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ENLARGMENT AND REDUCTION OF REMOTE SENSING IMAGES BY RESAMPLING

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In this paper we present a method of resampling an image for enlargment or reduction of a scene by a given ratio. This rescaling of the scene allows for comparison of scenes with a different instantaneous field of view.

I. INTRODUCTION

Each radiometric instrument for remotely sensed data has a different instantaneous field of view (IFOV), which is varying even for the same type of radiometers. So the spatial sampling (resolution) of a radiometer specifies the number of pixels required to cover a given ground area. In many cases it would be useful to compare the intensity values of the same point of the surface of the earth, measured by two different type (resolution) radiometers, i.e. Landsat MSS, TM or SPOT pixels. A direct comparison is not possible because of the different IFOV, e.g. 30 m × 30 m for tm landsat scenes and 20 m × 20 m for HRV scenes of Spot. Even in the case where radiometers have the same spatial resolution or measured are taken with the same radiometer, measured values do not cover the same surface area, so a displacement is required to a meaningful comparison of scenes. Hence, to compare two scenes it is necessary for these to cover exactly the same surface area sensed with the same spatial resolution. In these cases we use a resampling method for scene transformation. The most know methods of resampling relay on an interpolation algorithm, Shlien [1], Simon [2] and they are referred to as:

1) nearest-neighbour interpolation,
2) bilinear interpolation and
3) cubic convolution interpolation.

In the next paragraph we introduce a new resampling method ([3]), similar to a combination of the forementioned algorithms, which takes into account the pixel size (spatial resolution) and the displacement from a previous radiometric pass. This method transforms a given scene according to a second one and allows the comparison of them. The scenes can be from a different radiometric resolution or from the same radiometer but measured at different times or even at the same time, in which case we get an enlarged or reduced scene by a given ratio.

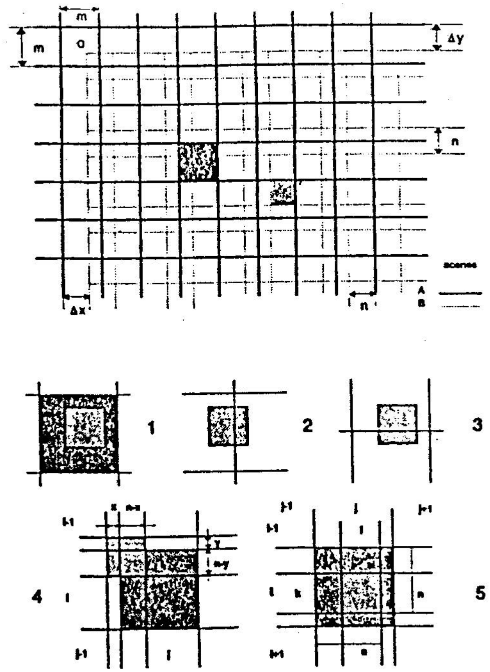

Fig. 1. Relations of pixels on scenes with different IFOV

II. RESAMPLING METHOD

In Fig. 1 we see two scenes with different pixel size (IFOV), which cover a common earth surface area. This area is covered with scene A having pixels with a size of $m \times m$ units and with a scene B having pixels with a size of $n \times n$ units. Pixels of scene A are denoted with solid lines and those of scene B with dotted lines and we have $m > n$. The resampling creates a new scene B using values from the $m \times m$ pixel-sized scene A and having the size of pixels $n \times n$. We observe that pixels of scene B span into pixels of scene a in four different ways, i.e:

1 - Lay as a whole inside a pixel of scene A,
2 - Span into two different pixels of scene A, in the same row,
3 - Span into two different pixels of scene A, in the same column and
4 - Span into four neighbour pixels of scene A, in rows $i-1$, i and columns $j-1$, j

We presume that the scene B has origin in the pixel (0,0) of scene A, otherwise we consider a subscene of A whose pixel (0,0) covers part of the pixel (0,0) of scene B, i.e. pixel (0,0) of scene B spans into pixel (0,0) of scene A. We denote with $p_m(i,j)$ the pixels of scene A, with $p_n(k,l)$ the pixels of scene B and with div and mod the usual integer division quotient and modulus. The forementioned relations are:

1. If $(\Delta x + n * l) \bmod (m) \geq n$ and $(\Delta y + n * k) \bmod (m) \geq n$, then the pixel $p_n(k,l)$ of scene B lays inside pixel $p_m(i,j)$ of scene A.
2. If $(\Delta x + n * l) \bmod (m) \geq n$ and $(\Delta y + n * k) \bmod (m) < n$, then the pixel $p_n(k,l)$ of scene B spans into pixels $p_m(i,j-1)$ and $p_m(i,j)$ of scene A.
3. If $(\Delta x + n * l) \bmod (m) < n$ and $(\Delta y + n * k) \bmod (m) \geq n$, then the pixel $p_n(k,l)$ of scene B spans info pixels $p_m(i-1,j)$ and $p_m(i,j)$ of scene A.
4. If $(\Delta x + n * l) \bmod (m) < n$ and $(\Delta y + n * k) \bmod (m)\hat{X}xn$, then the pixel $p_n(k,l)$ of scene B lies inside pixel $p_m(i-1,j-1)$, $p_m(i-1,j-1)$, $p_m(i-1,j-1)$, and $p_m(i-1,j-1)$ of scene A.

The x span of $p_n(k,l)$ into $p_m(i,j-1)$ is

$$x = (\Delta x + m * j)\mathrm{mod}(n). \tag{1}$$

The y span of $p_n(k,l)$ into $p_m(i-1,j)$ is

$$y = (\Delta y + m * i)\mathrm{mod}(n). \tag{2}$$

for the i and j values of $p_m(i,j)$ we have:

$$j = (\Delta x + n * l)\mathrm{div}(m) + 1 \tag{3}$$

$$i = (\Delta y + n * k)\mathrm{div}(m) + 1. \tag{4}$$

We assume that the gray level value of each pixel $p_n(k,l)$ of matrix B is a mean of gray level values of the pixels $p_m(i,j)$ of matrix A, into which B pixels span or lay, with weights of gray level $p_m(i,j)$ proportional of spans of $p_n(k,l)$ inside them, i.e.:

$$\beta_1 = x * y/m^2 \tag{5a}$$

$$\beta_2 = (n-x) * y/m^2 \tag{5b}$$

$$\beta_3 = x * (n-y)/m^2 \tag{5c}$$

$$\beta_4 = (n-x) * (n-y)/m^2. \tag{5d}$$

We compute the gray level for the general case:

$$\begin{aligned} p_n =& (\beta_1 * p_m(i-1,j-1) + \beta_2 * p_m(i-1,j) + \\ &+ \beta_3 * p_m(i,j-1) + \beta_4 * p_m(i,j))/(\beta_1 + \beta_2 + \beta_3\beta_4) \end{aligned} \tag{6}$$

and after some calculations we have the relation

$$\begin{aligned} p_n(k,l) =& (x * y * p_m(i-1,j-1) + (n-x) * y * p_m(i-1,j) + \\ &+ x * (n-y) * p_m(i,j-1) + (n-x) * (n-y) * p_m(i,j))/n^2 \end{aligned} \tag{7}$$

we have also for the other cases:

1. $p_n(k,l) = p_m(i,j)$ (8)
2. $p_n(k,l) = (x * n * p_m(i,j-1) + (n-x) * n * p_m(i,j))/n^2$ (9)
3. $p_n(k,l) = (y * n * p_m(i-1,j) + (n-y) * n * p_m(i,j))/n^2$. (10)

In case we resample the same scene we achieve

ENLARGEMENT,	**for $m > n$**
DISPLACEMENT,	**for $m = n$**
REDUCTION,	**for $m < n$.**

The relations (1) to (10) hold for $m \geq n$. For $m < n$, these are more complicated and computationally not effective. If we have on mind that for comparison of two scenes, enlargement of the "smaller" scene is the sought goal, i.e. coverage of the scene with greater IFOV with a scene having pixels with a smaller IFOV, then it becomes clear that resampling a scene with $m < n$ is for reduction the only purpose. Reducing a scene has little value and is useful only for presentation of big scenes, impossible to display them in normal monitors. Thus relations holding for $m \geq n$ can be used also for $m < n$, achieving scene reduction, considering thought that the computed gray level values are not precise and have no reliability for further processing.

Consider two scenes covering the same ground area, the first with a spatial resolution of $M \times M$ and IFOV m (pixel size $m \times m$), and the second with a spatial resolution of $N \times N$ and IFOV n (pixel size $n \times n$). Then we have:

$$\begin{aligned} &(M \times m) \times (M \times m) = (N \times n) \times (N \times n), i.e. \\ &M \times m = N \times n \quad \text{or} \quad M/N = n/m. \end{aligned} \tag{11}$$

The relation (11) gives the unknown IFOV n, given that we know the resolution factors M and N and also the IFOV m. Practically we use the ratio m/n.

III. EXAMPLES, REMARKS

Landsat TM scenes in BSQ form ([4]), have a spatial resolution of 3500 × 2945 pixels. It is evident that with the usual nowadays technology it is difficult to display a whole scene. Total memory requirements for a single scene is in the order of 10 MBytes. Usually we process sub-scenes with resolution of 512 × 512 pixels with memory requirements of 256 kBytes per scene. Image 1 displays an original sub-scene inlayed with a reduced one with ratio of $m/n = 1/2$. Image 2 presents an enlargement of a part of the previous scene, with a ratio of $m/n = 5/2$ and origin in pixel (135,291).

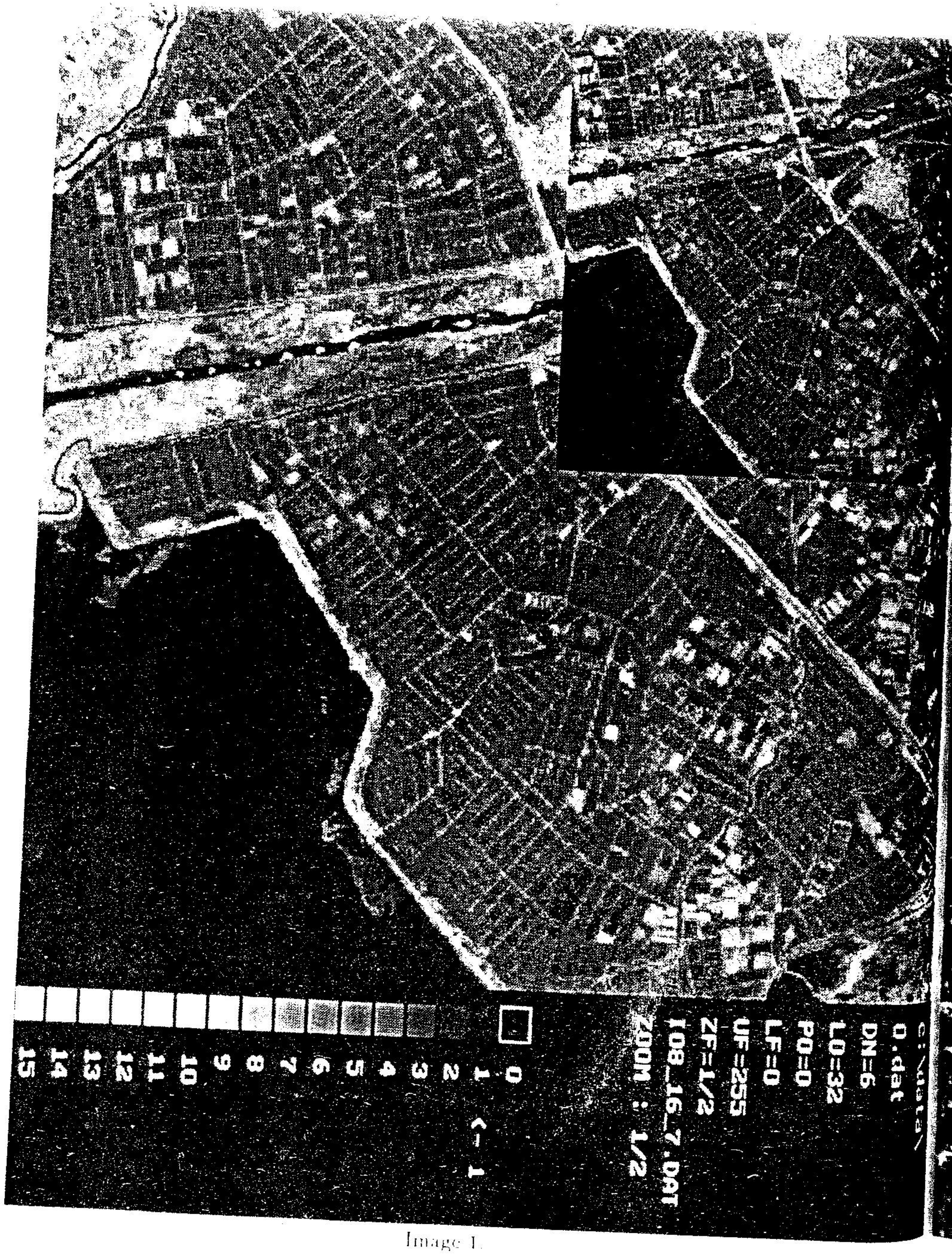

Image 1.

Image 2.

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