National Institute of Technology Karnataka

Parallel Computing Project Presentation

CONNECTED COMPONENT LABELLING

Under the guidance of

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Contents

Introduction

- Connected-component labelling (alternatively called region extraction)
- Algorithmic application of graph theory.
- Subsets of connected components are uniquely labelled based on a given heuristic.
- It is used in computer vision to detect connected regions in binary digital images.
- Colour images and data with higher dimensionality can also be processed.

Introduction (contd.)

- There exist many algorithms for computing connected components in a given image.
- Repeated pass algorithms
- Two-pass algorithms
- Algorithms with the hierarchical tree equivalent representations of the data parallel algorithms.

Problem Statement

- The project aims to compute the connected components in a binary image and label them.

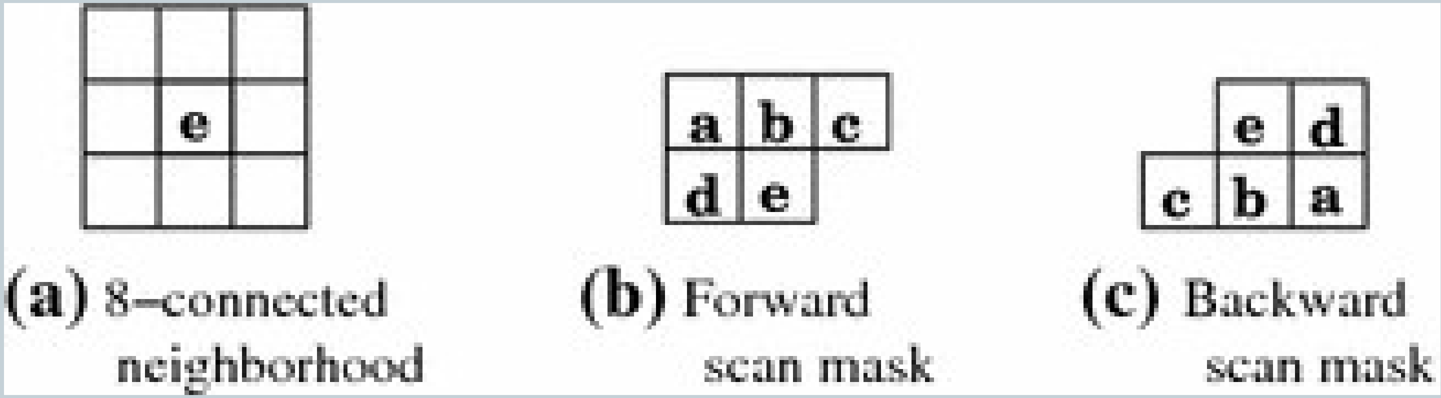
- The implementation of the algorithm has been done using thread level parallelism and pipelined architecture.

Objective

- The computational speed for labelling the binary image is compared to the serial implementation computational speed.

- Based on the result conclusive remarks are analysed and future work is being proposed.

Methodology Used



CONVENTIONAL AND SUZUKI'S ALGORITHM

Serial Implementation

The conceptual algorithm is given as follows :

```
1. Algorithm (data)
2.      First pass
3.          for row in data
4.              for column in row
5.                  assign a label to data[row][col] using Forward Mask
6.      Next passes
7.          while there is a change in labels do
8.              for row in data
9.                  for column in row
10.                     update the labels[row][column] using Backward Mask
11.             for row in data
12.                 for column in row
13.                     update the labels[row][column] using Forward Mask
14. return labels
```

CONVENTIONAL AND SUZUKI'S ALGORITHM

Parallel Implementation

```
for row in data
    #pragma omp parallel for
    for column in row
        while the condition is not 1 for this thread wait;
        label the pixel;
         if it is end of the row set the condition of the next thread to 1;
```

TWO PASS ALGORITHM

Serial Implementation

Main Function

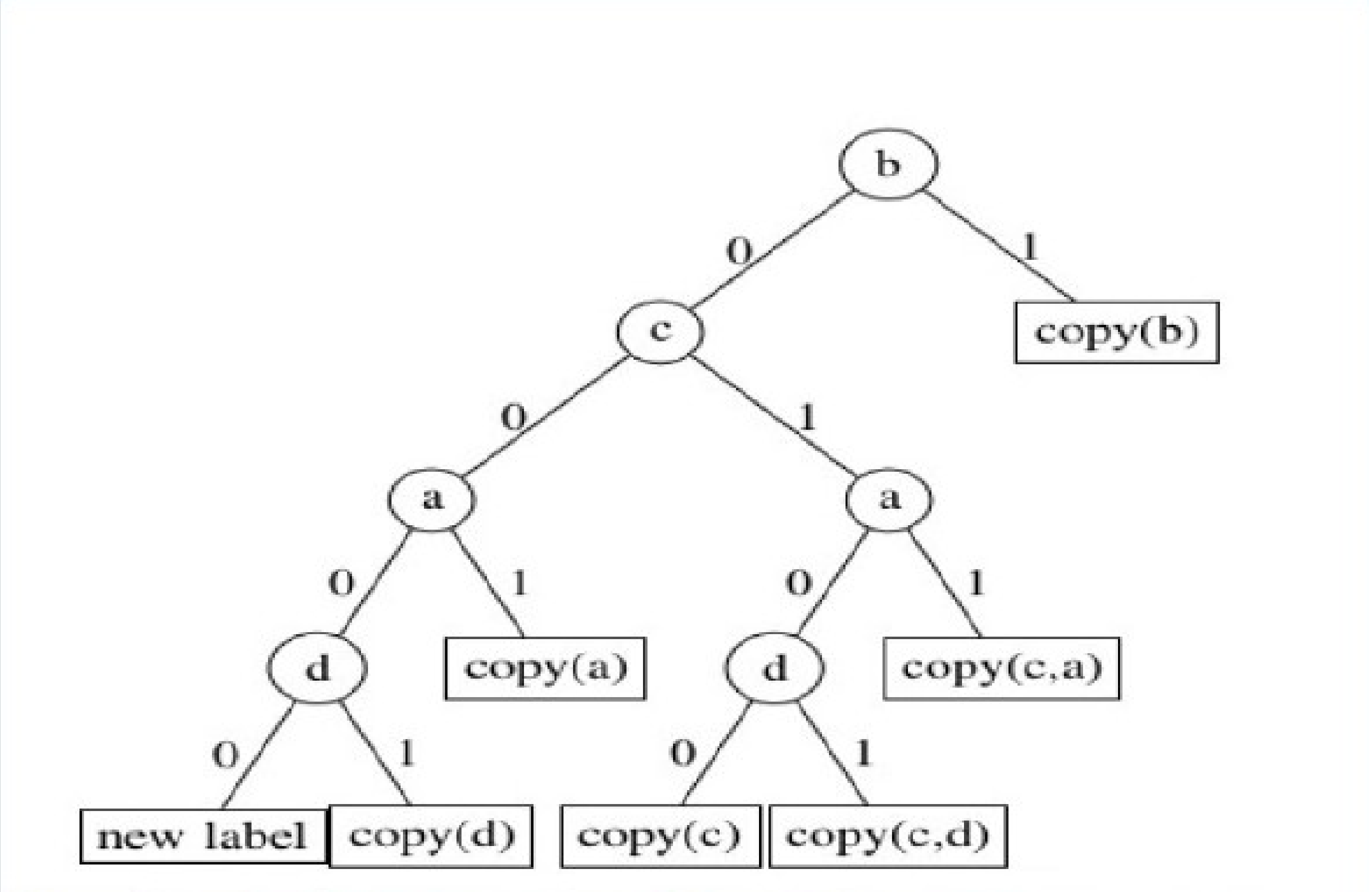
Input: $2D$ array *image* containing the pixel values

Output: $2D$ array *label* containing the final labels

function CCLRemSP(*image*)
    $Scan\_CCLRemSP(image)$ ▷ Scan Phase of CCLRemSP
    ▷ *count* is the max label assigned during Scan Phase
    $flatten(p, count)$ ▷ Analysis Phase of CCLRemSP
    for *row* in *image* **do** ▷ Labeling Phase of CCLRemSP
        for *col* in *row* **do** ▷ *e* is the current pixel to be labeled
            $label(e) \leftarrow p[label(e)]$
end function

TWO PASS ALGORITHM
Serial Implementation(Contd)

Decision tree used



TWO PASS ALGORITHM

Serial Implementation (Contd)

Scan Function

Input: $2D$ array $image$ containing the pixel values
InOut: $2D$ array $label$ containing the provisional labels and $1D$ array p containing the equivalence info
Output: maximum value of provisional label in $count$

```
function SCAN_CCLREMSP(image)
    for row in image do
        for col in row do
            if image(e) = 1 then
                if image(b) = 1 then
                    copy(b)
                else
                    if image(c) = 1 then
                        if image(a) = 1 then
                            copy(c, a)
                        else
                            if image(d) = 1 then
                                copy(c, d)
                            else
                                copy(c)
                    else
                        if image(a) = 1 then
                            copy(a)
                        else
                            if image(d) = 1 then
                                copy(d)
                            else
                                new label
    return count
end function
```

TWO PASS ALGORITHM

Parallel Implementation

Input: $2D$ array *image* containing the pixel values
Output: $2D$ array *label* containing the final labels

```
function PAREMSP(image)
    numiter ← row/2 ▷ As we are processing 2 rows at a time
    # pragma omp parallel
    chunk ← numiter/numberofthreads
    size ← 2 × chunk
    start ← start index of the thread
    count ← start × col
    # pragma omp for
    Scan_ARemSP(image)
    # pragma omp for
    for i = size to row − 1 do
        for col in row do
            if label(e) ≠ 0 then
                if label(b) ≠ 0 then
                    merger(p, label(e), label(b))
                else
                    if label(a) ≠ 0 then
                        merger(p, label(e), label(a))
                    if label(c) ≠ 0 then
                        merger(p, label(e), label(c))
        i ← i + size
    flatten(p, count)
    for row in image do
        for col in row do
            label(e) ← p[label(e)]
end function
```

Result

INPUT ▼	SERIAL		PARALLEL	
	SUZUKI	TWO PASS	SUZUKI	TWO PASS
1.	0.9122 ms	0.8841 ms	0.3575 ms	0.1902 ms
2.	0.9932 ms	0.8461 ms	0.5092 ms	0.5563 ms
3.	0.5832 ms	0.2000 ms	0.0681 ms	0.0332 ms

INPUT 1

0 0 0 0 1 1
0 0 1 1 0 0
1 1 0 0 0 0

INPUT 2

0 0 1 1
0 0 1 1
1 0 0 0
1 1 0 0

INPUT 3

0 0 1 1 0 0
0 0 1 0 0 1
0 0 1 1 0 0
0 0 0 0 0 1
0 1 1 0 0 0
0 0 1 1 0 0

Use of Critical Section

- In Suzuki algorithm : Assign label in forward and backward mask must be handled using critical section.

- In Two Pass Algorithm : Flatten function must be handled using critical section directive

Future Work

- A research of other architectures apart from the pipeline architecture used in this algorithm that may reduce communication costs.

- Better understanding of the performance features and trade-offs of these strategies.

- Apply other parallelisation strategies such as divide and conquer and tree architectures to optimize the parallel architecture.

Conclusion

• The task of connected components labelling is an important step in multiple image processing and computer vision projects.

• Reducing the speed of computation of this task while maintaining it's accuracy is indeed a necessity.

• Analyses show that a two-pass algorithm using the strategies implemented has the optimal worst-case time complexity O(p)

• Thus it can be implemented in practical scenarios.

Individual Contribution

- Divija : Suzuki Serial and Two Pass Serial
- Mukta : Two Pass Algorithm Serial and Two Pass Parallel
- Pooja : Suzuki Algorithm Serial and Parallel

References

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