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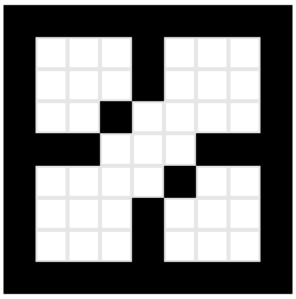
Flood fill

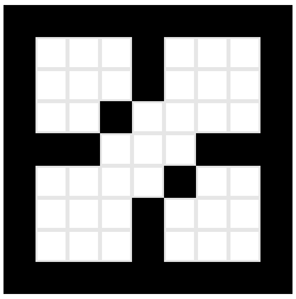
Flood fill, also called **seed fill**, is an algorithm that determines the area connected to a given node in a multi-dimensional array. It is used in the "bucket" fill tool of paint programs to fill connected, similarly-colored areas with a different color, and in games such as Go and Minesweeper for determining which pieces are cleared.


Recursive flood fill with 4 directions

Contents

The algorithm

The flood-fill algorithm takes three parameters: a start node, a target color, and a replacement color. The algorithm looks for all nodes in the array that are connected to the start node by a path of the target color and changes them to the replacement color. There are many ways in which the flood-fill algorithm can be structured, but they all make use of a queue or stack data structure, explicitly or implicitly.


Recursive flood fill with 8 directions

Depending on whether we consider nodes touching at the corners connected or not, we have two variations: eight-way and four-way respectively.

Stack-based recursive implementation (four-way)

One implicitly stack-based (recursive) flood-fill implementation (for a two-dimensional array) goes as follows:

```
Flood-fill (node, target-color, replacement-color):
 1. If target-color is equal to replacement-color, return.
 2. ElseIf the color of node is not equal to target-color, return.
 3. Else Set the color of node to replacement-color.
 4. Perform Flood-fill (one step to the south of node, target-color, replacement-color).
    Perform Flood-fill (one step to the north of node, target-color, replacement-color).
    Perform Flood-fill (one step to the west of node, target-color, replacement-color).
    Perform Flood-fill (one step to the east of node, target-color, replacement-color).
 5. Return.
```

Though easy to understand, the implementation of the algorithm used above is impractical in languages and environments where stack space is severely constrained (e.g. Java applets).

Alternative implementations

An explicitly queue-based implementation (sometimes called "Forest Fire algorithm"[1]) is shown in pseudo-code below. It is similar to the simple recursive solution, except that instead of making recursive calls, it pushes the nodes onto a queue for consumption:

```
Flood-fill (node, target-color, replacement-color):
  1. If target-color is equal to replacement-color, return.
  2. If color of node is not equal to target-color, return.
  3. Set the color of node to replacement-color.
  4. Set Q to the empty queue.
  5. Add node to the end of Q.
  6. While Q is not empty:
  7.     Set n equal to the first element of Q.
  8.     Remove first element from Q.
  9.     If the color of the node to the west of n is target-color,
             set the color of that node to replacement-color and add that node to the end of Q.
 10.     If the color of the node to the east of n is target-color,
             set the color of that node to replacement-color and add that node to the end of Q.
 11.     If the color of the node to the north of n is target-color,
             set the color of that node to replacement-color and add that node to the end of Q.
 12.     If the color of the node to the south of n is target-color,
             set the color of that node to replacement-color and add that node to the end of Q.
 13. Continue looping until Q is exhausted.
 14. Return.
```

Practical implementations intended for filling rectangular areas can use a loop for the west and east directions as an optimization to avoid the overhead of stack or queue management:

```
Flood-fill (node, target-color, replacement-color):
 1. If target-color is equal to replacement-color, return.
 2. If color of node is not equal to target-color, return.
 3. Set Q to the empty queue.
 4. Add node to Q.
 5. For each element N of Q:
 6.     Set w and e equal to N.
 7.     Move w to the west until the color of the node to the west of w no longer matches
target-color.
 8.     Move e to the east until the color of the node to the east of e no longer matches
target-color.
 9.     For each node n between w and e:
10.         Set the color of n to replacement-color.
11.         If the color of the node to the north of n is target-color, add that node to Q.
12.         If the color of the node to the south of n is target-color, add that node to Q.
13. Continue looping until Q is exhausted.
14. Return.
```

Adapting the algorithm to use an additional array to store the shape of the region allows generalization to cover "fuzzy" flood filling, where an element can differ by up to a specified threshold from the source symbol. Using this additional array as an alpha channel allows the edges of the filled region to blend somewhat smoothly with the not-filled region.

Fixed-memory method (right-hand fill method)

A method exists that uses essentially no memory for four-connected regions by pretending to be a painter trying to paint the region without painting themselves into a corner. This is also a method for solving mazes. The four pixels making the primary boundary are examined to see what action should be taken. The painter could find themselves in one of several conditions:

1. All four boundary pixels are filled.
2. Three of the boundary pixels are filled.
3. Two of the boundary pixels are filled.
4. One boundary pixel is filled.
5. Zero boundary pixels are filled.

Where a path or boundary is to be followed, the right-hand rule is used. The painter follows the region by placing their right-hand on the wall (the boundary of the region) and progressing around the edge of the region without removing their hand.

For case #1, the painter paints (fills) the pixel the painter is standing upon and stops the algorithm.

For case #2, a path leading out of the area exists. Paint the pixel the painter is standing upon and move in the direction of the open path.

For case #3, the two boundary pixels define a path which, if we painted the current pixel, may block us from ever getting back to the other side of the path. We need a "mark" to define where we are and which direction we are heading to see if we ever get back to exactly the same pixel. If we already created such a "mark", then we preserve our previous mark and move to the next pixel following the right-hand rule.

A mark is used for the first 2-pixel boundary that is encountered to remember where the passage started and in what direction the painter was moving. If the mark is encountered again and the painter is traveling in the same direction, then the painter knows that it is safe to paint the square with the mark and to continue in the same direction. This is because (through some unknown path) the pixels on the other side of the mark can be reached and painted in the future. The mark is removed for future use.

If the painter encounters the mark but is going in a different direction, then some sort of loop has occurred, which caused the painter to return to the mark. This loop must be eliminated. The mark is picked up, and the painter then proceeds in the direction indicated previously by the mark using a left-hand rule for the boundary (similar to the right-hand rule but using the painter's left hand). This continues until an intersection is found (with three or more open boundary pixels). Still using the left-hand rule the painter now searches for a simple passage (made by two boundary pixels). Upon finding this two-pixel boundary path, that pixel is painted. This breaks the loop and allows the algorithm to continue.

For case #4, we need to check the opposite 8-connected corners to see whether they are filled or not. If either or both are filled, then this creates a many-path intersection and cannot be filled. If both are empty, then the current pixel can be painted and the painter can move following the right-hand rule.

The algorithm trades time for memory. For simple shapes it is very efficient. However, if the shape is complex with many features, the algorithm spends a large amount of time tracing the edges of the region trying to ensure that all can be painted.

This algorithm was first available commercially in 1981 on a Vicom Image Processing system manufactured by Vicom Systems, Inc. The classic recursive flood fill algorithm was available on this system as well.

Pseudocode

This is a pseudocode implementation of an optimal fixed-memory flood-fill algorithm written in structured English:

The variables: cur, mark, and mark2 each hold either pixel coordinates or a null value

```
   NOTE: when mark is set to null, do not erase its previous coordinate value.
         Keep those coordinates available to be recalled if necessary.
```

cur-dir, mark-dir, and mark2-dir each hold a direction (left, right, up, or down) backtrack and findloop each hold boolean values count is an integer

The algorithm:

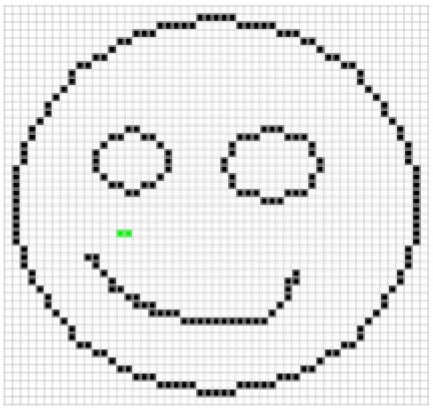
(NOTE: All directions (front, back, left, right) are relative to cur-dir)

```
set cur to starting pixel
set cur-dir to default direction
clear mark and mark2 (set values to null)
set backtrack and findloop to false

while front-pixel is empty do
    move forward
end while

jump to START

MAIN LOOP:
    move forward
    if right-pixel is empty then
        if backtrack is true and findloop is false and either front-pixel or left-pixel is empty
then
            set findloop to true
        end if
        turn right
PAINT:
        move forward
    end if
START:
    set count to number of non-diagonally adjacent pixels filled (front/back/left/right ONLY)
    if count is not 4 then
        do
            turn right
        while front-pixel is empty
        do
            turn left
        while front-pixel is filled
    end if
    switch count
        case 1
            if backtrack is true then
                set findloop to true
            else if findloop is true then
                if mark is null then
                    restore mark
                end if
            else if front-left-pixel and back-left-pixel are both empty then
                clear mark
                fill cur
                jump to PAINT
            end if
        end case
        case 2
            if back-pixel is filled then
                if front-left-pixel is not filled then
                    clear mark
                    fill cur
                    jump to PAINT
                end if
            else if mark is not set then
                set mark to cur
                set mark-dir to cur-dir
                clear mark2
                set findloop and backtrack to false
            else
                if mark2 is not set then
                    if cur is at mark then
                        if cur-dir is the same as mark-dir then
                            clear mark
                            turn around
                            fill cur
                            jump to PAINT
                        else
                            set backtrack to true
                            set findloop to false
                            set cur-dir to mark-dir
                        end if
                    else if findloop is true then
                        set mark2 to cur
                        set mark2-dir to cur-dir
                    end if
                else
                    if cur is at mark then
                        set cur to mark2
                        set cur-dir to mark2-dir
                        clear mark and mark2
                        set backtrack to false
                        turn around
                        fill cur
                        jump to PAINT
                    else if cur at mark2 then
                        set mark to cur
                        set cur-dir and mark-dir to mark2-dir
                        clear mark2
                    end if
                end if
            end if
        end case
        case 3
            clear mark
            fill cur
            jump to PAINT
        end case
        case 4
            fill cur
            done
        end case
    end switch
end MAIN LOOP
```

Scanline fill

The algorithm can be sped up by filling lines. Instead of pushing each potential future pixel coordinate on the stack, it inspects the neighbour lines (previous and next) to find adjacent segments that may be filled in a future pass; the coordinates (either the start or the end) of the line segment are pushed on the stack. In most cases this scanline algorithm is at least an order of magnitude faster than the per-pixel one.

Efficiency: each pixel is checked once.


Scanline fill (click to view animation)

Vector implementations

Version 0.46 of Inkscape includes a bucket fill tool, giving output similar to ordinary bitmap operations and indeed using one: the canvas is rendered, a flood fill operation is performed on the selected area and the result is then traced back to a path. It uses the concept of a boundary condition.

Large-scale behaviour

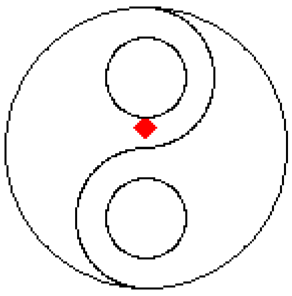
The primary technique used to control a flood fill will either be data-centric or process-centric. A data-centric approach can use either a stack or a queue to keep track of seed pixels that need to be checked. A process-centric algorithm must necessarily use a stack.

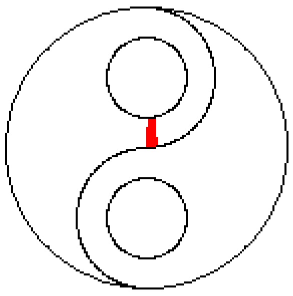
A 4-way flood-fill algorithm that uses the adjacency technique and a queue as its seed pixel store yields an expanding lozenge-shaped fill.

Efficiency: 4 pixels checked for each pixel filled (8 for an 8-way fill).

A 4-way flood-fill algorithm that use the adjacency technique and a stack as its seed pixel store yields a linear fill with "gaps filled later" behaviour. This approach can be particularly seen in older 8-bit computer games, such as those created with *Graphic Adventure Creator*.

Efficiency: 4 pixels checked for each pixel filled (8 for an 8-way fill).


Four-way flood fill using a queue for storage


Four-way flood fill using a stack for storage

See also

- Breadth-first search
- Depth-first search
- Graph traversal
- Connected-component labeling
- Dijkstra's algorithm

External links

- Didactical Javascript implementation of scanline polygon fill (https://web.archive.org/web/20180627153239/http://gpolo.awardspace.info/fill/main.html), by Guilherme Polo.
- Sample implementations for recursive and non-recursive, classic and scanline flood fill (http://lodev.org/cgtutor/floodfill.html), by Lode Vandevenne.
- Flash flood fill implementation (http://www.emanueleferonato.com/2008/06/06/flash-flood-fill-implementation/), by Emanuele Feronato.
- QuickFill: An efficient flood fill algorithm. (http://www.codeproject.com/KB/GDI/QuickFill.aspx), by John R. Shaw.
- FloodSpill: an open-source flood filling algorithm for C# (https://github.com/azsdaja/FloodSpill-CSharp), by Paweł Ślusarczyk

References

1. Torbert, Shane (2016). *Applied Computer Science* (https://books.google.com/books?id=HpdPDAAAQBAJ&pg=PA158) (2nd ed.). Springer (published 2016-06-01). p. 158. doi:10.1007/978-3-319-30866-1 (https://doi.org/10.1007%2F978-3-319-30866-1). ISBN 978-3-319-30864-7. LCCN 2016936660 (https://lccn.loc.gov/2016936660). Archived (https://web.archive.org/web/20161221185356/https://books.google.com/books?id=HpdPDAAAQBAJ&pg=PA158) from the original on 2016-12-21.