Fast and Optimal Binary Template Matching Application to Manga Copyright Protection

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Introduction

Definition. Template matching can be defined as a method of parameter estimation, to choose the template position that minimizes a similarly measure between a discrete function $T_{x,y}$ (taking values in a window *W*) and an image *I* e.g. with sum of squared differences

$$\min e = \sum_{(i,j)\in I} \sum_{(x,y)\in W} \left(I_{x+i,y+j} - T_{x,y}\right)^2$$

The template matching problem is concerned with different parameters

n	the size of the template
$O(f(n))$	the computation cost of the similarity measure
m	the image size
θ_k	the orientation search parameter
S_k	the scale search parameter
p	the template number

The combination of the parameters m, θ_k, S_k, p is the search space, the computation cost depends on the search space dimension and the used similarity measure $O(f(n))$

Binary Similarity Measures

Binary similarity (or dissimilarity) measures can be applied to binary images by requiring significantly less resource comparing to the ones working in the gray domain.

We consider *X*,*Y* two n-dimensional binary vectors

$X = (x_1,\dots,x_m,\dots,x_n)$ is one of the templates $X_1,\dots,X_C$

$Y = (y_1,\dots,y_m,\dots,y_n)$ is the image to compare

$$\delta_m(u,v) = \begin{cases} 1 & \text{if } x_m = u \; y_m = v \\ 0 & \text{otherwise} \end{cases}$$

$$n_{uv} = \sum_{m=1}^{n} \delta_m(u,v)$$

u \ v	0	1
0	n_{00} negative matches	n_{01} missmatches
1	n_{10} missmatches	n_{11} positive matches

Based on n_{00}, n_{11}, n_{10}, n_{01}, **76 binary similarity measures** *S(X,Y)* are defined in the literature with close relationships. In DIA, common measures includes those of Table I

Measure	$S(X,Y)$	Range
Inner Product (IP)	n_{11}	$[0,+\infty[$
Jaccard and Needham ($Jaccard$)	$\frac{n_{11}}{n_{11}+n_{10}+n_{01}}$	$[0,1]$
Dice ($DICE$)	$\frac{n_{11}}{2n_{11}+n_{10}+n_{01}}$	$[0,0.5]$
Russel-Rao ($RUSS$)	$\frac{n_{11}}{n}$	$[0,1]$
Kulzinsky (KUL)	$\frac{n_{11}}{n_{10}+n_{01}}$	$[0,+\infty[$
Hamming ($Hamming$)	$n_{11}+n_{00}$	$[0,+\infty[$
Sokal and Michner (SM)	$\frac{n_{11}+n_{00}}{n}$	$[0,1]$
Rogers and Tanimoto (RT)	$\frac{n_{11}+n_{00}}{n_{11}+n_{00}+2(n_{10}+n_{01})}$	$[0,1]$
Correlation ($CORR$)	$\frac{n_{11}n_{00}-n_{10}n_{01}}{\sqrt{n_{1x}n_{0x}n_{x1}n_{x0}}}$	$[-1,1]$
Yule and Kendall ($Yule$)	$\frac{n_{11}n_{00}-n_{10}n_{01}}{n_{11}n_{00}+n_{10}n_{01}}$	$[-1,1]$

Table I. COMMON BINARY SIMILARITY MEASURES IN DIA

Where $n_{ix} = n_{i0} + n_{i1}$, $n_{xi} = n_{0i} + n_{1i}$, $n = n_{ix} + n_{xi}$

Weighting is presented as very effective for boosting classification performance with negative matches i.e. '0' provides less information of separability than '1'.

We can define a weighted version for each dissimilarity measure by weighting n_{00} with $\beta(0 \le \beta \le 1)$

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The IP, Jaccard, DICE, RUSS, and KUL are independent of n_{00}.

Optimal template matching

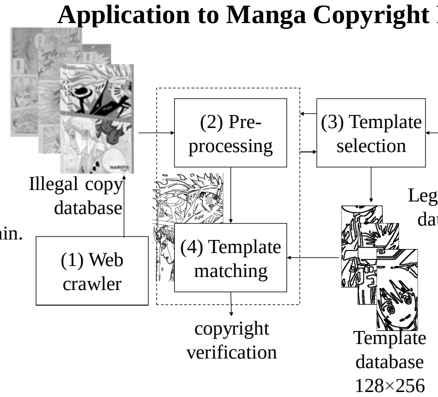
Definition. Optimal or Full-Search (FS) template matching scans the entire image and evaluates the similarity between the pattern and an area.

Method	Complexity	Coding	K=1	K=2	K≥3
Brute-force	$O(MNmn)$	integer			
FFT	$K\times O(M^{*2}\log_2 M^*)$	float	IP, RUSS, Ham, SM	Jaccard, Dice, KUL, RT	Yule, CORR
Bitwise operator	$K\times O(MNr)$	boolean	IP, RUSS, Ham, SM, RT,	Jaccard, Dice,	Yule, CORR

with *MN* and *mn* the image/RoI and template size respectively, M^* is *M* padded of the template size and round to a power of two, $r = \min(m,n)$

K depends of the distance computation

Application to Manga Copyright Protection

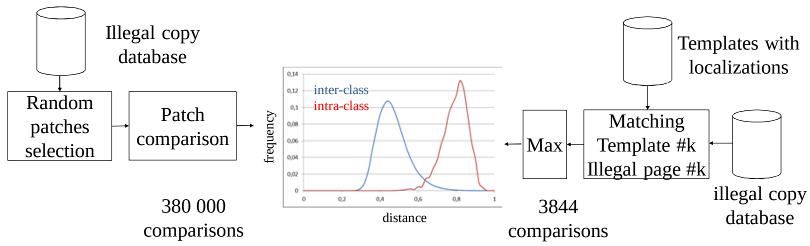


Database

	legal	illegal
resolution	128 dpi	
magazines	10	10
pages	3844	3844
total pages	7688	

- ✓ Pre-processing include canny edge detection and morphological dilatation operator
- ✓ Template selection ensures a minimum ratio $n_{1x}/n_{0x}+n_{1x}$
- ✓ Binary template matching implements optimal approaches and binary measures

Binary similarity measure characterization can be expressed as an inter-class intra-class discrimination problem,

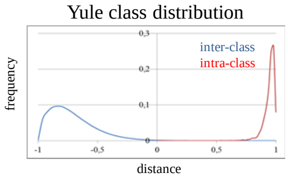


The Bhattacharyya coefficient measures the amount of overlap between two probability distributions *p(x)*, *q(x)*

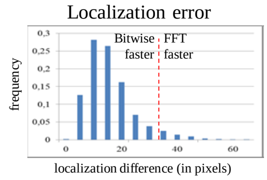
$$BC(q,p) = \sum_{\forall x} \sqrt{p(x)q(x)}$$

	$BC(p,q)$	
	$\beta=1$	$\beta=n_{11}/n_{00}$
Jaccard	**0,01614**	
Dice	0,01857	
Russ	0,25975	
Yule	0,00926	**0,00224**
RT	0,16604	0,01641
SM	0,16898	0,25461

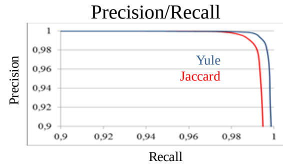
Yule class distribution



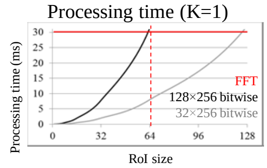
Localization error



Precision/Recall



Processing time (K=1)



Conclusion and perspectives

- ✓ Template matching is a good candidate for copyright verification supporting skew distortion, image shifting, scale approximation, compression & digitalization artifacts, scalable recognition.
- ✓ With a suitable selection of the distance and the template size, copyright verification problem is almost separable (near to a 1/1 Precision/Recall) on medium resolution images (128 dpi).
- ✓ Fast and optimal template matching can be achieved in some ten ms from regions of interest of 64×64 to 128×128 sizes, fitting with the localization errors, using a priori positions of templates.
- ✓ Major time improvement could be obtained with non-optimal approaches and template pruning strategies.