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AUTOMATIC SEGMENT SHIFTER STUDY

BY

GEORGE MAY AND NED JONES

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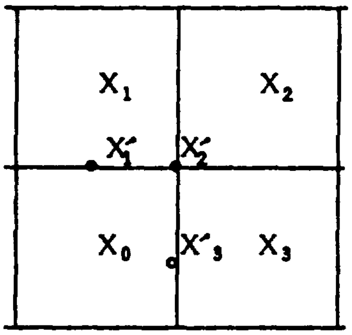
Background

One of the tasks in preparing Landsat data for analysis is the proper location of the ground-truth data (JES segment) in the Landsat scene. This task, otherwise known as registration, consists of two parts, global registration and precision registration. Methodology used by USDA, SRS is detailed in a paper by Paul W. Cook (1). In global registration, Landsat row-and-column coordinates are matched with map latitude-and-longitude. A regression equation is estimated to convert from [latitude longitude] to [row, column] and vice versa. Global registration gives approximate locations of segments in the scene ($\pm$ 5 rows and $\pm$ 5 columns).

Precision registration is an exact alignment of the segment and the Landsat data. This step utilizes a greyscale and plot corresponding to each segment. A greyscale is a computer generated representation of one channel of Landsat data. Different levels of reflectance are represented by levels of grey ranging from black to white. The greyscale locations are calculated from the global-registration function, and the greyscale edges correspond to a border of 20 pixels about the segment. The segment plot is drawn at the same scale as the greyscale. The segment plot is moved over the greyscale until the best match of segment field patterns and grey levels is found. The difference between this best match location and the global registration location is referred to as the segment shift. The shift is recorded as [$\pm$ rows, $\pm$ columns]. The sign indicates the direction of the shift. This allows the analyst to extract the exact window--that is, box of pixels,--containing the segment's Landsat data.

To assist with segment shifting, the Automatic Segment Matching Algorithm (ASMA) was developed by Graham of NASA/NSTL (2). The algorithm compares segment boundaries with pixel reflectance to find the maximum difference in reflectance which coincides with the segment boundaries.

The difference in reflectance is actually measured by using an edge enhancement technique on the Landsat data. The window coordinates in the Landsat data are determined by global registration. The search windows for each segment in the Landsat data is taken to be 5 rows and 5 columns more than each maximum and 5 rows and 5 columns less than each minimum. For each segment search window a 2 by 2 sliding window is moved through the data. The gradient values based on the diagram and equations below are computed as



$$x_1' = \frac{|X_0 - X_1|}{2}$$

$$x_2' = \sqrt{\left(\frac{X_0 - X_2}{2}\right)^2 + \left(\frac{X_1 - X_3}{2}\right)^2} \text{, and}$$

$$x_3' = \frac{|X_0 - X_3|}{2}$$

Where X_0, X_1, X_2, and X_3 are the observed Landsat values and X_1', X_2' and X_2' are the new guadient values.

These value are computed in bands 2 and 4 and added to determine the difference in reflectance for each X'_i (i = 1, 2, 3). The maximum total value is set to 10 because the intent of the edge enhancement is to use relative values to determine if a pixel is different from its neighbor. After each X'_i (i = 1, 2, 3) is computed for the 2 by 2 window, the window is move one column to the right and the process is repeated. After all columns are covered for the two rows, the window is moved down one row and the process is repeated for the next pair of rows. This process continues until the segment search window has been covered. The output values of the sliding window occur at Landsat half rows and half columns and the resulting output array initially has "holes" in it where no output values are determined. The holes are filled by averaging the eight (five at the file edges) neighboring values.

The segment is reconstructed at half Landsat row and column intervals by rounding the computed coordinates to the nearest half row and column. The segment is reconstructed as an array where 1's represent boundary points, 0's represent points outside the segment and USDA/SRS assigned field numbers represent each field within the segment. For the technique used in this algorithm, boundary points are defined as points that touch any line connecting two vertices. Any 1/4 Landsat pixel that touches the line connecting two vertices is assigned a boundary value of 1. For the boundary matching part of the algorithm, the field numbers are ignored. The field numbers are used for the second stage test of within field dispersion.

The reconstructed segment array, containing 1's for boundaries and 0's elsewhere (field numbers are also taken to be 0 for this part of the algorithm) is referenced to the edge array (containing the differences in reflectance X_i (i = 1, 2, 3) by the global registration. The edge array is multiplied by the segment array and the results are summed. This sum shall be referred to as a "shift sum". The segment array is then shifted in half column and half row increments computing the shift sum of the segment array, edge array products for each shift.

Standardized shift sums, s_{ij} are calculated for each i column and j row shift. The standardized shift sums are determined using the following equation:

$$s_{ij} \text{ (Standardized shift sum)} = \frac{\text{(shift sum) - (mean shift sums for the segment}}{\text{(standard deviation of the shift sums for the segment)}}$$

If a shift has a negative standardized shift sum, the standardized value is set to zero, because they represent minimum matching between the segment boundary pattern and the Landsat data. The largest sum represents the shift with the best defined edges in term of the segment boundaries. This shift is taken as the best match in the first stage.

The standardized value of the shift sum from the first stage determines the next step. If the standardized value is less than 2.0, the segment is thrown out, because there is not enough difference in reflectance for ASMA to predict a shift. If the standardized value is greater than 3.4 the associated shift becomes the ASMA predicted shift. If the standardized value is greater than 2.0 and not greater than 3.4 the segment goes into second stage processing.

The second stage test examines the homogeneity within the segment field boundaries. The algorithm uses the edge array to calculate a measure of within field variability for each shift. Basically, the gradient values of the edge array represent how similar adacent pixels are. The sum of squared gradients within each field is taken as a measure of homogeneity. The test is calculated as follows:

Let g_{ij_k} = gradient value for pixel i j in field k.

$$d_k = \sum_{ij} \frac{g_{ijk}}{n}$$

dispersion for field k, where n is the number of non-boder pixel in field k.

$$d_{s_{ij}} = \sum_k d_k \quad \text{dispersion value for shift } s_{ij}$$

The second stage test uses the following statistic to determine which shift to select

$$V = \underset{L}{MAX} \left[\frac{s}{d_{s_{ij}}} \right]$$

The ratio of the s, standard shift sum from the first stage to the d_s value is maximized. This value gives the shift with the largest gradient along the boundaries, relative to the dispersion within the boundaries. The set L is the set of shifts from the first stage which had standardized values in the 2.0-3.4 range. The shift with the value V is chosen as the second stage shift.

A final acceptance test of the second stage shifts is based on the assumption that the accepted first stage shifts make up a sample of reliable shift values. By constructing a confidence interval around the mean accepted first stage shift an acceptance region is established for the second stage shifts. The current test is to accept the second stage shift if both the row and column value are within:

$$\overline{Y} \pm 1.7 \ \hat{\sigma}_Y$$

where $\overline{Y}$ is the mean shift from the 1st stage test and $\hat{\sigma}_Y$ is the standard deviation.

Comparing ASMA and Manual Shifts

In the Missouri analysis the authors compared manual and ASMA shifts in order to characterize ASMA performance. Most of the SRS analysts using ASMA felt it was unreliable and needed to be evaluated further than the testing performed by Kalcic of NASA/NSTL [3].

The authors developed a data set for evaluating ASMA from the 418 Missouri segments. Each segment was shifted manually and then processed through ASMA. The manual shift was compared with the ASMA shift for each segment and one of the two shifts was selected as a final shift. The data set for evaluating ASMA contained the following information:

segment identifier
stratum identifier
manual row shift
manual column shift
ASMA row-shift
ASMA column shift
ASMA shift limits indicator
shift accepted (ASMA or manual)

The ASMA shift limits indicator, indicates whether ASMA could shift the segment. Also each shift pair was analyzed as a vector by applying the Pythagorean theorem to the row and column shifts to determine a shift magnitude. The difference between the ASMA row shift and the manual row shift for each segment was also examined. A similar difference was calculated for the column shifts.

The resulting magnitude of the difference vector was calculated from these row and column differences. Formulas for these variables are as follows.

R_m = manual row shift

C_m = manual column shift

R_a = ASMA row shift

C_a = ASMA column shift

Magnitude

Manual

$$M_m = [(R_m)^2 + (C_m)^2]^{\frac{1}{2}}$$

ASMA

$$M_a = [(R_a)^2 + (C_a)^2]^{\frac{1}{2}}$$

Difference

Row

$$D_r = R_m - R_a$$

Column

$$D_c = C_m - C_a$$

Magnitude of the Difference

$$M_o = [(D_r)^2 + (D_c)^2]^{\frac{1}{2}}$$

The shifts for the 418 segments are summarized in Table (1). There were 266 segments for which ASMA predicted a shift, and the shift was either a first stage shift, or a second stage shift that was within the ASMA limits. These segments will be referred to as "IN". "OUT" will refer to the 152 segments for which the ASMA shift was unreliable as deemed by ASMA or there was not enough difference in reflectance for ASMA to predict a shift. Ten segments fell into the latter group, ASMA did not predict shifts because there was to little difference in reflectance.

The final accepted shifts are also summarized in table (1). ASMA predicted the final accepted shift for 217 of the segments or 52% of the time. The manual shift was the final accepted shift for the remaining 201 segments. For the 266 IN segments ASMA was the final accepted shift for 189 of the segments or 71% of the IN segments. This amounted to 45% of the total 418 segments. The manual shift was the final accepted shift for 77 of the 266 IN segments. When the ASMA shift was OUT, ASMA was the final accepted shift for 28 of the segment and the manual shift was the final shift for 124 of the segments. So the manual shift was the final shift for 82% of the OUT segments. From this information the authors concluded that ASMA was the preferred shift for the IN segments and manual was preferred for the OUT segments; however, this does not indicate whether the differences between the ASMA and the manual shifts was large enough to be meaningful.

Table 2 summarizes shift information by ASMA shift-limit indicator and by final accepted shift. When ASMA was IN and ASMA was the accepted shift there was very little difference between the ASMA shift and the manual shift. The ASMA mean row and column shifts were 2.48 and -1.57 and the manual shifts were 2.38 and -1.74. Furthermore, the mean magnitude of the ASMA and manual shifts

Table 1. Summary of Segment Shifts Missouri 1983

by ASMA acceptance limit and final accepted shift

ASMA Acceptance Limit	Final Accepted Shift		
	ASMA	Manual	Total
"IN"	189*	77	266
"OUT"	28	124**	152**
Total	217	201	418

*includes 37 ties

**includes 10 segments which did not have enough difference in reflectance for ASMA to predict a shift

were 3.57 and 3.58 respectively. The average difference in row shift was -0.10 while the column difference mean was -0.16. The mean magnitude of the difference was 0.58. Both row and column differences and the magnitude of the difference were significantly difference from zero; however, they were small. The mean magnitude of the difference, 0.58, was only slightly larger than the smallest measurable difference in distance, 0.5.

When ASMA was IN but manual was the selected shift, the differences between the ASMA shift and the manual shift were larger than when ASMA was the selected shift. The mean shifts for manual were 2.35 in row and -1.82 in column. ASMA had a row mean of 2.79 and a column mean of -1.36. The mean magnitude of the shifts was 4.06 for ASMA and 3.30 for manual. The mean difference in the row shifts was -0.44 and in the columns -0.47. The mean magnitude of the difference between the ASMA shift and the manual shift was 2.00, which was significantly different from zero. The difference in the row shift was significantly different from zero; however, we were not able to show that the difference between the column shifts was significantly different from zero.

When the ASMA shift was OUT but ASMA was the selected shift there were only slight differences between the ASMA shift and the manual shift. The mean shifts were in row 2.02, in column-1.62 for ASMA and in row 2.14 and in column -1.39 for manual. The mean magnitude was 3.10 for both ASMA and manual. The average difference in row shift was -0.13 and column shift was -0.23. The mean magnitude of the difference between ASMA and manual was 0.67. The difference in the column shifts was significantly different from zero; whereas the row shift difference was not. The mean magnitude of the difference between ASMA and manual was significantly differently from zero, but the difference was small--especially when compared to the smallest measurable distance.

Table 2. Summary of Shift Information by ASMA Shift- Limit Indicator and by Final Accepted Shift, Missouri, 1983, 418 Segments.

ASMA Limit	Final Accepted Shift	Variable	n	Mean	Standard Deviation	Minimum Value	Maximum Value
					(pixels)		
IN	ASMA	manual row shift	189	2.38	1.48	-2.5	6.0
		manual column shift	189	-1.74	1.80	-5.0	4.5
		ASMA row shift	189	2.48	1.47	-3.0	5.0
		ASMA column shift	189	-1.57	1.78	-5.0	4.5
		magnitude manual shift	189	3.58	1.14	0.5	7.8
		magnitude ASMA shift	189	3.57	1.11	0.5	6.7
		difference row shift	189	-0.10	0.49	-1.5	1.5
		difference column shift	189	-0.16	0.46	-1.5	1.5
		magnitude of the difference	189	0.58	0.38	0.0	1.8
IN	MANUAL	manual row shift	77	2.35	1.23	-2.0	5.0
		manual column shift	77	-1.82	1.51	-5.0	2.5
		ASMA row shift	77	2.79	1.83	-3.5	5.0
		ASMA column shift	77	-1.36	2.26	-5.0	5.0
		magnitude manual shift	77	3.30	1.23	0.7	5.7
		magnitude ASMA shift	77	4.06	1.22	1.1	6.4
		difference row shift	77	-0.44	1.51	-4.0	5.0
		difference column shift	77	-0.46	2.22	-8.0	4.0
		magnitude of the difference	77	2.00	1.90	0.0	8.7

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Table 2. con't

MA hit	Final Accepted Shift	Variable	n	Mean	Standard Deviation	Minimum Value	Maximum Value
					(pixels)		
OUT	ASMA	manual row shift	28	2.02	1.35	-0.5	5.0
		manual column shift	28	-1.62	1.48	-3.5	2.5
		ASMA row shift	28	2.14	1.41	-0.5	5.0
		ASMA column shift	28	1.39	1.60	-3.5	2.5
		magnitude manual shift	28	3.10	1.00	1.80	5.4
		magnitude ASMA shift	28	3.10	1.15	1.41	6.1
		difference row shift	28	-0.13	0.46	-1.5	0.5
		difference column shift	28	-0.23	0.59	-1.0	1.5
		magnitude of the difference	28	0.67	0.40	0	1.5
	MANUAL	manual row shift	124	1.94	1.98	-7.0	5.0
		manual column shift	124	-1.41	1.74	-5.0	4.0
		ASMA row shift	114*	-0.25	3.48	-5.0	4.0
		ASMA column shift	114*	0.34	3.33	-5.0	5.0
		magnitude manual shift	124	3.33	1.27	0.0	7.6
		magnitude ASMA shift	114*	4.49	1.44	0.7	7.1
		difference row shift	114*	2.35	3.99	-7.0	9.5
		difference column shift	114*	-1.15	3.77	-8.0	7.5
		magnitude of the difference	114*	5.27	2.99	0.5	10.7

*ASMA did not predict a shift for 10 segments were quite different from the ASMA shifts. The shift means were in row 1.94, and in column -1.41 for manual and in row -0.25, in column -0.34, for ASMA. The mean magnitudes were 3.33 manual and 4.59 ASMA. The mean differences were row 2.35 and column -1.15. The mean magnitude of the difference between the manual shift and the ASMA shift was 5.27. The row difference the column difference and the magnitude of the row column difference were all significantly different from zero.

A further look at the segments ASMA predicted a shift for, the IN segment, seems justified, since these are the shifts used from ASMA in actual practice. When ASMA was the accepted shift, there was very little difference between the ASMA shift and the manual shift. The ASMA shifts were never more than 1.5 rows or columns different from the manual. If manual was considered the standard, ASMA did a very good job of mimicking it for these segments. ASMA did not perform well for all of the IN segments which it would have had predicted shifts.

When manual was the accepted shift there were 20 segments which had row or column shifts more than 1.5 pixels different. Ten of these had row or column differences which were 40 or more. The largest difference was -8.0 in row, -3.5 in column which is about 0.5 of a kilometer different from the manual shift. In any single scene a difference of just a few rows or columns in a couple of segments could decrease the regression estimator precision.

Based on this study the authors recommend that SRS analysts stop using ASMA or always check the predicted shifts unless the reliability of the ASMA shifts can be improved by changing the algorithm. When manual was the accepted shift and ASMA was IN the ASMA shift tended to be larger than the manual shift. This can be seen in Figure (1) which is a plot of the magnitude of the ASMA shift vs. the magnitude of the manual shift most of the observations fall along the 1 to 1 line, but when an observation is very different the majority of these observation fall on the ASMA side of the 1 to 1 line.

ASMA as a Checker

It would appear that the primary use of ASMA would be to use it as a checker of manual shifts. The cost of using ASMA in this manner, however, should be considered. For the 418 segments in this study, the cost was $1519 for 390 CPU minutes. The average costs and average per CPU minute was $3.89 indicates that the majority of the ASMA run were made on the first and second BBN shift with very few run on the third shift. The average c¬sts for various types of segments were as follows:

	Number	Average CPU Minutes	Average Cost
ALL segments	418	.93	$3.63
IN segments	265	1.47	$5.73
IN segments manual within 1.5 pixels of manual shift	246	1.58	$ 6.17

The cost per CPU minute by shift were as follows:

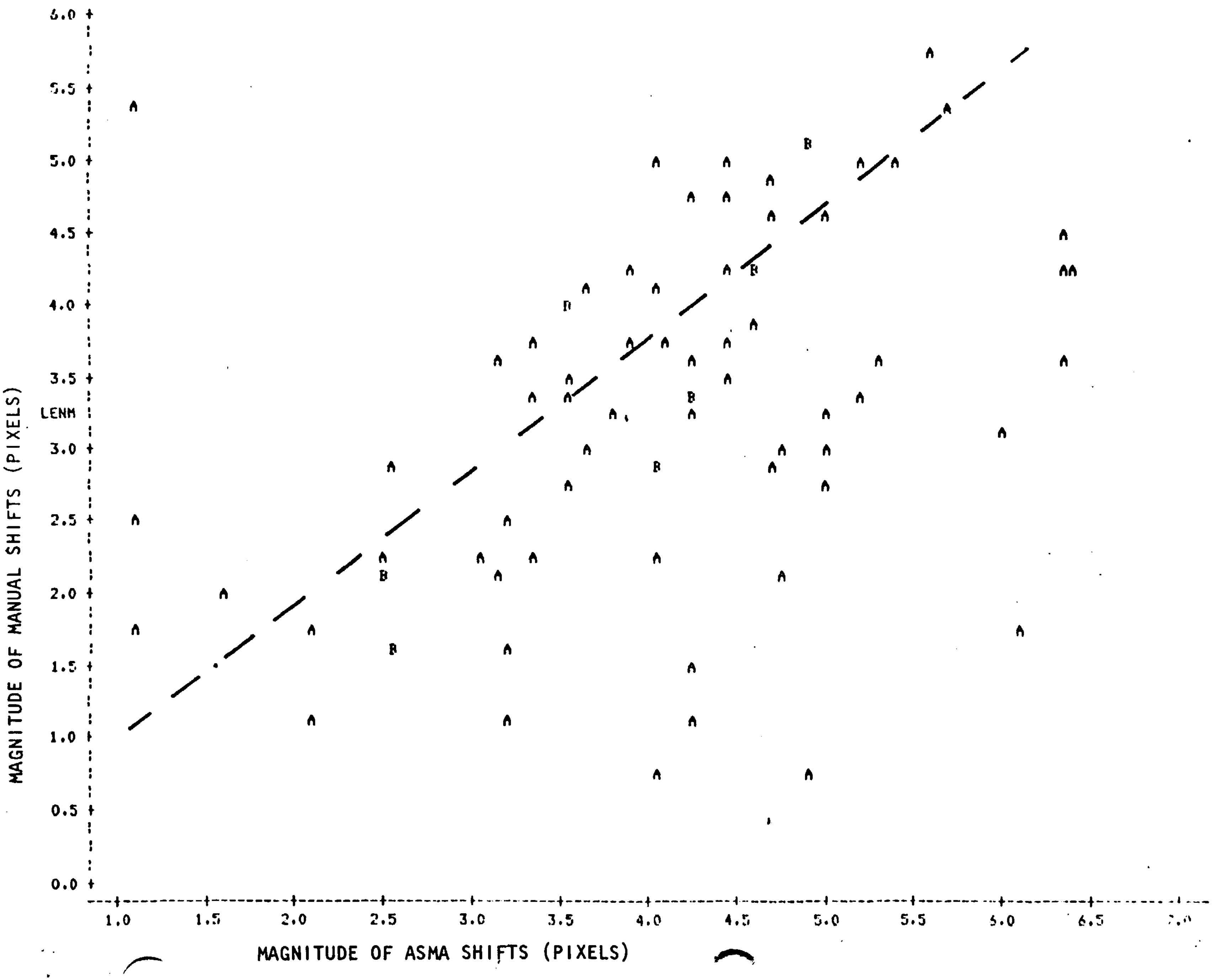
First Shift	Second Shift	Third Shift
5.21	2.61	1.30

So if ASMA could have been run on the third shift the cost per good check would have been $2.06. The hour rate for a person checking 12 segments per hour could be as great as $24 per hour and be cheaper than ASMA.

As an additional note when ASMA is run using a half-pixel mask from video digitation cost fall by about 1/3. The cost of a good check in our example could be as low as $1.37 if video mask were used. Again assuming 12 segments per hour the hourly rate for a person could be as much as $16 per hour and still be less expensive than ASMA.

Until the performance of the ASMA algorithm can be improved by reducing the computer cost, the use of ASMA does not appear to be an efficient use of resources unless ASMA is the only resource available. One possible alternative may be to put ASMA up on the Cray to reduce computer cost.

FIGURE (1) MAGNITUDE OF AN ASMA VS. MANUAL SHIFTS WHEN ASMA PREDICTED A SHIFT BUT MANUAL WAS THE ACCEPTED SHIFT



References

[1] Cook, Paul W., Landsat Registration Methodology Used by U.S. Department of Agriculture's Statistical Reporting Service.

[2] Graham, M. H. AN Alogritham for Automating the Registration of USDA Segment Ground Data to Landsat MSS Data.

[3] Kalcic, M. T., Automation Segment Matching Algoritham Theory, Test and Evaluation.