# COMPARATIVE STUDY OF PARALLEL THINNING ALGORITHMS

***SAKET PORWAL***


## *ABSTRACT :*

**The following paper deals with detailed comparative study of parallel thinning algorithms for skeletonization of images . The relative performance of the algorithms in regards to skeleton quality and rough iteration count is reported . It begins with a brief introduction to various algorithms included in the study , followed by the algorithm comparison in various fields , namely : number of iterations , thinness , sensitivity to noise and rotation .**

***INTRODUCTION TO VARIOUS ALGORITHMS :***

Five algorithms are compared to gauge the relative performance of the algorithm in regards to skeleton quality and rough iteration count .If for pixel p , X(p) is equal to half the number of transition from a white pixel to a black & vice versa . N(p) is summation over n(j), j=1 to 8 , neighbors of p.

- PSTA : Its based on Rutovitz crossing number and template matching . Full parallelism is achieved by an operator support larger than 3x3 . The initial thinning criteria is X(p) = 1 and $1 < N(p) < 7$ . This is followed by 2 simple cleaning cycles are executed , after which the algorithm terminates .
- HSCP : HSCP is also based on X(p) . Its fully parallel with a higher operator support . It computes the edge status not only of p but of its S , E and SE neighbors as well . It then uses the values of its neighbors in conjunction with the edge values of those three neighbors in simple logical conditions to determine final thinning status . The algorithm terminates when no pixels are thinned between consecutive iteration .
- CWSI : CWSI function by using a set of 10 windows . A pixel is thinned if it matches any of the 8, 3x3 thinning windows , unless it also matches the 3x4 or the 4x3 restoring window . The algorithm terminates when no pixels are thinned between consecutive iterations .
- AFP3 : AFP3 is based on X(p) , but unlike HSCP and PSTA , it accepts N(p)=7 as an edge when the single white pixels is one of the connected neighbors . It uses 3 restoring windows to prevent disconnectivities and 2 additional thinning windows to eliminate step skeletons . The algorithm terminates when no pixels are thinned between consecutive iterations .
- JC : It uses a set of 30 thinning and restoring windows , labeled A(1) to A(30) ranging in size from 3x3 to 5x5 .The 4 largest windows are unique in that they check for the interior of right angles . This alleviates the problem of skeletons loosing mediality by cutting sharp corners , a characteristic which is common to most thinning algorithms .

***COMPARISION RESULTS :***

- Number of Iterations : The discrepancy between different algorithms in number of iterations needed to arrive a final skeleton varies from image to be thinned. On the whole JC leads slightly ( i.e. takes fewer iterations ) , PSTA and AFP3 require the same number of iterations and CWSI algorithm lag by a few. When 90° corners aligned with the grid are involved the JC algorithm tends to take fewer iterations than PSTA and AFP3 due to its A(17-20) windows .
- Thinness : Ideal skeleton is one pixel wide . This lead a minor ambiguity in the case of a diagonal line . Ideally ,diagonally adjacent pixels are connected to form a minimal diagonal line( Fig. 1). While the zigzag or step skeleton gives rise to ambiguity . Of the 5 algorithms PSTA , HSCP , CWSI , produce step skeletons while AFP3 and JC produce 8 connected diagonal lines . To address this is the reason the cleaning stages were developed for PSTA . If a perfectly connected skeleton is not required PSTA by itself gives a skeleton with good isotropy and noise immunity .
- Sensitivity to Noise : Noise arises from equipment limitations , interference , extraneous foreign elements and the like . Here noise is divided into 4 steps : *irregular edges , positive edge noise , negative edge noise and internal noise* . *Irregular edges* are an attribute of the image itself . The image has a very strong intuitive skeleton combined with a wide variety of edge configurations . CWSI shows the worst noise sensitivity , followed by AFP3 . JC does not show any noise and produces the best skeleton , followed by PSTA . An extra black pixel extending beyond the image's border , referred to as the *positive edge noise* , or as a pixel missing from the border , referred to as *negative edge noise* . None of the algorithms are affected much by the positive edge noise . The JC and AFP3 algorithms are the most sensitive to the negative edge noise , greatly so when happening on a diagonal edge . The strong erosiveness in acute corners of JC caused by the A(17-20) windows causes negative noise to ripple propagate in front of the eroding edge . *Internal Noise* occurs when a pixel internal to the image is missing . PSTA and CWSI algorithms donot erode the edges of single pixel internal holes . The AFP3 and JC algorithms erode these holes and produce large circles around them . One can identify single pixel holes from the skeleton produced by the PSTA and CWSI algorithms . AFP3 or JC it is often difficult to determine the size of the hole which caused the circular skeleton .

- Sensitivity to Rotation : All of the algorithms are basically insensitive to rotation , most showing only minor variation . PSTA is the only algorithm which is perfectly insensitive to 90° rotations due to their symmetric nature . The CWSI algorithm shows greatly varying skeletons for such objects rotated by 45° . One noticeable effect of 45° rotation is the change in the noise sensitivity of some of the algorithms . Both the AFP3 and JC algorithms become more sensitive to negative edge noise on diagonal lines. These two algorithms are potentially sensitive to rotation of irregular shaped objects .

***CONCLUSION :***

This discrepancy between different algorithms in various fields with the image being thinned . But the relative performance of the algorithms , as general trends , were reported in regards to skeleton quality , rough iteration count , sensitivity to noise and rotation . The measure of speed per iteration , however , is left to the hardware being used .

***REFERENCES :***

CWSI : "A one pass thinning algorithm and its parallel implementation " , Comput. Vision Graphics Image Processing , Vol. 40 , 1987

AFP3 : " Fast fully parallel thinning algorithm ",CVGIP, Image Understanding, Vol. 55 , 1989

PSTA : " Design of an array processor for parallel skeletonization of images " , IEEE trans. Circuits and Systems , Vol. 44 , No. 4 , 1997

HSCP : " An improved parallel thinning algorithm " , Communication ACM , Vol. 30, No. 2 , 1987

JC : " One pass parallel thinning : Analysis , Properties & Quantitative evaluation " , IEEE trans. Pattern Analysis , Machine Intelligence , Vol. 14 , 1992