

APPENDIX

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The Connected Component Labeling (CC labeling) Algorithm ⁽⁴³⁾:

I. The Top-Down Process:

Step 1: Three tables are used for the global minimum of each row in a binary image (1: foreground, and 0: background). All three tables are initialized at the beginning when processing each row.

- a. Label table: This table records every label number which occurred in this row.
- b. Equal table: This table has two columns indicating the different labels at the left (first) and right (second) columns belonging to the same classification. The label number at the first column is equal to or larger than that at the second column.
- c. Link table: Each link table records the label numbers within the same classification, which can be linked together and arranged by increasing order.

Step 2: A 2 x 3 (row x column = r x c) CC labeling operator

(r-1,c-1)	(r-1,c)	(r-1,c+1)
(r,c-1)	(r,c)	

has been used for each row beginning from the left most and top most (0,0) position of the image. (r,c) is the center position of the operator at row 'r' and column 'c', and $I(r,c)$ is its corresponding binary value. Label(r,c) means a label number is assigned to the pixel at position (r,c).

If $I(r,c) > 0$, then process as following; otherwise go to next pixel.

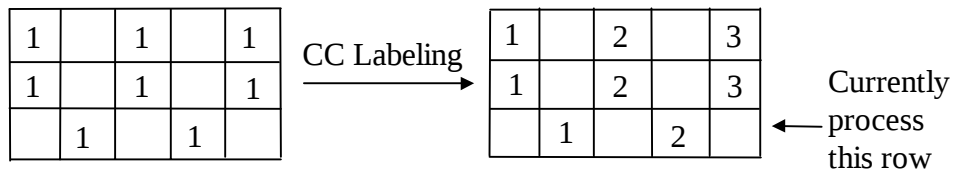
- a. If $I(r-1,c) > 0$, then $\text{Label}(r,c) = \text{Label}(r-1,c)$. Else
- b. If $I(r-1,c+1) > 0$, then $\text{Label}(r,c) = \text{Label}(r-1,c+1)$.

1. If $I(r-1, c-1) > 0$ and $\text{Label}(r-1, c+1) \neq \text{Label}(r-1, c-1)$, then record both label numbers to Equal table and put both number to the Link table. Else
2. If $I(r, c-1) > 0$ and $\text{Label}(r-1, c+1) \neq \text{Label}(r, c-1)$, then record both label numbers to Equal table and put both number to the Link table. Else
- c. If $I(r-1, c-1) > 0$, then $\text{Label}(r, c) = \text{Label}(r-1, c-1)$. Else
- d. If $I(r, c-1) > 0$, then $\text{Label}(r, c) = \text{Label}(r, c-1)$.

Step 3: Check each Link table. If nothing exists in this table, then no label number will be changed. Otherwise, use the label number in the current Link table to do the following process in the top-down order.

Scan the second column in the whole Equal table from top to bottom. If there is the same label number as the Link table, then check if the label number at the first column is larger than the label number at the current Link table. If it is, then the label number at the first column of Equal table is replaced by the label number at the current Link table.

Example:

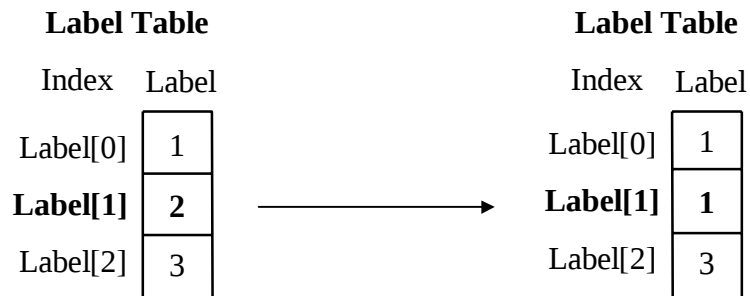


After this step, these three tables will be like these examples:

Label Table		Equal Table		Link Table	
Index	Label	Index	Label 1st 2nd	Index	Link Label
Label[0]	1	Equal[0]	2 1	Link[0]	1
Label[1]	2	Equal[1]	3 2	Link[1]	2
Label[2]	3			Link[2]	3

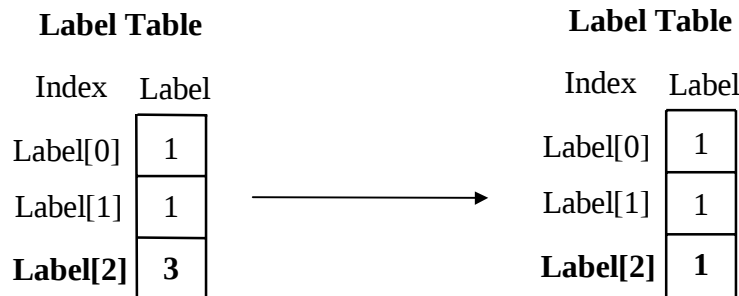
1.1 Pop out label number $\text{Link}[0] = 1$ from the Link table, and find out if label number '2' is equal to '1' from the Equal table: $\text{Equal}[0](\text{Label}[1], \text{Label}[0])$ where $\text{Label}[1] = 2$ and $\text{Label}[0] = 1$.

1.2 Because $\text{Equal}[0](\text{Label}[1], \text{Label}[0])$, and $(\text{Label}[1] = 2) > (\text{Label}[0] = 1)$ at Equal table, $\text{Label}[1] = 1$. That is, $\text{Label}[1] = 2 = 1 = \text{Label}[0]$.



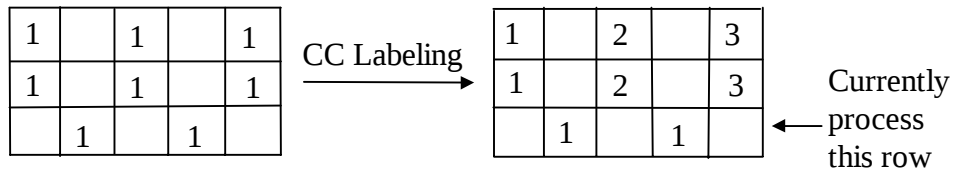
2.1 Pop out label number $\text{Link}[2] = 3$ from the Link table, and find out if label number '3' is equal to '2' from the Equal table: $\text{Equal}[1](\text{Label}[2], \text{Label}[1])$ where $\text{Label}[2] = 3$ and $\text{Label}[1] = 2 = 1 = \text{Label}[0]$.

2.2 Because $\text{Equal}[1](\text{Label}[2], \text{Label}[1])$, and $(\text{Label}[2] = 3) > (\text{Label}[1] = 2)$ at Equal table, $\text{Label}[2] = 1$. That is, $\text{Label}[2] = 3 = \text{Label}[1] = 2 = \text{Label}[0] = 1$.



3.1 Pop out label number $\text{Link}[3] = 3$ from the Link table, but there is no label number '3' at the second column of the Equal table: Then stop.

Step 4: The same row of the image is examined again (the second pass). If the label number is different from the Label table, then change it.



II. The Bottom-Up Process:

The process is similar to the Top-Down process by two passes for each row, beginning from the bottom to the top rows of the image, and left to right for each row.

The 2 x 3 operator is:

$(r, c-1)$	(r, c)	
$(r+1, c-1)$	$(r+1, c)$	$(r+1, c+1)$

Since the Link table is already set, we only need the Label table and Equal table to set the same connected components to have the same label number.