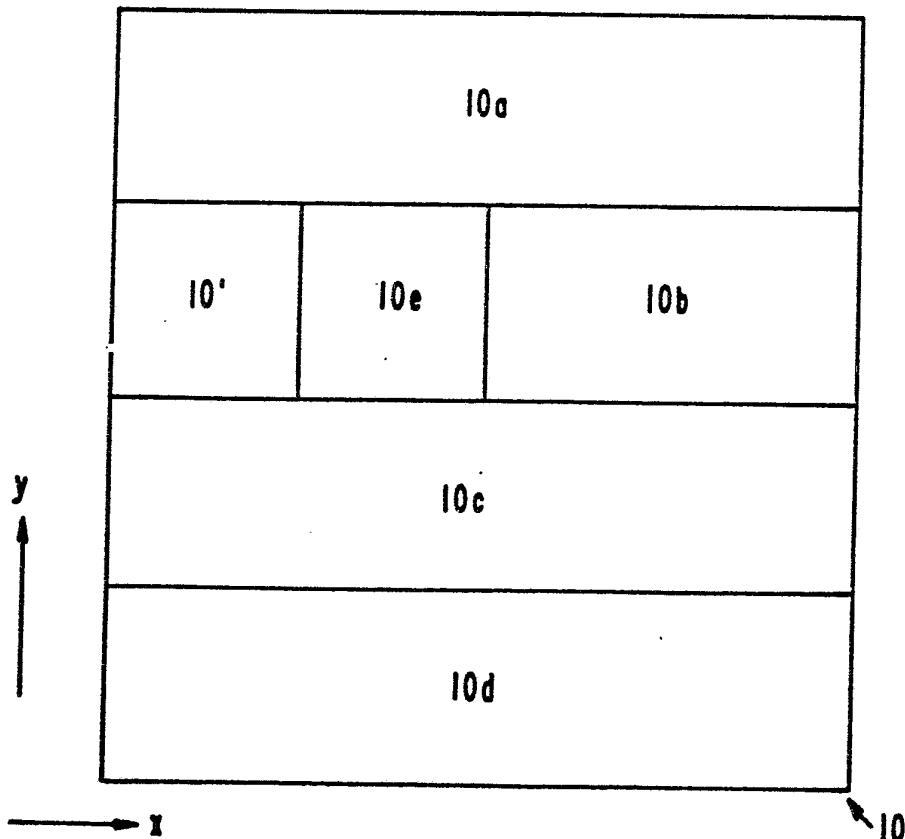
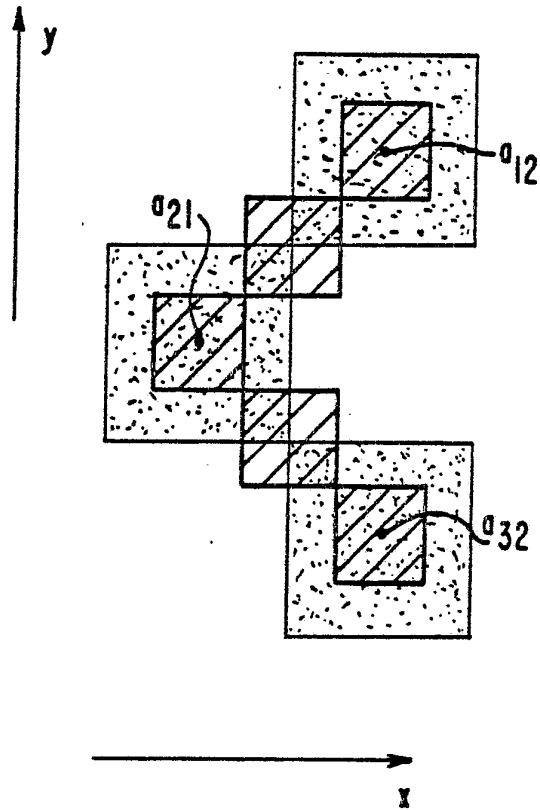


Fig. 4.



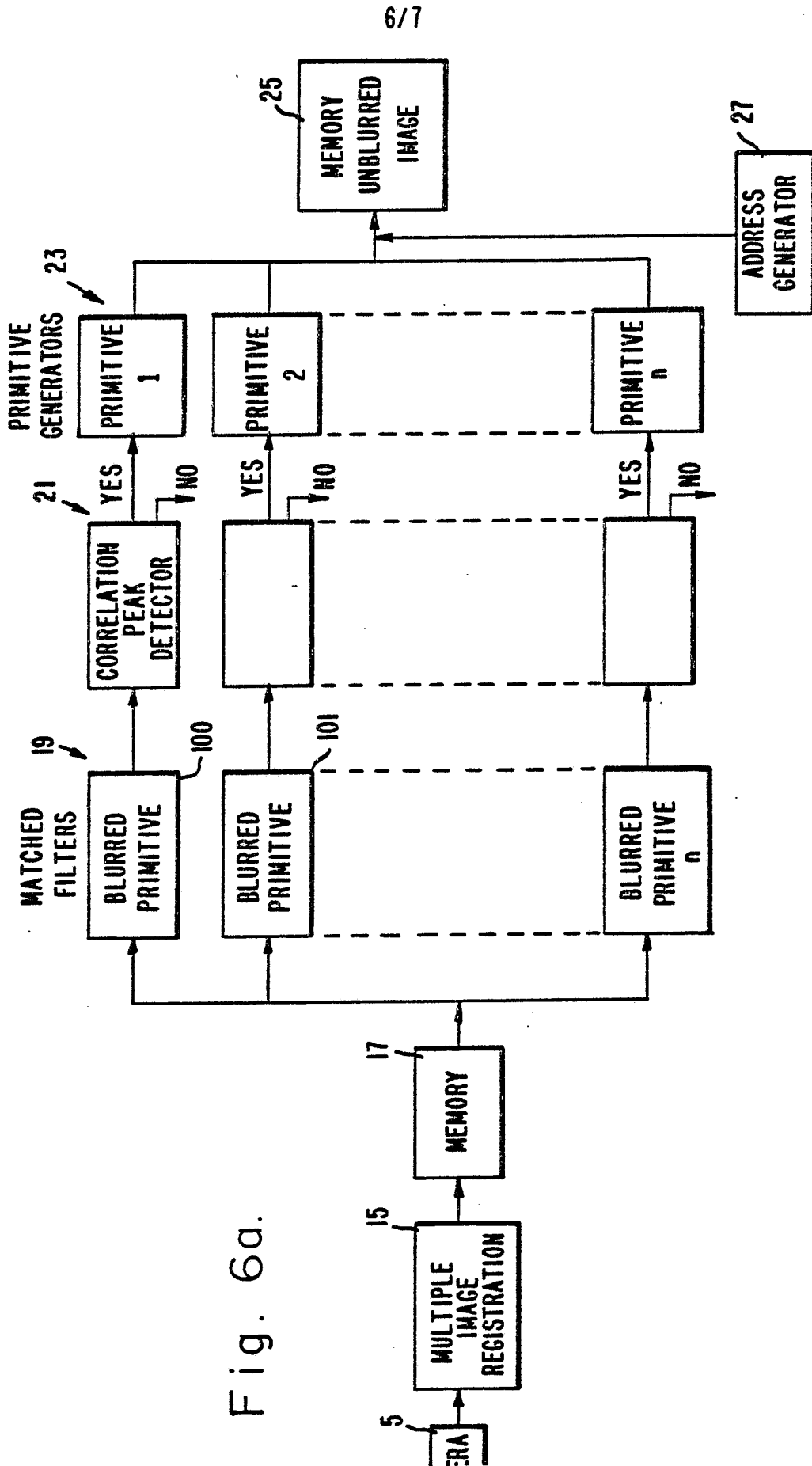


Fig. 6a.

Fig. 6b.

