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Purdue University

DIGITAL PICTURE QUALITY ENHANCEMENT EXPERIMENT

by

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The primary visual scanner data representation used at LARS is a computer line printer pictorial printout which uses an alphabetic, a numeric, or a special character to reproduce a gray-scale spot in the scanner line. The pictorial printout program creates a digital picture on the printer which closely resembles a black and white photograph of the area scanned. The question asked in the work described in this note is: What is the quality of the digital picture representation compared to a photograph of the area in question?

The most frequently used pictorial form is the "single width" printout which represents the scanner imagery by 110 gray-scale points per line. The LARS A/D system presently samples the scanner data at the equivalent of every 6 milliradians of scanner rotation. The 110 point printout uses every other of these samples, thus the angular resolution represented is 12 m-rad. A "double width" printout can be produced by taking each sample available, thus a 6 m-rad picture can be printed.

A considerable amount of work has been done by the LARS data handling staff to improve the pictorial printout program. The quality of the printer picture is dependent on the method of relating a data value to a gray-scale level and on the choice of printer character to be used for each level. The DH staff has studied the gray-scale level value of all the characters available on the printer and has in the past two years selected a steadily improving set. A level selection method was developed

which computes a histogram of a selected area of imagery and uses this data to assign gray levels to data values on an equal likelihood basis. The pictorial printouts produced by this optimized program are of good quality; however, much work must still be done to further improve image quality. Research results in this area will apply both to printer output as well as digital display imagery.

An experiment was carried out, which is described herein, in which a visual comparison was made between photographed pictorial printouts having different resolution values. A question has been asked regarding the improvement which would be achieved if the scanner imagery were digitized at twice the present rate. Modifications in the present data conversion system would have to be made in order to do this. To get a preliminary immediate answer, the decision was made to generate a data storage tape having twice the present samples per line by interpolation on the existing samples. This was carried out for data from the 1968 PF21 flight line.

The interpolation scheme employed is simple linear interpolation. An approximate sample, which is the average of the two adjacent ones, is inserted between each present sample.

$$y_{2i-1} = x_i \qquad i = 1,\text{NPTS}$$

$$y_{2i} = \frac{x_{i+1} + x_i}{2} \qquad i = 1,\text{NPTS}$$

where: x_i are the sample values in the input line $i = 1,\text{NPTS}$

y_j are the samples in the interpolated line $j = 1,2\cdot\text{NPTS}-1$

NPTS is the number of points in the input line.

Also an interpolated line is inserted between each existing line. In this line, each point is the average of the points in the same column in the preceeding and succeeding lines interpolated from the input tape. Every odd point in this estimated line is the average of two actual input points. The even points, however, are interpolated from two points which were interpolated from two actual line points so are the average of four real points, that is;

$$y_{ij} = \frac{y_{i+1,j} + y_{i-1,j}}{2} \qquad \begin{matrix} j = 1,2 \cdot NPTS-1 \\ i = 2,4,6,\cdots \end{matrix}$$

where: y_{ij} is the data value for the ith line and jth column.

Obviously line i+1 must be computed before line i can be computed. The even points have estimated values in terms of the inputs:

$$y_{2i,2j} = \frac{x_{i+1,j+1} + x_{i+1,j} + x_{i,j+1} + x_{i,j}}{4} \qquad \begin{matrix} j = 1,NPTS \\ i = 1,2,\cdots \end{matrix}$$

In order to maintain compatibility with the existing LARS data storage tape format, the output tape was written in half line records. The first record is the left half of the double length version of the original first line. The second record is the right half of this line. The third record is the left half of the line formed by interpolation of the first and second double length lines from the input tape. The fourth is the right half of this line. This sequence is continued to the last input line. Four output records are produced for each input record.

A data tape was written in this manner and the pictorial printouts made of the 440 samples per line blown-up flight line. A double width, 220 sample printout was also made for comparison. These printouts were

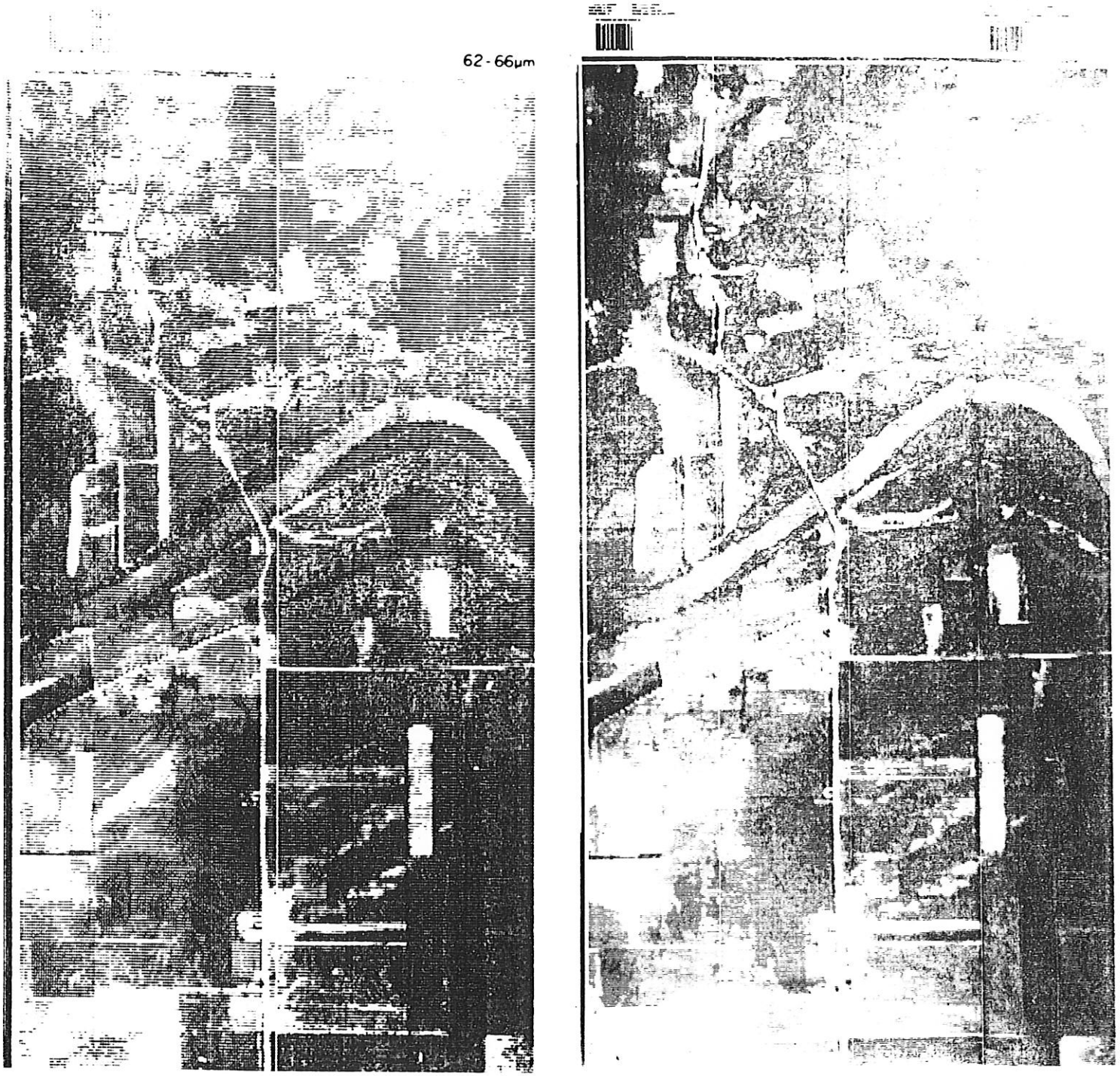
photographed and prints were made such that both printouts were the same size. The double width printout is pictured on the left side of Figure 1 and the interpolated 440 samples per line printout is on the right.

At first glance the 220 point picture appears to have sharper definition. A second look, however, reveals the fact that the computer print characters are still clearly visible in the 220 point version whereas in the blow-up (blow-up will refer to the 440 point version) they are almost invisible. The character visibility is one of the major picture quality problems and the 440 point printout effectively eliminates this annoyance. The second big problem is gray-scale resolution and it appears that the blow-up improves this situation also. The shades of gray have smoother transitions from black to white. The tone and texture of the gray values are much better in the blow-up and it resembles the tone of an actual photograph more closely. The blow-up also shows variations within fields better than the 220 point printout. In general, borders are much more clearly identifiable in the blow-up. This is true at several points in the picture. Note the two narrow rectangular parallel fields in the bottom right part of the upper half picture (Figure 1a). In the 220 point printout it is very difficult to see any border between the two, whereas in the 440 point version, a clear difference in gray level can be seen and the border is clear along most of the length of the field. The full impact of increased resolution cannot be judged by a brief look at a comparison photo. More work must be done in this area and a broader evaluation of the benefits made.

The value of any improvement in digital picture quality depends on what the reproduction is going to be used for. For most illustrations of fields already outlined for reports and other analysis displays the double or single width resolution may be adequate. There are situations,

however, in which higher resolution would be desirable. Identification of ground areas in new data, and training and test field selection would be cases where higher resolution would be welcomed by researchers. The results of the above comparison tend to indicate that the 440 point version offers significant improvement both for data selection (borders are clearer) and for gray-level resolution (seeing variations within a field). For the PF21 flight line the flight altitude was 5,000 feet so the 6 mr 220 picture has a resolution element around 30 feet. The 440 point picture has an effective resolution of 15 feet. It must be remembered that this experiment is a simulation of 3 mr sampling and actual sampling at this rate should give even better results. The opportunity would exist to blow up a true 3 mr picture to 1.5 mr which would give an effective resolution element of 7.5 feet for PF21.

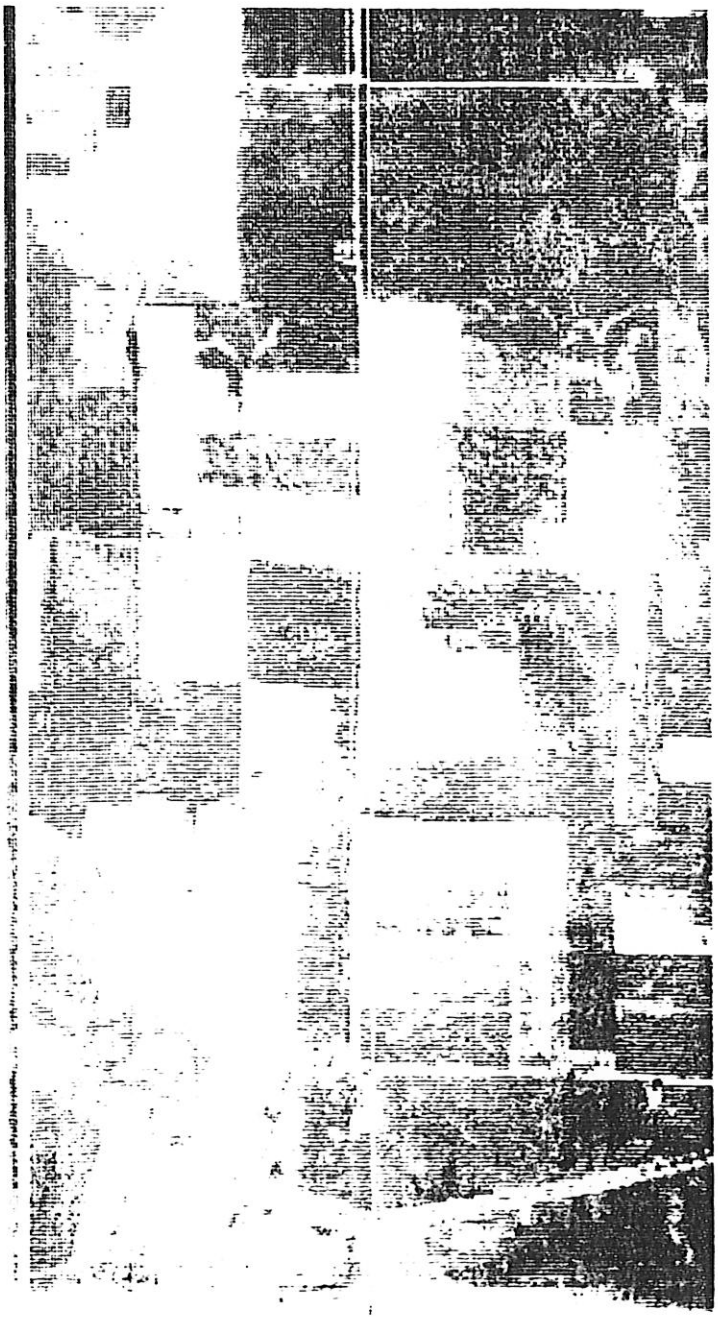
Appreciation is extended to Mr. Jack Halsema who carried out all the photographic work for this comparison. Composing, photographing, and printing computer printouts of the size produced by the blow-up process is a tedious job and requires considerable skill to achieve even illumination and focus.



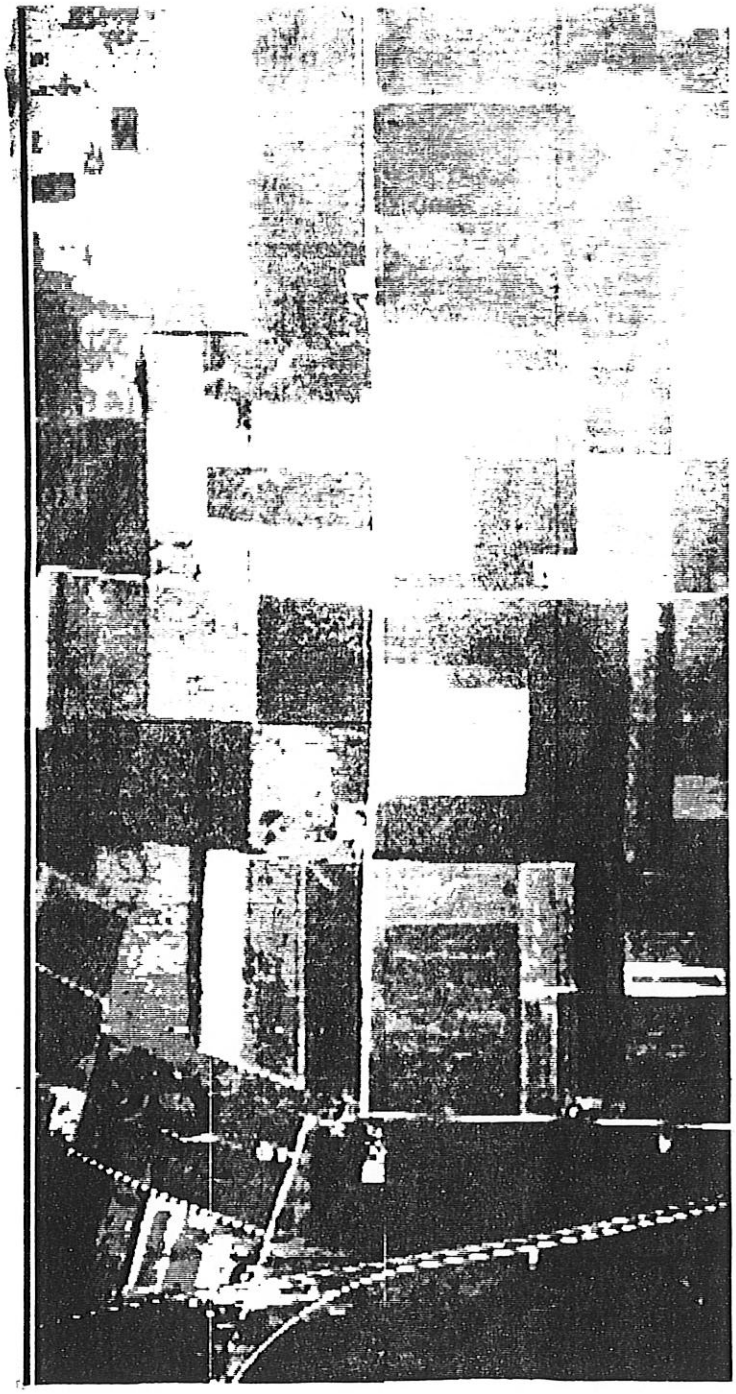
Double width printout
(220 points/line)

Interpolated printout
(440 points/line)

Figure 1a. Pictorial printout comparison
Upper half of flight line PF21



Double width printout
(220 points/line)



Interpolated printout
(440 points/line)

Figure 1b. Pictorial printout comparison
Lower half of flight line PF21