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SOME VISION ALGORITHMS

Final Report

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Johnson Space Center

Prepared by:	Gordon G. Johnson
Academic Rank:	Professor
University & Department:	University of Houston Department of Mathematics Houston, Texas 77004

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Branch:	Technology and Applications
JSC Colleague:	Robert Savely
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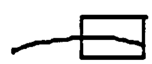
ABSTRACT

The ability to determine the contents of a scene by a machine has obvious applications. There are reasons for seeking hoizontal, vertical and diagonal line segments of varying lengths in order to interpret the content of a scene. Such line segments aid in determining 'edges' that determine the boundaries of objects within the scene. Algorithms for each of the above as well as for data compacting are presented.

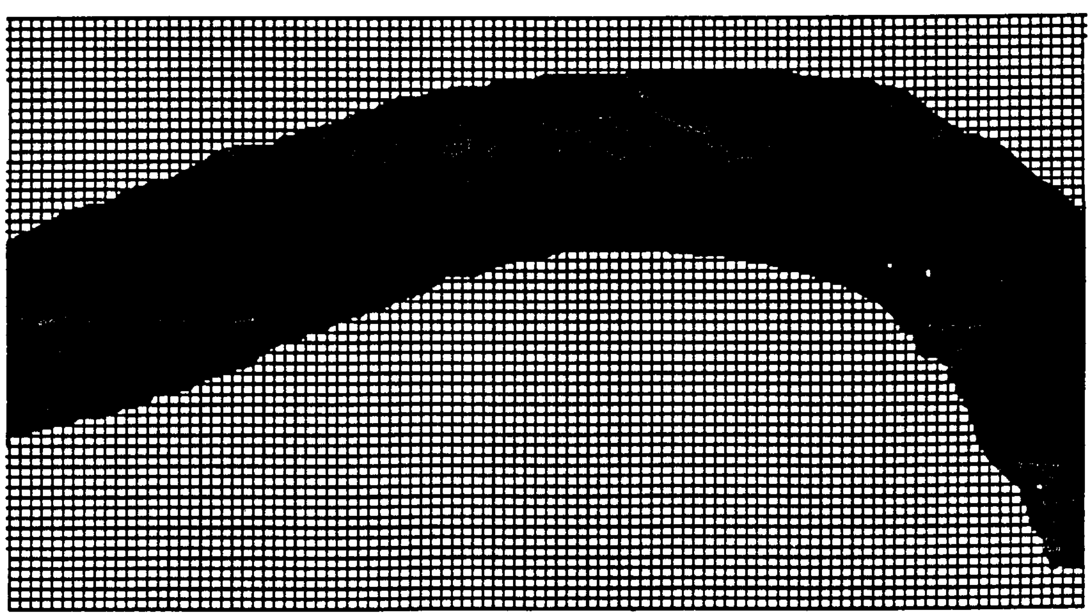
SCENE ANALYSIS

There is, for obvious reasons, an interest in having machines analyze scenes for content. A scene usually contains many objects each having many features. No object can be recognized unless it is already known. This does not mean to imply that the particular object must be known, but rather that the class or classes of objects to which it belongs must be known. The machine then identifies the object as belonging to a class and so indicates. If a significant portion of the scene data set cannot be reconciled with any known data, then the possibility of defining a new object class exists.

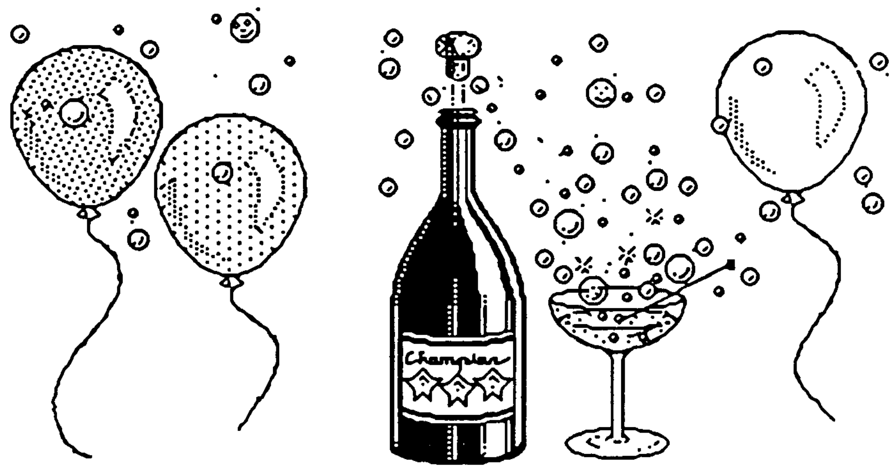
When attempting to process and recognize written letters, a portion of the writing is analyzed at a time, not letter by letter (although this maybe required from time to time when an ambiguity occurs). There is the understanding that the writing, as indicated below, is really studied from a magnified view.



Magnify the above to produce that which is below.

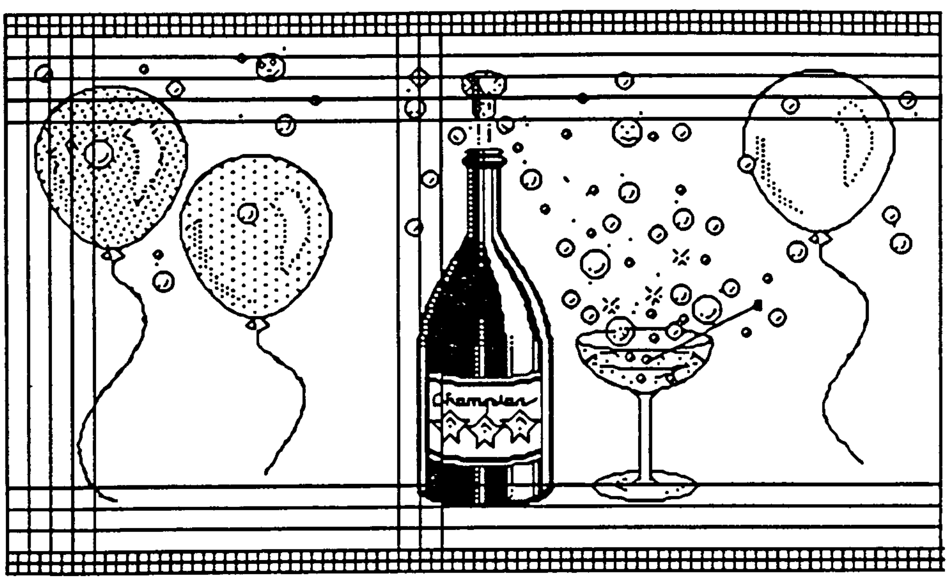


This then is processed by data reduction (explained later), which reduces the data to elementary forms that are then analyzed .



In a complex scene such as the one above, the first task is to identify prominent objects in the scene. This is to be accomplished by first preprocessing of the raw data by data reduction followed by a search for line and edge characteristics. If the nature of the scene is known, then the size of the prominent object or objects normally expected would determine the length of the straight line segments used in the horizontal, vertical and diagonal line searches. On the other hand, if the nature of the scene is unknown, then a standard line length is used, usually one tenth scene height.

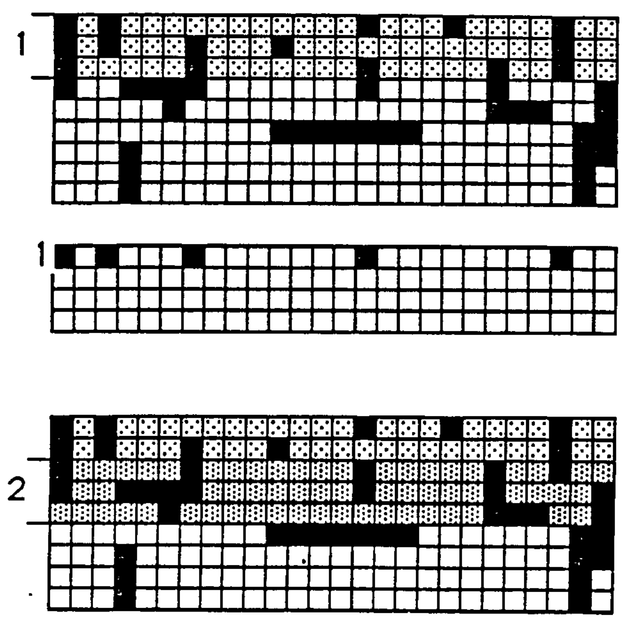
The reduced scene data is first examined for coarse or large figure characteristics formed from line segments. These characteristics allow identification of the classes to which the prominent object or objects in the scene belong.

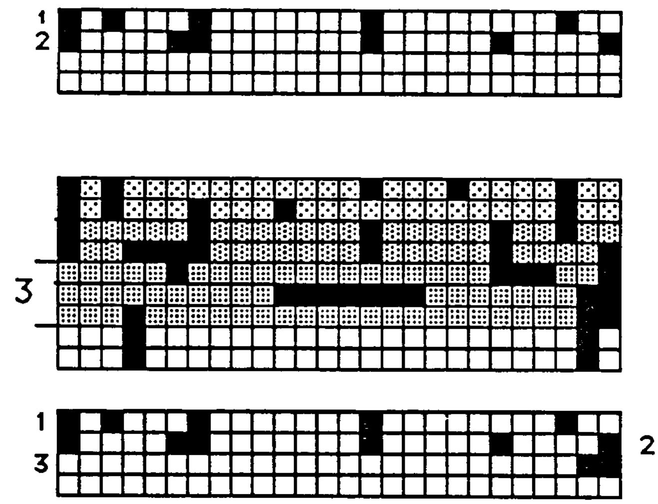


The small object content of an entire scene is expected to be difficult, unless the search is guided by information known about the already identified prominent objects. This information about a particular prominent object would allow the grouping together only thosre smaller objects that could normally be expected to be detected in the region of the particular prominent object. In the event that a significant portion of the data from a region cannot be attributed to any particular object within the restricted grouping, then the analysis is extended to 'out of place' objects.

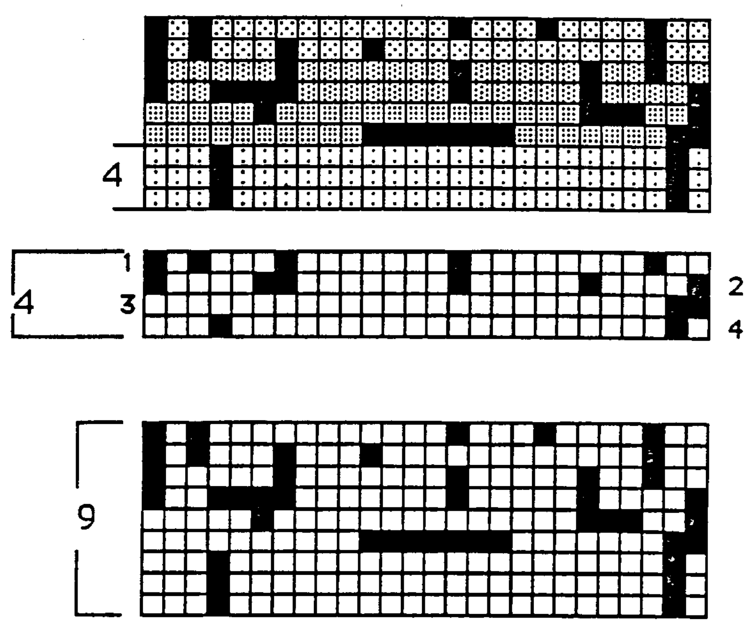
DATA REDUCTION

We now describe how the raw data can be reduced. This reduction reduces the data set by a factor of four. The data is reduced first vertically and then horizontally by considering the top first three rows and determining, in each column of lenght three, if two or more squares are black, in which case a black is saved, else a white. After completing the above for each column, the rows three through five are processed in the same manner. Note that there is a overlap of one row with the first three rows





We are now at the last stage in the vertical portion of the reduction.



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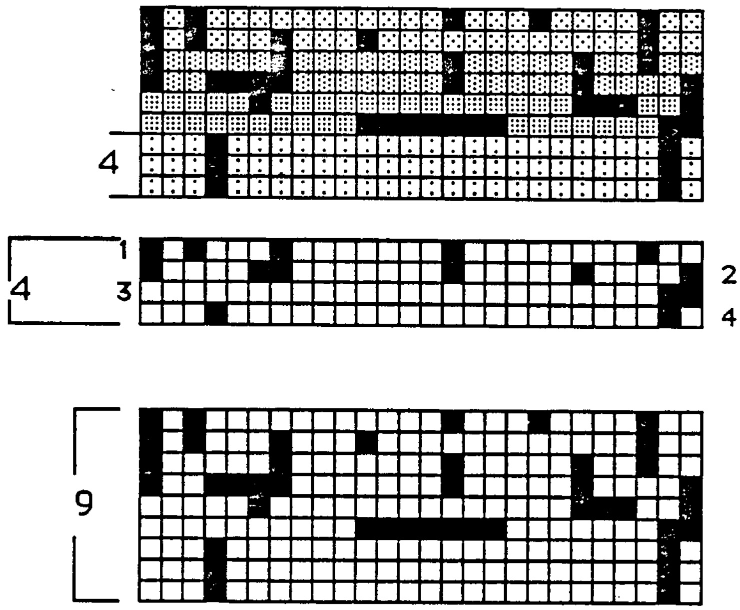
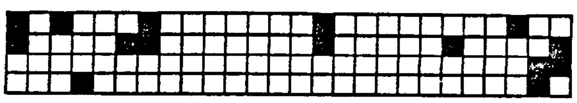
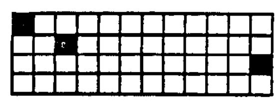


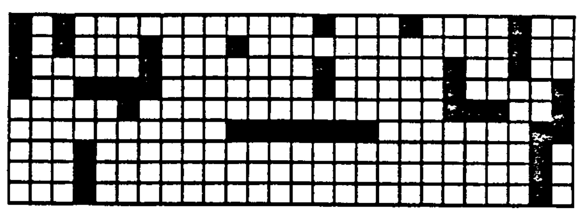
The last figure is the original data set and the figure immediately above is the data reduced vertically.

Below we complete the process by the horizontal reduction.





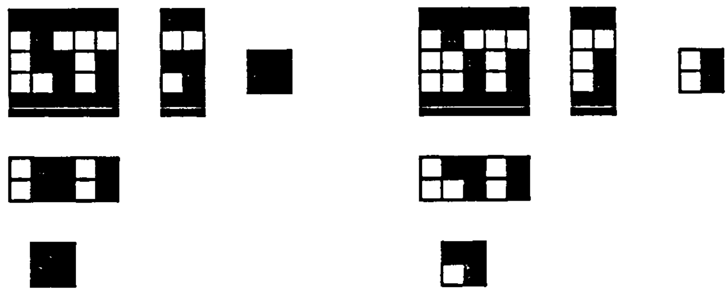
final reduced data



original data set

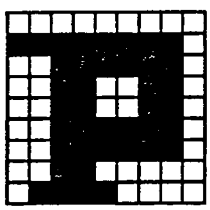
Below are several more examples, where the vertical reduction is followed by the horizontal reduction resulting in the final reduced data set.

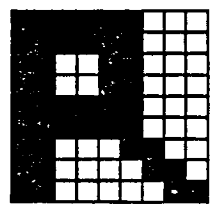
5x5 5x5



Notice that the order of reduction produces different results in the two examples above.

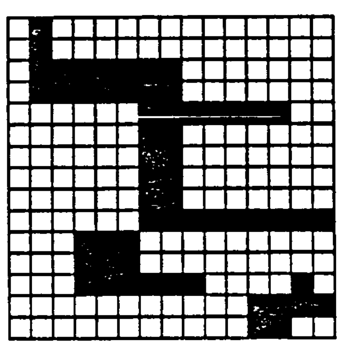
9x9 9x9

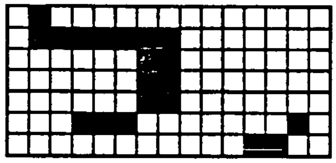




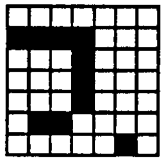
3x3

15x15





7x7

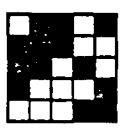


There are other data reduction schemes one of which is in when the first five rows are analyzed looking for three or more blacks in each column, then proceeding to the rows four through eight again looking for three or more in each column. This is continued until the last rows is processed. Notice that this has a two row overlap, as against a one row overlap in the three row case. The three row case results in a reduction by a factor of four while the five row case results in a factor of nine.

The reduction process can be repeated on the reduced set producing a doubly reduced data set.

LINE SEGMENT SEARCH

We now turn to the analysis for determining line segments contained within the reduced data. Data is usually in the form of a square matrix. We create two matrices that we shall use to determine hoizontal, vertical and diagonal line segments contained in the data.



Original or reduced data

$$D = \begin{bmatrix} 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

Matrix for horizontal line segment search of length three.

(Data matrix is to be on the left)

$$H = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$

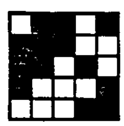
The computation is DxH = HS1, where HS1 is the matrix with the raw horizontal line segment data. We now decide a minimum cutoff value. When this is determined, then the final horizontal line segment matrix is HS.

$$DH = \begin{bmatrix} 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$

$$HS1 = \begin{bmatrix} 2 & 2 & 2 \\ 3 & 2 & 1 \\ 2 & 2 & 1 \\ 0 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$$

If the cutoff value is three, then we have the matrix below.

$$HS = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$



Notice that there is a 1 in the first position in the second row in HS which corresponds to the three black dots in a row in the data grid.

If the cutoff value is two, then we have the matrix below.

$$HS = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

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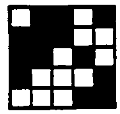
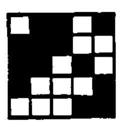
Notice that, when broken into blocks of three, that the three ones in the first row of HS correspond to the first row in the data grid, the two ones in the second row correspond to the three black dots of the second row and so forth.



Matrix for vertical line segment search of length three.
(Data matrix is to be on the right)

$$V = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 \end{bmatrix}$$

The inital vertical line segment computation is VxD =VS1 that contains the raw vertical line segment data. Again a minimum cutoff value is to be decided. Once this minumum is decided, then the final vertical line matrix is VS.



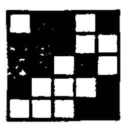
$$VXD = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

$$VS1 = \begin{bmatrix} 2 & 3 & 2 & 1 & 1 \\ 3 & 2 & 1 & 1 & 1 \\ 2 & 1 & 0 & 2 & 2 \end{bmatrix}$$

If the cutoff value is three, then we have the vertical line matrix below.

$$VS = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Notice the one in the second position of the first row which corresponds to the three vertical dots in the second column of the data grid, and the one in the first position of the second row which corresponds to the three vertical dots in the first column of the data grid.

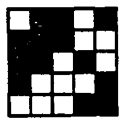


$$VS1 = \begin{bmatrix} 2 & 3 & 2 & 1 & 1 \\ 3 & 2 & 1 & 1 & 1 \\ 2 & 1 & 0 & 2 & 2 \end{bmatrix}$$

The first column in VS1 corresponds to the first column in the data grid. Recall that there is an overlap of two between each pair of of the rows in the V matrix.

If the cutoff value is two, then we have the vertical line matrix below.

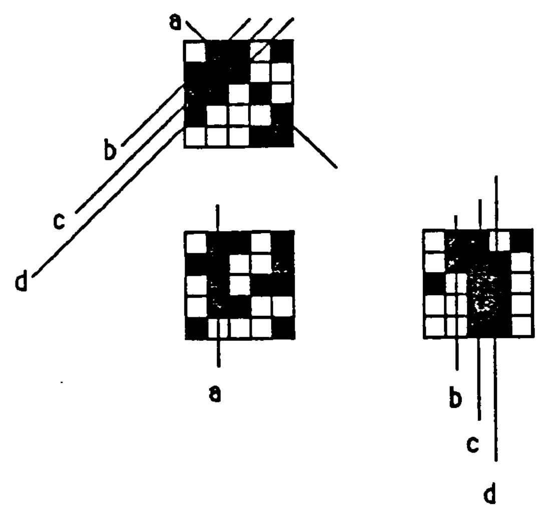
$$VS = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 1 \end{bmatrix}$$

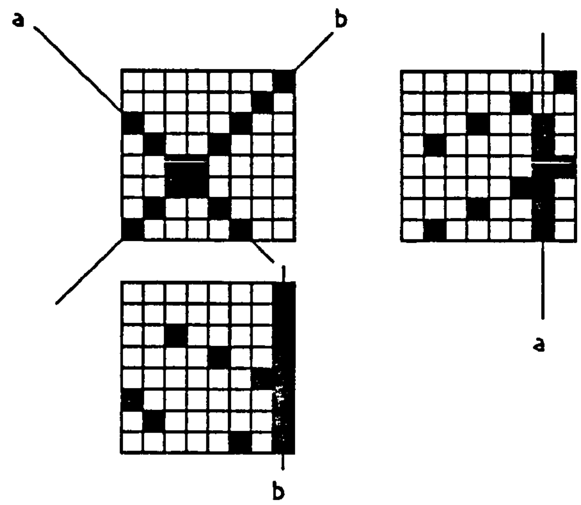


DIAGONAL LINE SEGMENTS

To search for diagonal line segments sloping down from top to the right, we index the second row one to left, third row two to left, etc. and then apply vertical lineseeker.

To search for diagonal line segments sloping from bottom up to left, we index second row one to right, third row two to the right, etc. and then apply vertical lineseeker.





There is may be some difficulties with data from a 'hazy' scene, i.e., a scene where all outlines are blurred such as would be caused by an out of focus camera, very low lighting levels or fog.

References

Frisby, John P., SEEING, Oxford University Press, New York, NY (1980)

Luckiesh, M., VISUAL ILLUSIONS, Dover Pub., New York, NY (1965)