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STUDY OF ALGORITHMS FOR RECOGNITION OF PIXEL IMAGE RAPPORTS

G.I. BORZUNOV

(The Moscow State Textile University named after A.N. Kosygin)

Extensive use of information technologies in practical work of decorative design of dobby weave fabric resulted in the fact that original pixel images of woven fabric patterns are most commonly developed by designers in the graphics editor environment or are produced as a result of scanning of hard copies of pictures. These images are to be converted into a type which meets the requirements of the appropriate textile technology [1]. One of the tasks of the above mentioned conversion is recognition of repeatable rectangular fragments (rapports) in pixel images. It is assumed that rapports can apply to the original pattern entirely and have no common areas (overlapping).

Terms and algorithms used in this study are presented as pseudocodes with utilization of C programming language elements. Let us assume that pixel image is presented by means of bidimensional integer array A[m][n]. Furthermore, it is assumed that the width of the original pattern equals to n, and the height to m. Let us consider the integer array R[mr][nr] as a rapport which is a part of the array A[m][n] or is created from a part of the array A[m][n] as a result of processing: for(i=0; i<mr; i++) for(j=0; j<nr; j++) {ia=(id+i)/%m; ja =(jd+j)/%n; R[i][j] = F(A[ia][ja]);}, where F() − processing function, (id, jd) − coordinates of the left upper corner of the area A[m][n], from which rapport R[mr][nr] is formed, "%" − here and further it represents a division operator to obtain the remainder. The width nr can vary from 2 to n/2, and the height mr − from 2 to m/2. The limits of changes of rapport size are based upon the assumption that the pixel images under consideration are not monochrome (rapport is not degenerated into a pixel) and contain, at least, two rapports horizontally and two rapports vertically, one of which can be presented in A[m][n] only partially. The array V[m][n] is called overlapping of the image A[m][n] by rapport pixels R[mr][nr] which is obtained from R[mr][nr] as a result of the fol-

lowing calculations: for(i=0; i<m; i++) for(j=0; j<n; j ++) {if(i>id) ir=(i-id)%mr; else ir=mr-(id-i)%mr; if(j>jd) jr=(j-jd)%nr; else jr=nr-(jd-j)%nr; V[i][j]=R[ir][jr]}.

Let us evaluate the possible rapports by their overlappings of original images by means of W mismatch function: int W(A [m][n], V[m][n]) {int s=0; for(int i=0;i<m;i++) for(int j=0;j<n;j++) {if(A[i][j]<V[i][j]) s+= V[i][j] - A[i][j]; else s+= A[i][j] - V[i][j];} return s;}. Now the task of recognition of a rapport consists in determining the preset original image A[m][n] of the rapport of minimum size R[mr][nr], of such one that W(A[m][n],V[m][n]) → min. Images, for which R[mr][nr] is available are such that W(A[m][n],V[m][n])=0, will be called class 1 images. The second class of images is characterized by the fact that with any variant of R[mr][nr] the value of mismatch function exceeds zero: W(A [m][n],V[m][n])>0. Images of both classes are used in textile design. So, class 1 images are usually obtained as a result of repeat of a certain rapport in the graphics editor environment and are distributed on different storage media or by means of network technologies. The class 1 images are obtained as a result of scanning or by means of digital photographing. In this case, change of color of separate image pixels has a random nature and can be considered as just noise, laid over the true image.

Let us consider possibilities for utilization of full constructive enumeration for determining of class 1 image rapports. For each preset array A[m][n] we will enumerate variants of rapports R[mr][nr] in the order of increasing of their sizes considering the upper left corners A[m][n] and R[mr][nr] as matching ones, and calculating W(A[m][n],V[m][n]) of each R[mr][nr]. The purpose of such enumeration is to define R[mr][nr] for which W(A[m][n],V[m][n]) =0. To speed up the above described constructive enumeration, it is advisable to modify the mismatch functions: int W1(mr, nr, A [m][n]) { int ir, jr; for(int i=0; i<m; i++) for(int j=0; j<n; j++) {ir = i%mr; jr = j%nr; if (A[i][j] ≠ A[ir][jr]) { return 1;} }return 0;}. To enumerate R[mr][nr] in the order of increasing of their sizes, let us apply the variable pr, value of which is equal to the "semiperimeter of the array R[mr][nr]": pr=mr+nr. The pseudocode of the algorithm for determing of class 1 image rapports will then take the form of Rpt1 function: int mr=0, nr=0; /* variables mr, nr − global */ void Rpt1(A[m][n]) {int pr=0, prmax=m/2+n/2; for(pr=4; pr≤prmax; pr++) {mr=2, nr=pr-mr; if(nr>n/2){nr=n/2; mr=pr-nr;} while(mr≤m/2&&nr≥2) { if(W1(mr, nr, A [m][n]) == 0) return; mr++; nr--;}} mr=nr=0; return;}. When after completing Rpt1 the values mr of variables nr are not equal to zero, then R[mr][nr] = A[mr][nr]. With values of mr variables being equal to zero, nr for this A [m][n] does not provide rapport, exact repetition of which is overlapping this image. Without restricting generality of analysis results of time complexity of algorithms under consideration, it can be considered that m = n = K. Then, in worst case, calculation of the mismatch function W1(mr, nr, A [m][n]) will require execution of K^2 cycles, and, correspondingly, time complexity of function evaluation will be equal to: $T1(K)=K^2 \approx O(K^2)$. Call of the mismatch function W1(mr, nr, A [m][n]) is executed in cycle while((mr≤m/2)&&(nr≥2)). It is easy to verify that the mentioned cycle, depending upon the values of pr variable, is repeated the following way: 1, 2, …, K-3. Total number of repetitions of this cycle (recycling) determines its time complexity: $T2(K) = ((K-3)\times(K-2))/2 = (K^2 - 5\times K + 6)/2 \approx O(K^2)$. Consequently, asymptotic estimate of time complexity of Rpt1 algorithm, in the worst case, appears to be equal to $T3(K)= T1(K)\times T2(K) = O(K^4)$. Then, by K=1000, extraction of rapport by means of Rpt1 algorithm, in the worst case, will require about 1 hour time of computation with 10 GHz clock frequency.

Assume that now class 2 image array 2 A[m][n] is defined. As before, we will consider variants of R[mr][nr] rapports in the order of increasing of their sizes (mr, nr). For each variant of combining of values of mr and nr parameters we will consider all possible matches between the upper left corner of rapport and all A[m][n] points computing the value of mismatch function for each such match. The purpose of such enumeration is to define such combination of R[mr][nr] and coordinate values of its upper left corner (id, jd) for which the value of mismatch function appears to be minimum. We will compute the value of V[m][n] array by the following algorithm: for(i=0; i<m; i++) for(j=0; j<n; j ++) {if(i>id) ir=(i-id)%mr; else ir=mr-(id-i)%mr; if(j>jd) jr=(j-jd)%nr; else jr=nr-(jd-j)%nr; V[i][j]=R[ir][jr]}. In order to speed up the above mentioned enumeration of variants, it is advisable to modify the mismatch function as follows below: /*variables int mr, nr id, jd, − global */ long int W2(A [m][n]) {long int s=0; int ir, jr; for(int i=0; i<m; i++) for(int j=0; j<n; j++) {if(i>id) ir=(i-id)%mr; else ir=mr-(id-i)%mr; if(j>jd) jr=(j-jd)%nr; else jr=nr-(jd-j)%nr; if(A[i][j] < A[ir][jr]) s+=(A[ir][jr] - A[i][j]); if(A[i][j] > A[ir][jr]) s+=(A[i][j] - A[ir][jr]);} return s;}.

Taking into consideration the above stated remarks, Rpt2 function will execute extraction of rapport in class 2 images: long int Rpt2(A [m][n]) {int pr=0; int prmax= =m/2+n/2; long int wmin=255×n×m; long int ww =0; int mrmin=0, nrmin=0, idmin=0, jdmin=0; for(pr=4; pr≤prmax; pr++) {mr=2, nr=pr-mr; if(nr>n/2){nr=n/2; mr=pr-nr;} while((mr≤m/2)&&(nr≥2)) {for(int id=0; id<m; id++) for(int jd=0; jd<n; jd++) {ww= W2(A[m][n]); if(ww < wmin) { mrmin=mr; nrmin=nr; idmin=id; jdmin=jd; wmin=ww; } mr++; nr--; } } if(wmin==255×n×m) {mr=0, nr=0, id=0, jd=0;} else { mr=mrmin; nr=nrmin; id=idmin; jd=jdmin;} return wmin;}

The Rpt2 algorithm contains additionally, in comparison with Rpt1 algorithm, two nested loops for(int id=0; id<m; id++)for(int jd=0; jd<n; jd++), time complexity of which (taking into consideration the accepted assumption K=m=n) is equal T4= $O(K^2)$. Then, time complexity of the Rpt2 algorithm, in the worst case, can be evaluated using assessment for the Rpt1 algorithm: T5=T3×T4≈$O(K^6)$. This way, in the worst case by K=100, extraction of the optimum rapport in the class 2 image by the above specified method (Rpt2) will require about 1 hour of computation with clock frequency of 10 GHz.

C O N C L U S I O N S

1. The theoretical analysis of elementary algorithms reveals that these algorithms make it possible to extract rapports in the class 1 images, dimensionality of which does not exceed the dimensionality 1000×1000, or in class 2 images, provided that their dimensionality does not exceed the dimensionality 100×100.

2. To extract rapport in the images, dimensionality of which exceeds the mentioned limits, more faster algorithms are needed which will be discussed in the next paper.

B I B L I O G R A P H Y

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