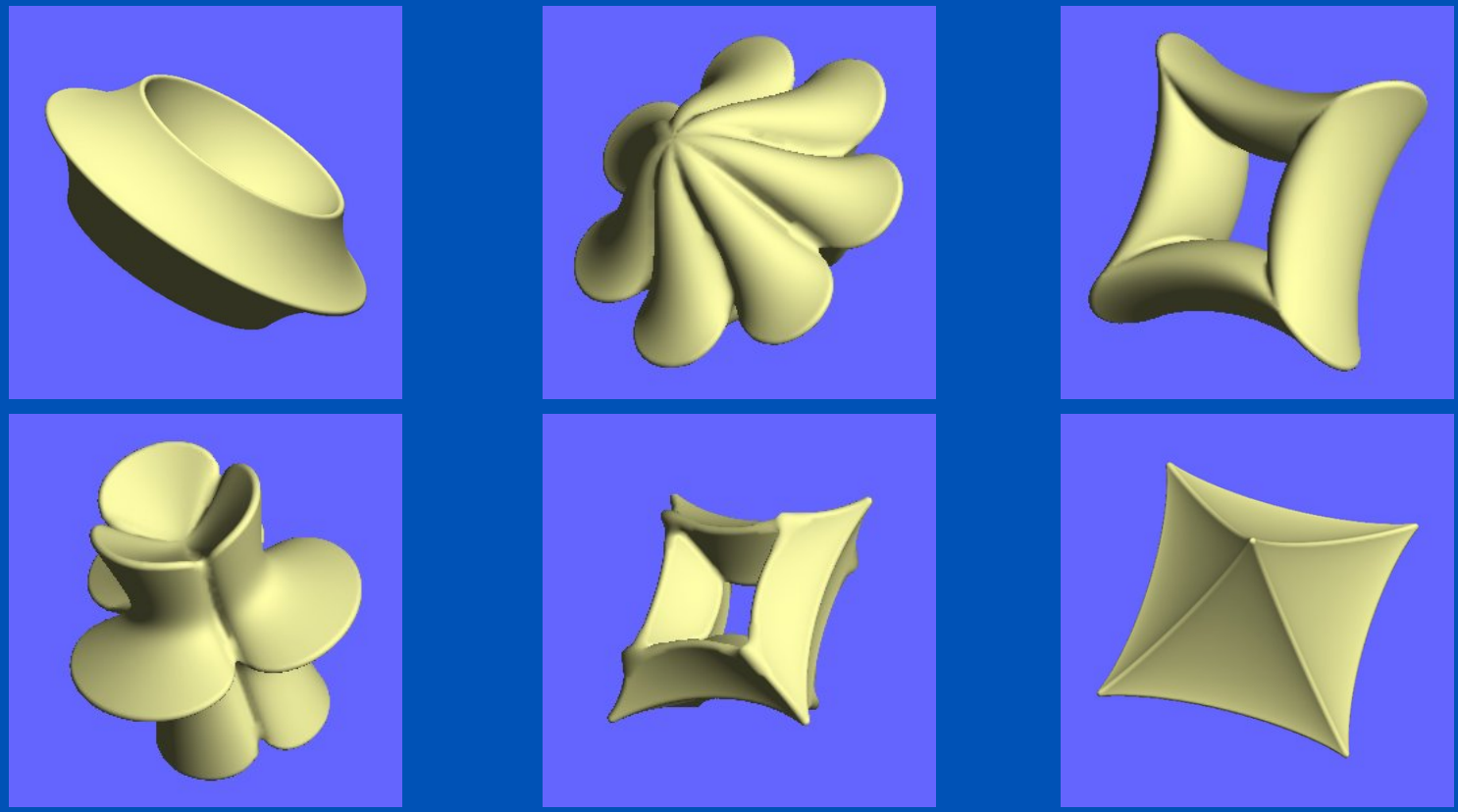
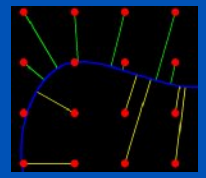
The Problem of Sharp Details in the Distance Fields Representation

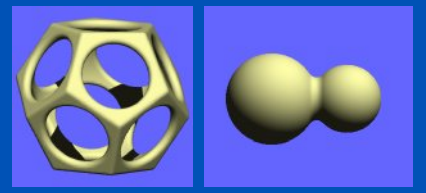


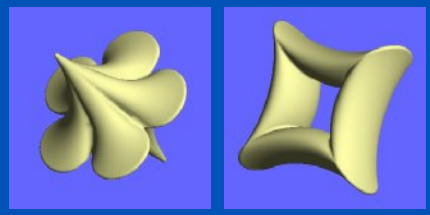
Outline

- Object representation by truncated distance fields (TDFs)
- CSG operations with voxelized solids [CGI 2004]
- Voxelization of implicit solids with sharp details in TDFs [VG 2005]
- New results:

  Extension of the previous method for solids with non-convex sharp details

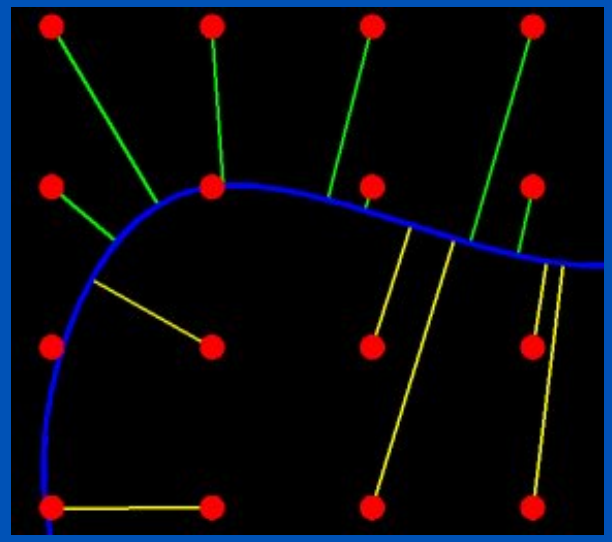






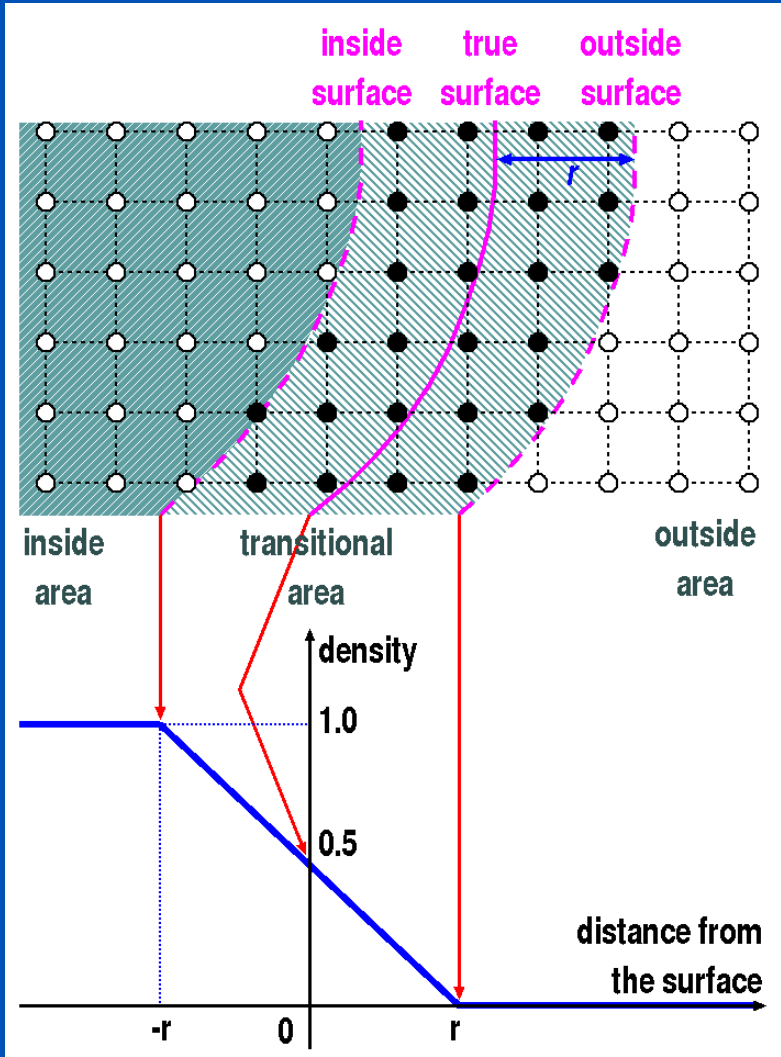
Distance Fields

- Distance to the object surface is stored in voxels
- Inside and outside area can be distinguish using different signs
- Surface can be reconstructed by interpolation and thresholding
- Distance estimation for implicid solids defined by function *f(X) = 0* can be done as follows:



$$D(X) = \frac{f(X)}{\| \nabla f(X) \|}$$

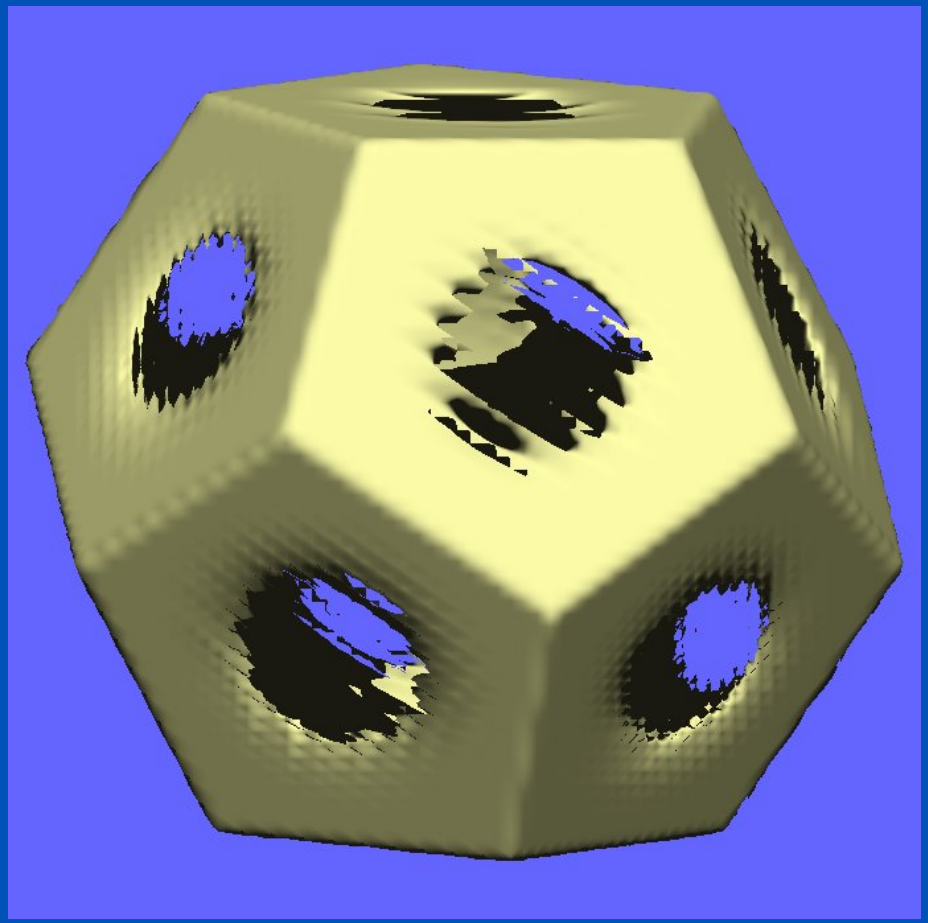
Object Representation by TDFs



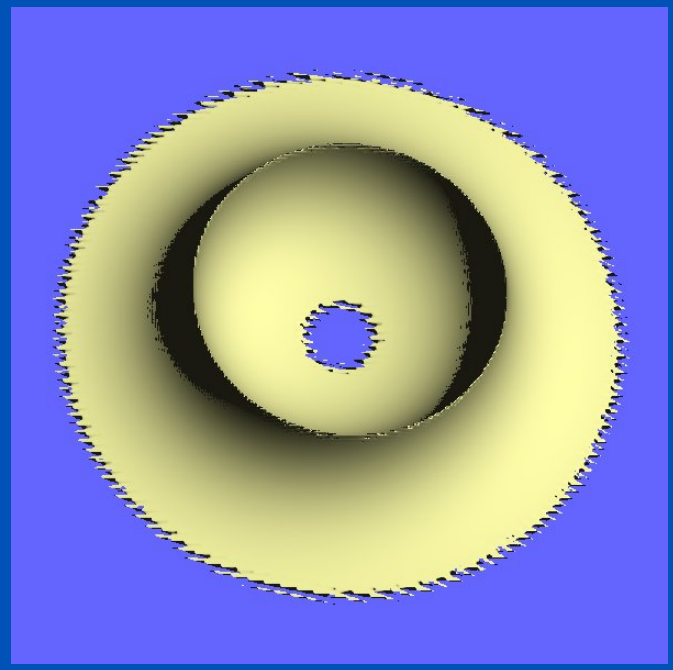
Volume is divided into three areas:

- Inside
- Outside
- Transitional:
  - In the surface vicinity
  - Thickness: *2r*
  - Stored values:
    - density (distance from the surface)
    - direction of the density gradient (surface normal)

Problem of Sharp Details

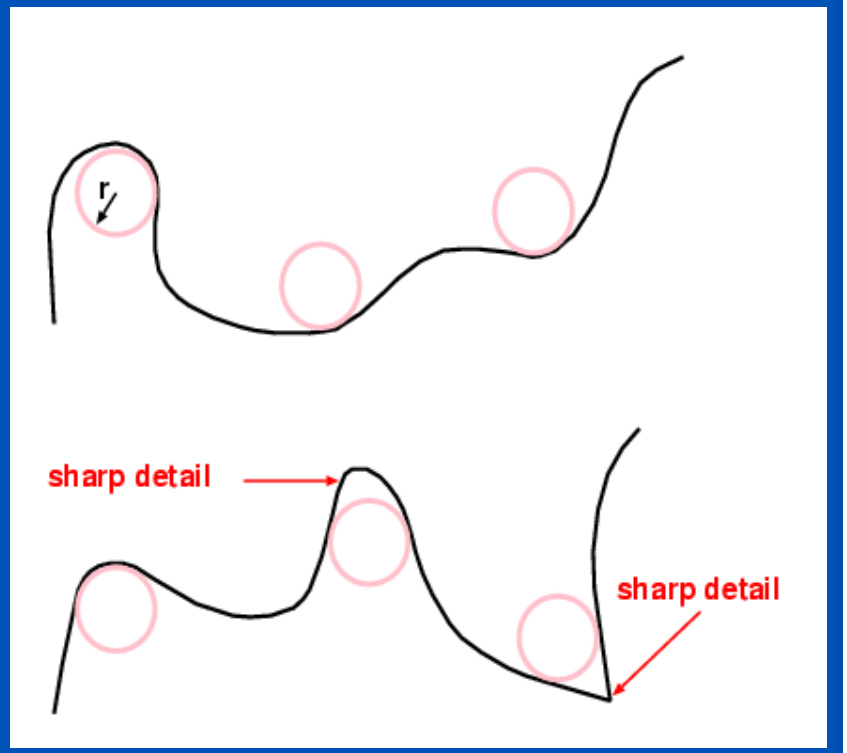


- Edge artifacts
- A problem of representation



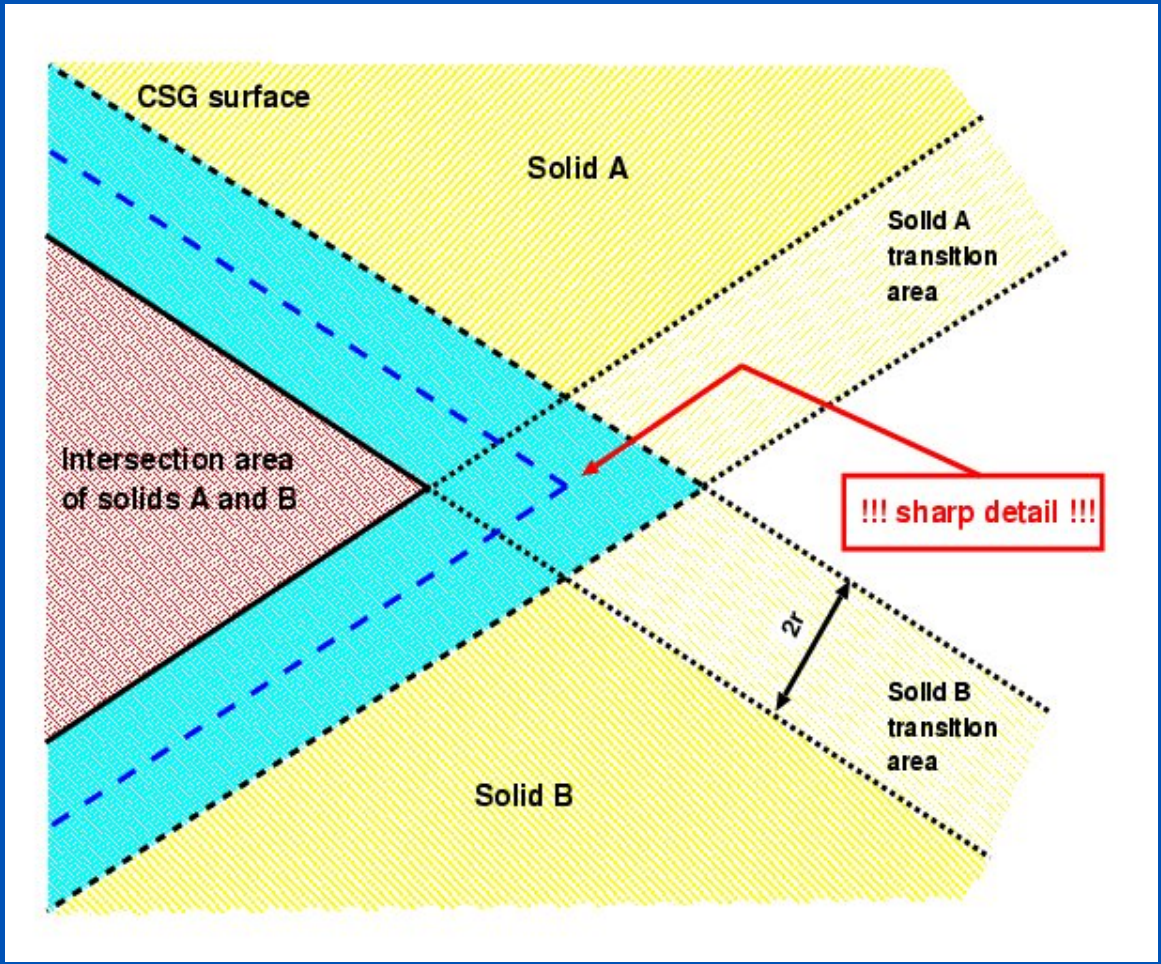
The Object Representability Criterion [Baerentzen 2000]

- Only solids with smooth surfaces without sharp details are representable in a discrete grid
- The criterion:
  - It is possible to roll a sphere of the given radius *r* from both sides of the surface
  - *r* :
    - defines thickness of the transitional area
    - determined by the reconstruction filter



CSG Operations

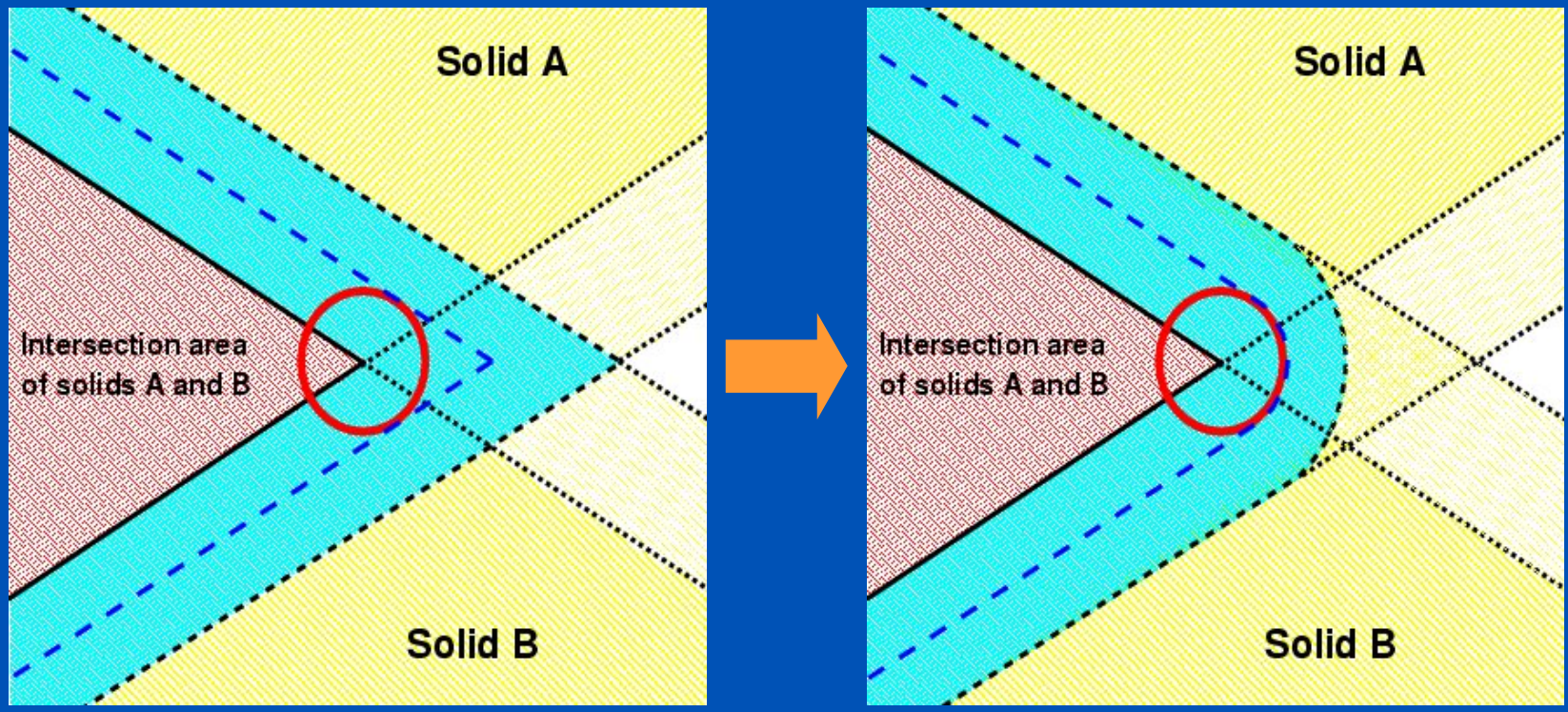
[Novotný, Dimitrov, Šrámek: CGI'04]



- The result of CSG operations often contains sharp details

Representable CSG Solids

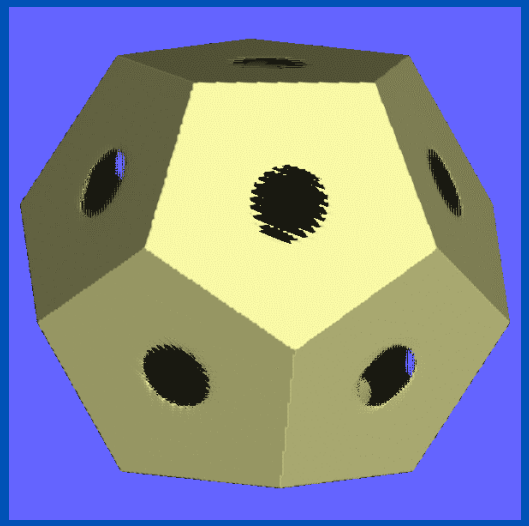
- To avoid artifacts, edges of CSG solids must be rounded!



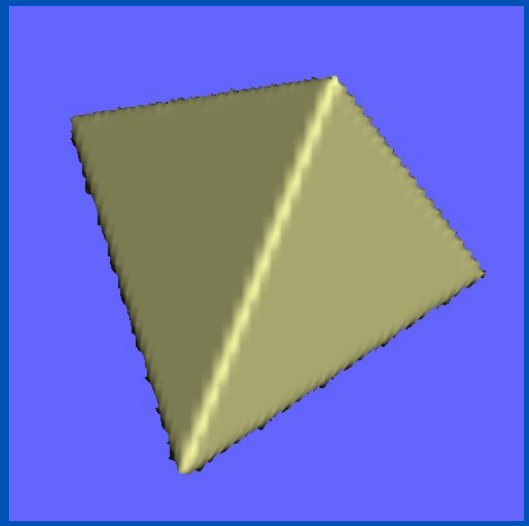
CSG solid with artifacts

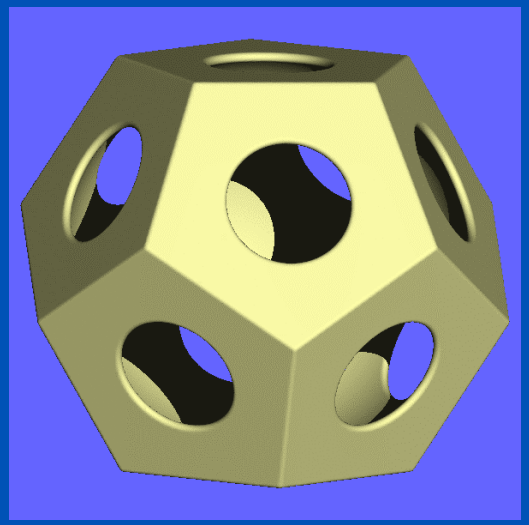
A representable CSG solid

Our Earlier Results

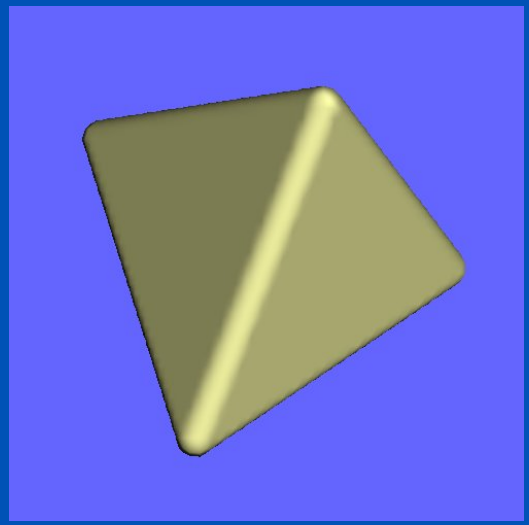


CSG solids with artifacts





Representable CSG solids



Voxelization of Implicit Solids: An SDC Method

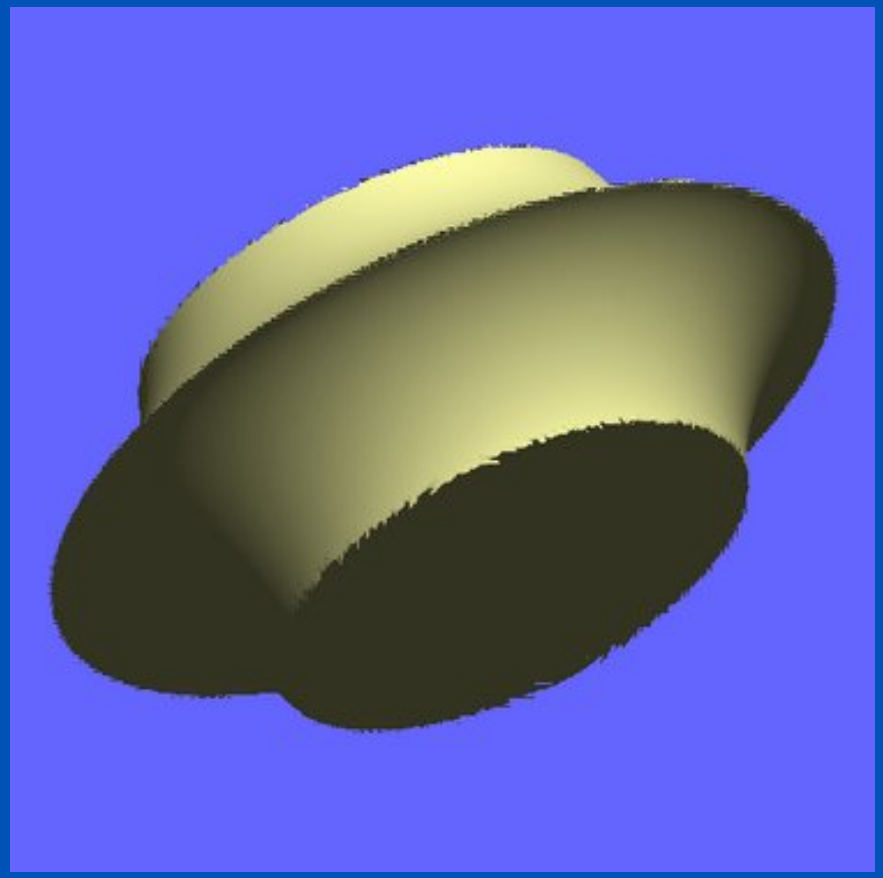
[Novotný, Šrámek: VG'05]

Problem:

- Implicit solids can contain sharp details (artifacts)

The proposed solution:

- Round edges to get representable objects – Sharp Details Correction (SDC) Method



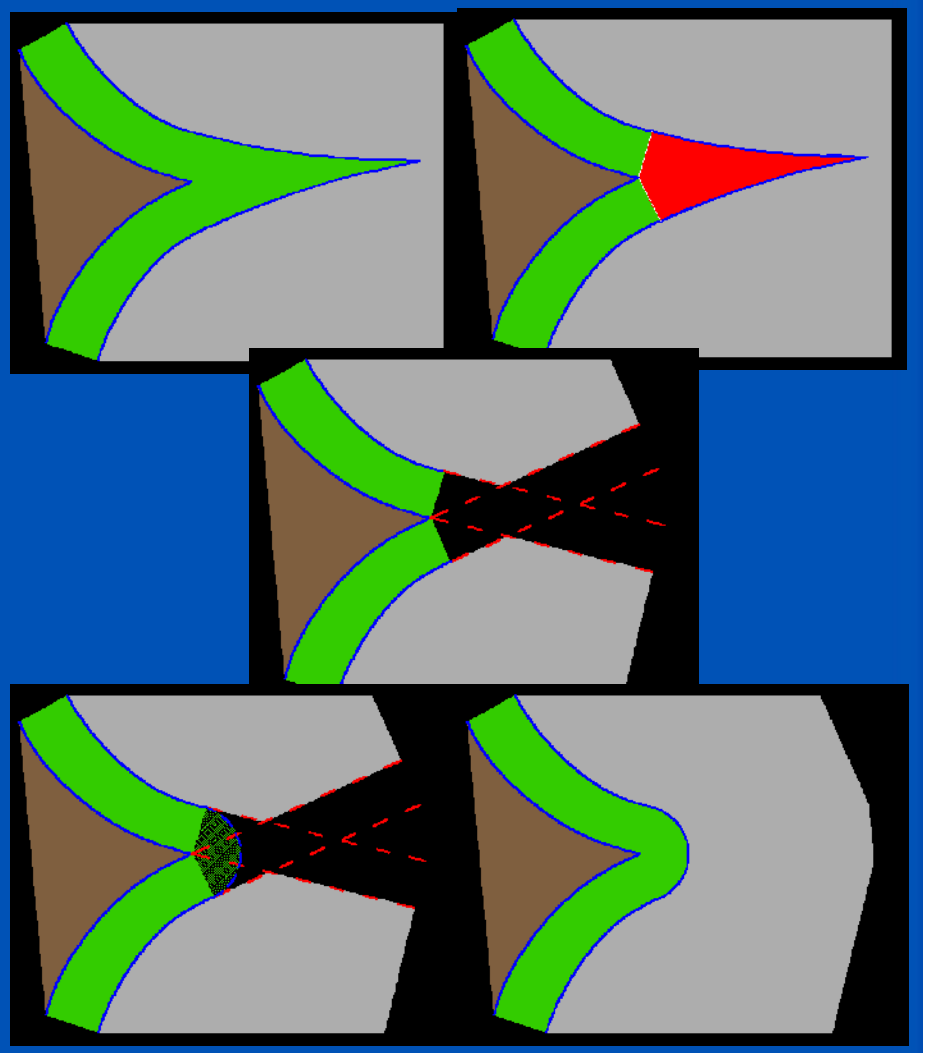
SDC Method – Overview

Stage 1:

- Evaluate voxels in a standard way
- Identify critical areas

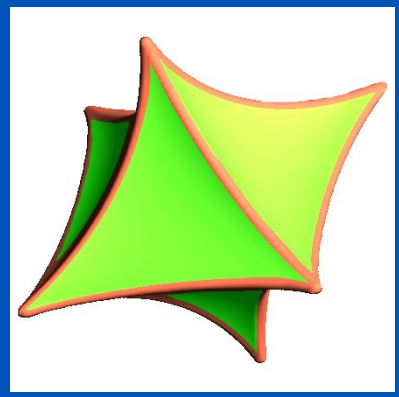
Stage 2:

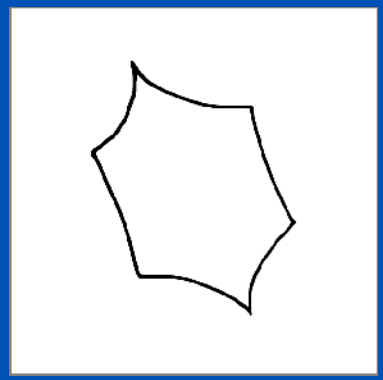
- Extrapolate values from non-critical areas (linearly)
- Compute final values of voxels by approximation: CSG intersection of two halfspaces

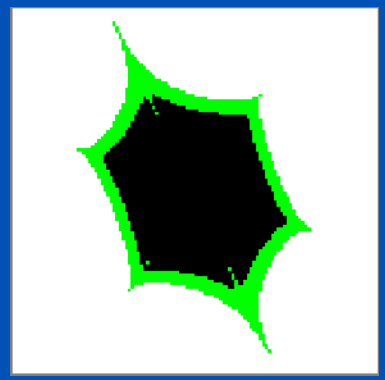


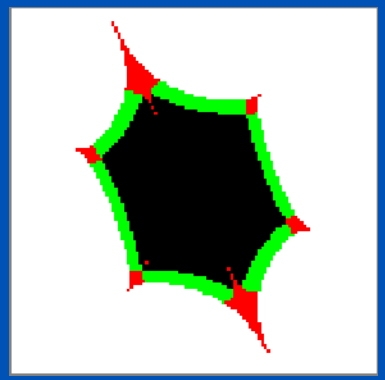
Stage 1

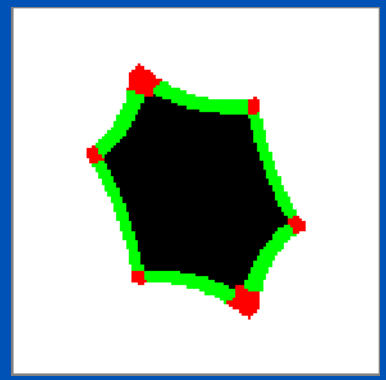
- Voxelization è inside, outside and transitional voxels
- Identification of critical voxels
- Adjustment of the critical area







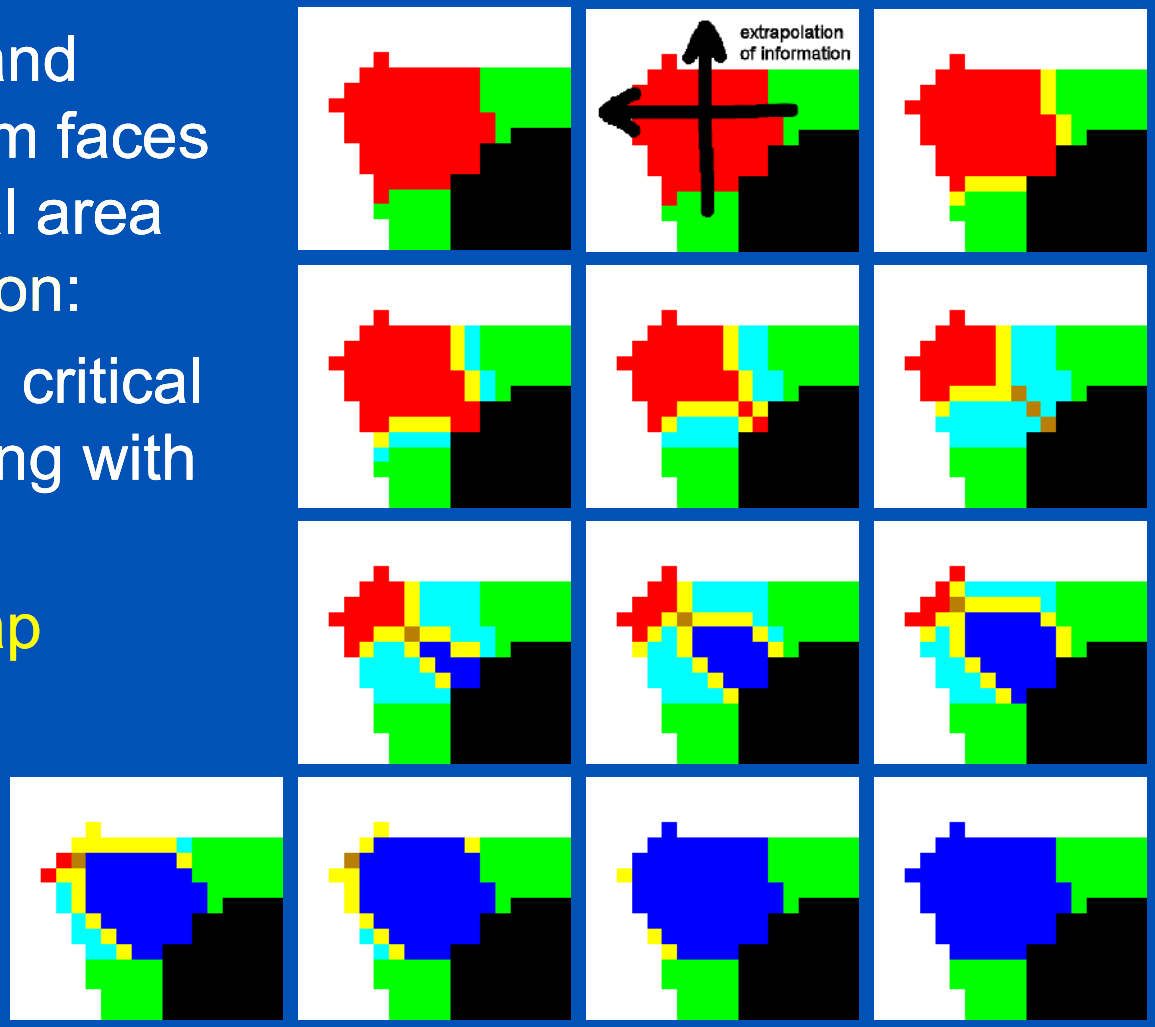




Stage 2 – Extrapolation

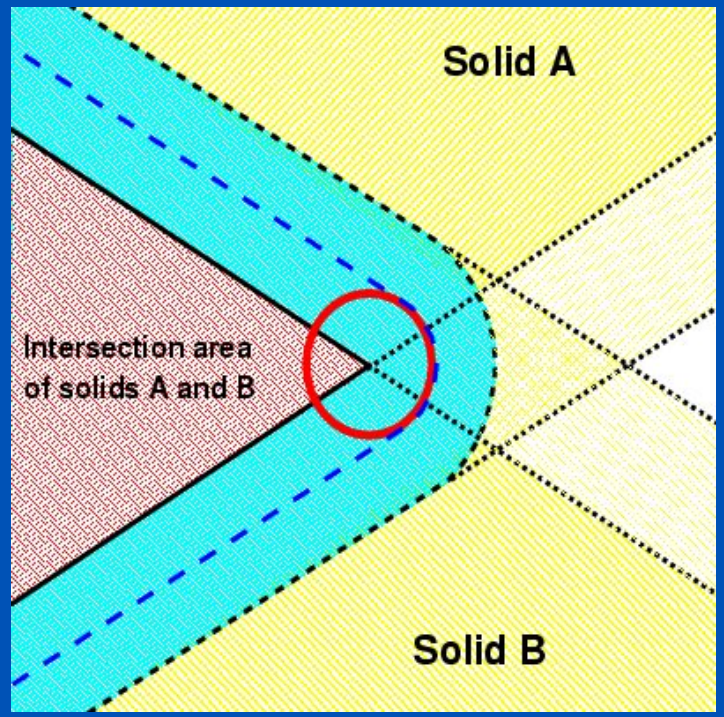
Transfer density and normal values from faces through the critical area by front propagation:

- Initialization – find critical voxels neighbouring with transitional area
- Fronts may overlap

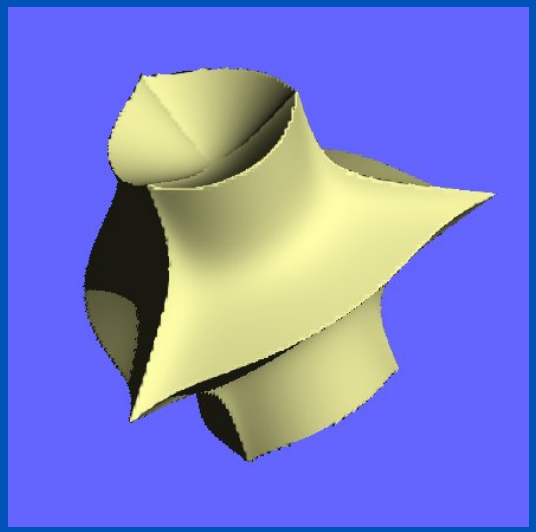
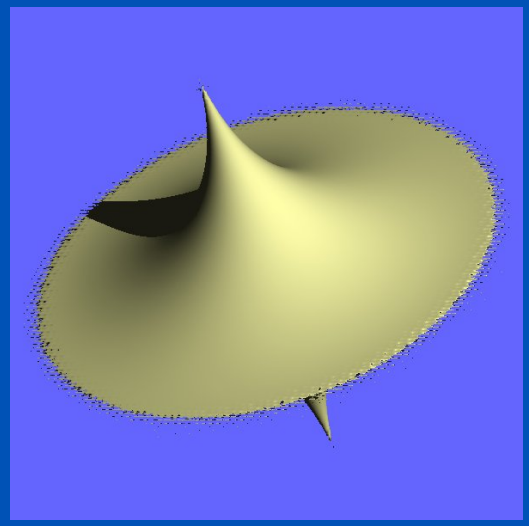
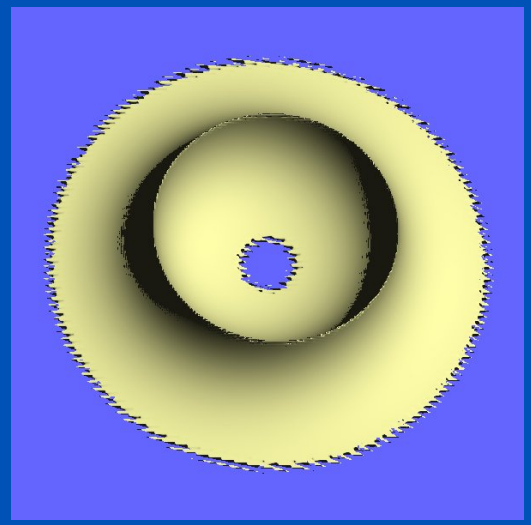
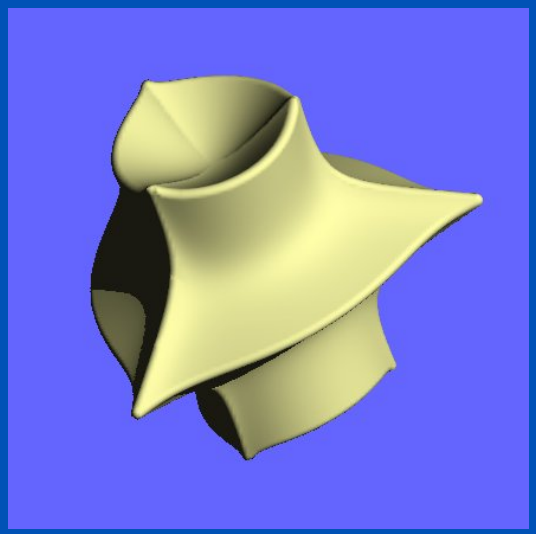
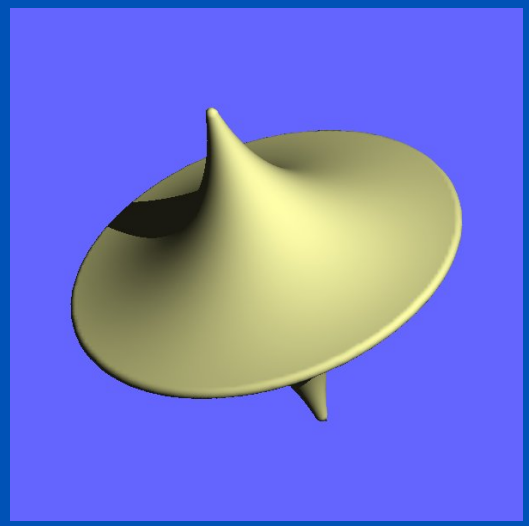
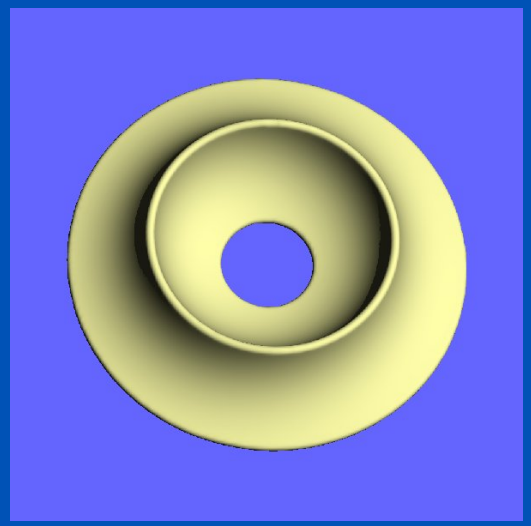


Stage 2 – Final Evaluation

- At the end of the front propagation – each critical voxel stores several values of density and gradient (description of several halfspaces)
- Resulting value: CSG intersection of halfspaces (according to our previous technique for CSG operations)

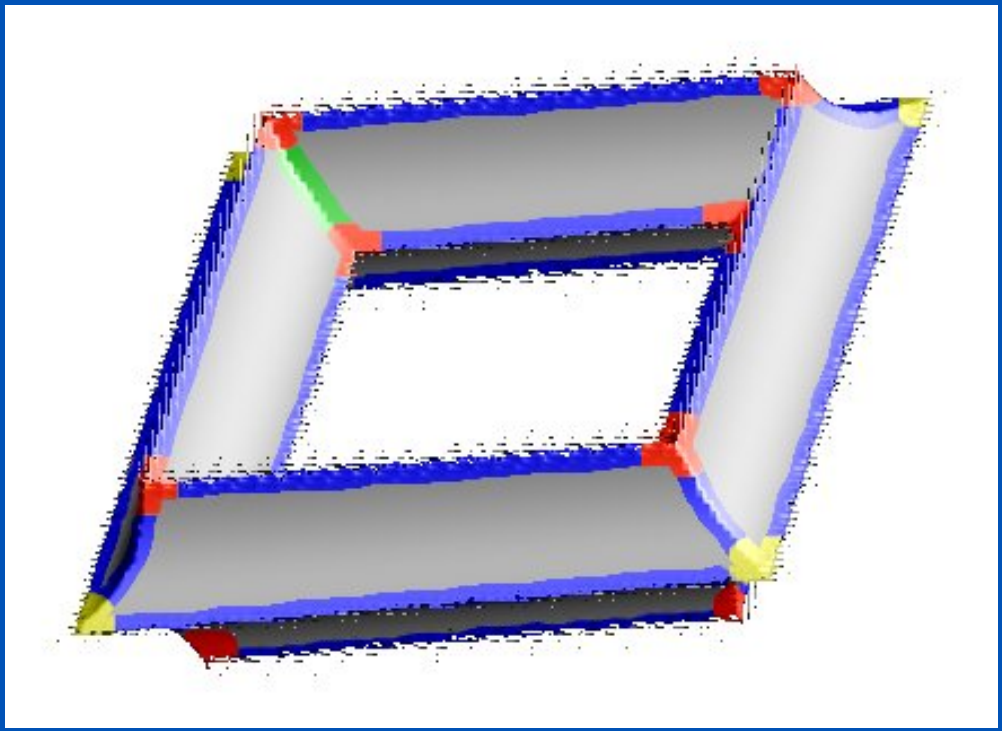


Results

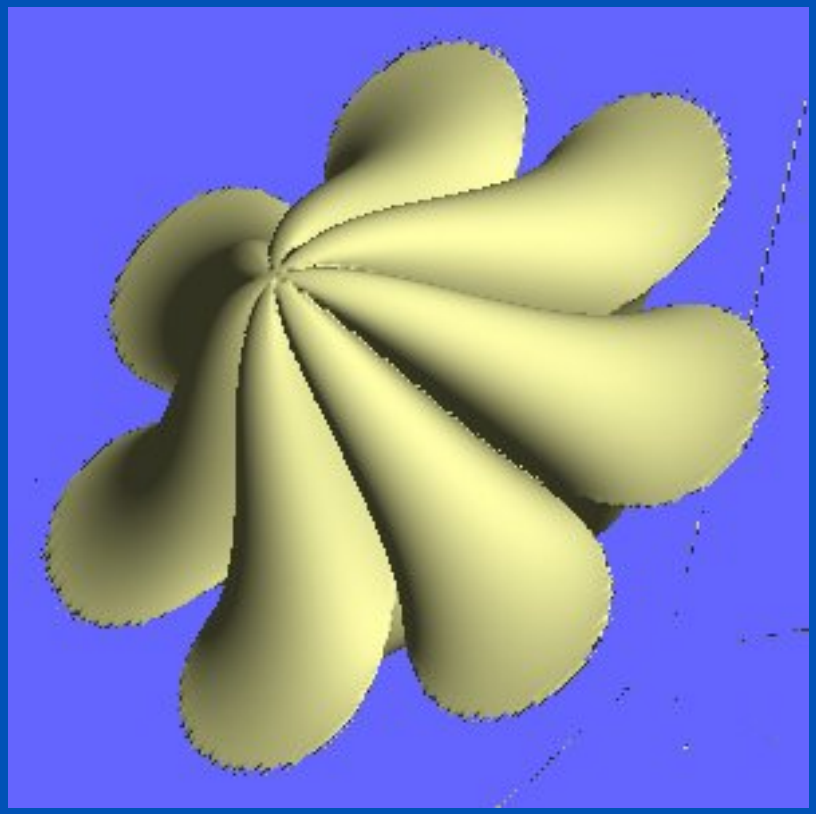
Open Problems

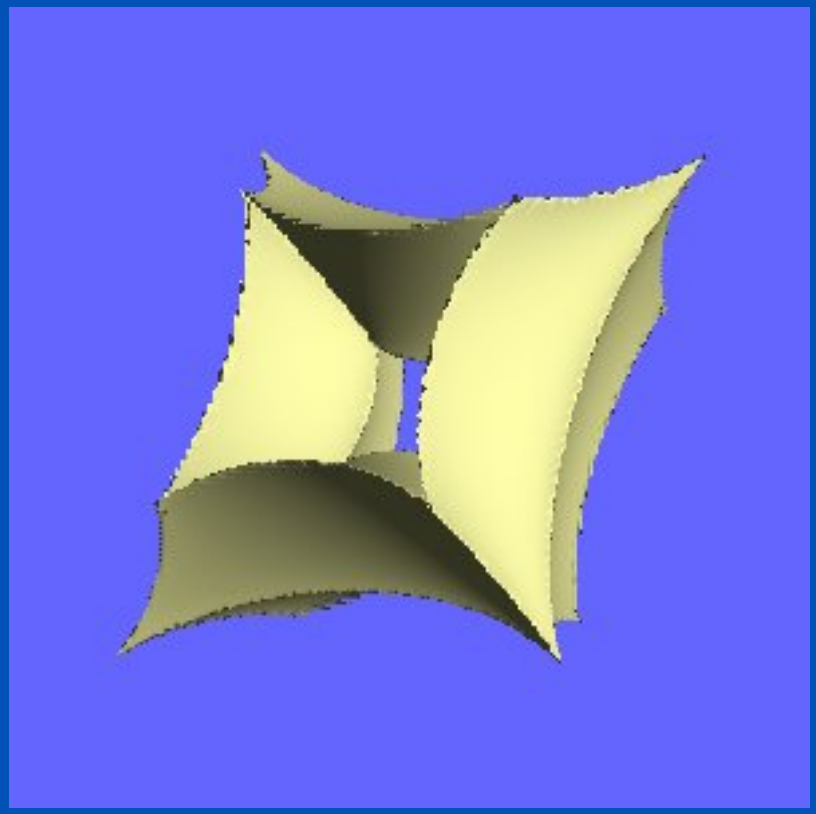
- Solids with non-convex sharp details **è** only CSG intersection operator is not sufficient **è** need for a further research…



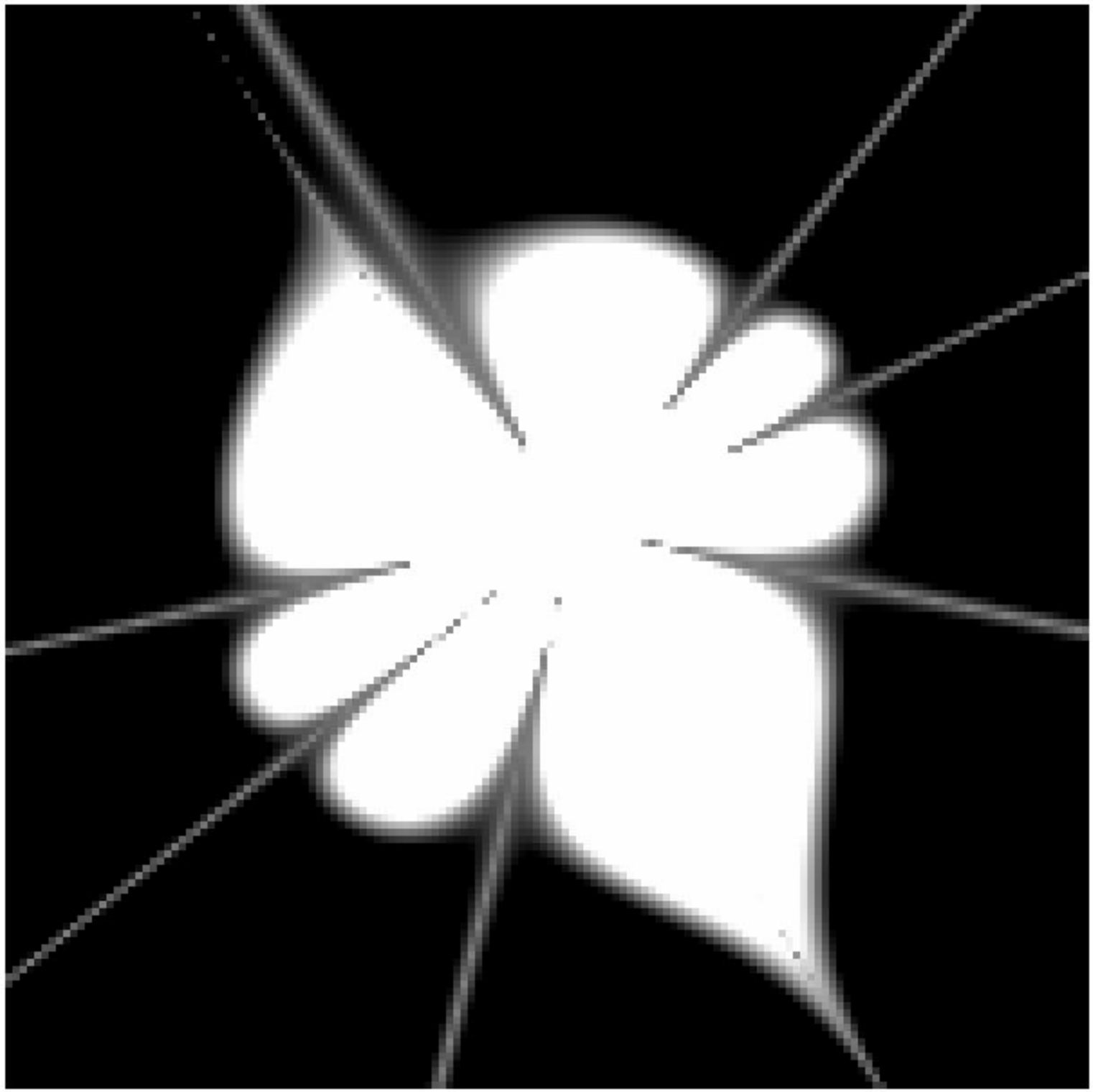
What is new?

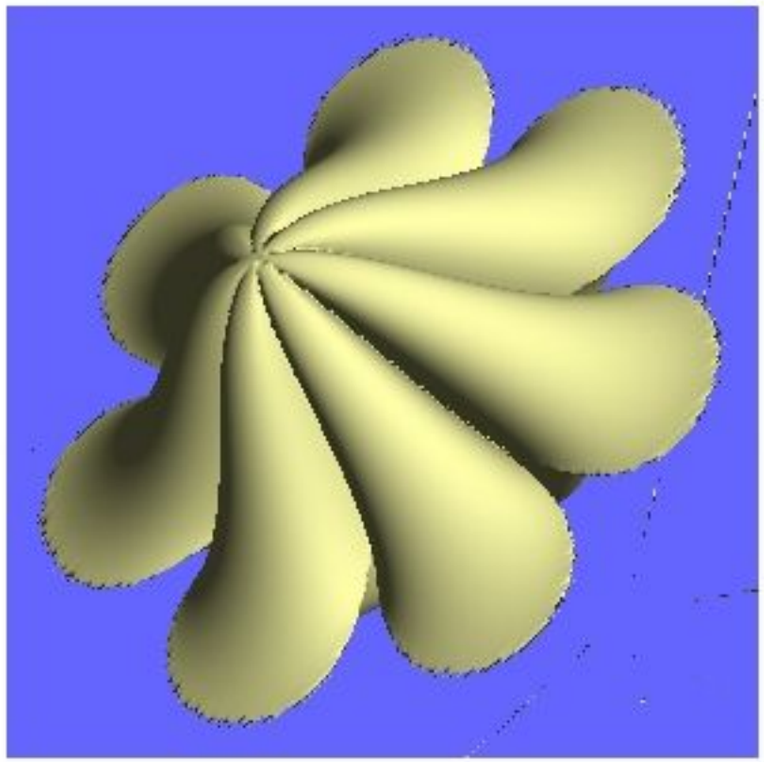
Solids with Non-convex Sharp Details



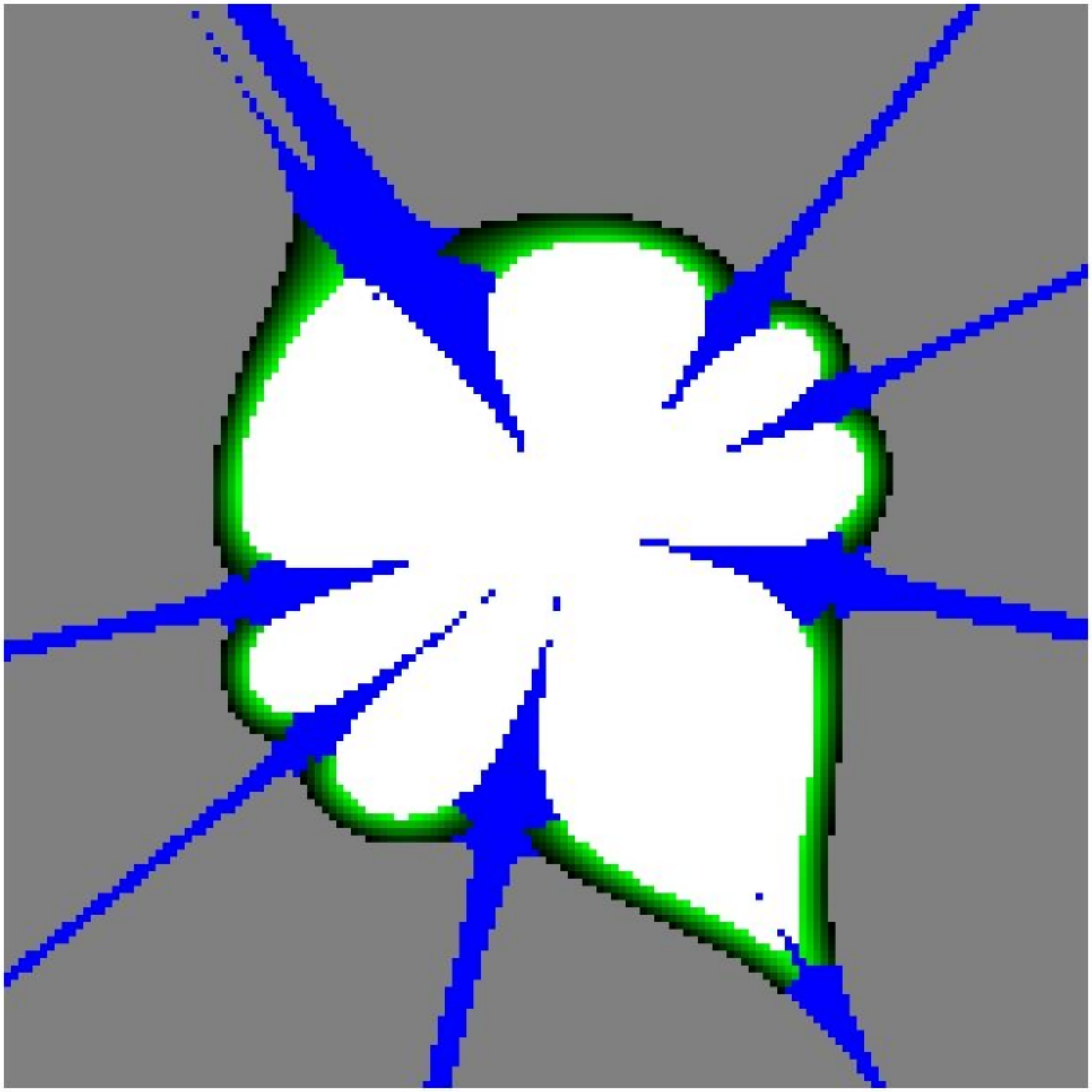


Switch to an alternative way of the presentation… J





Trivial Voxelization



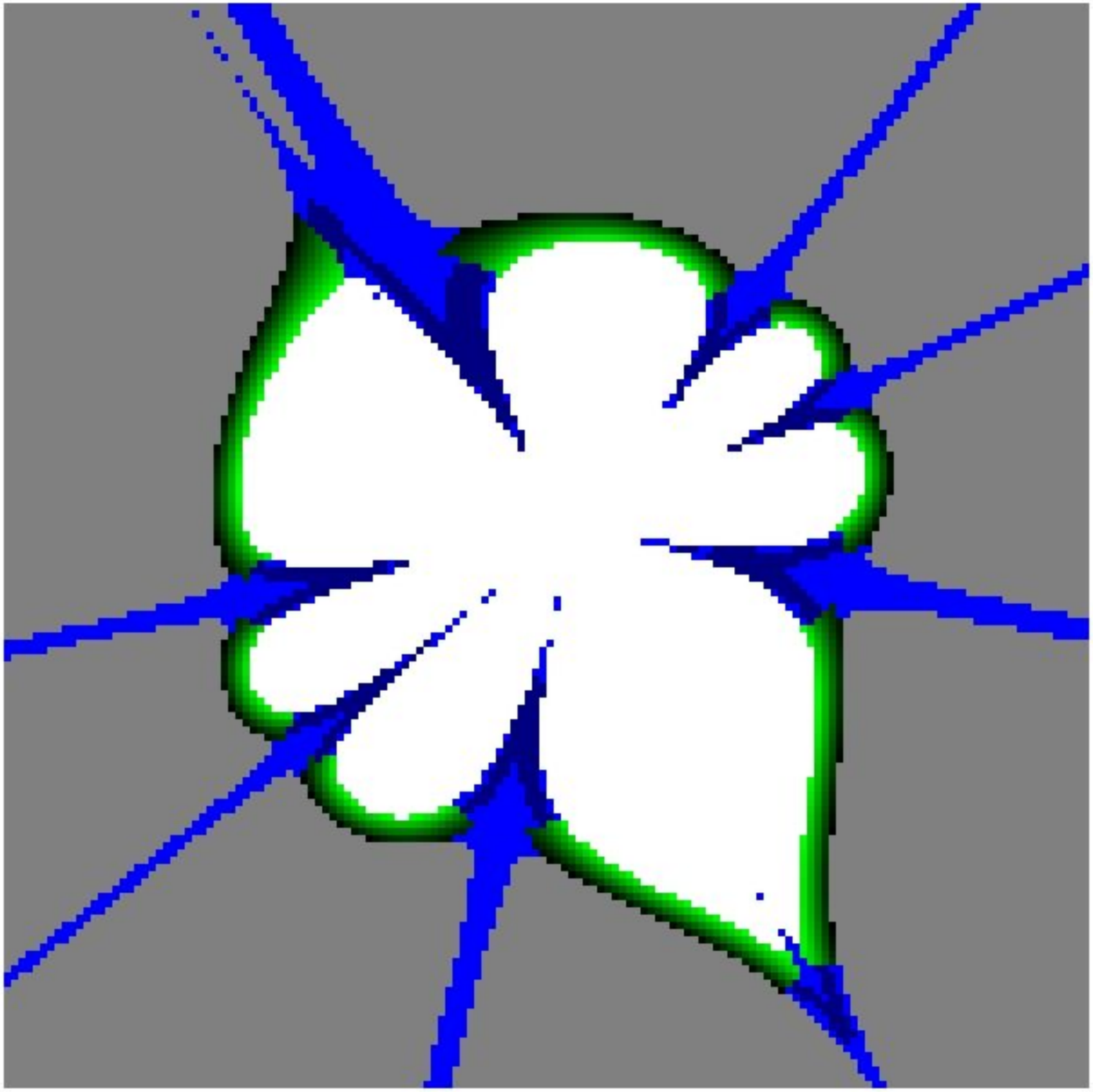
Classification:

Outside

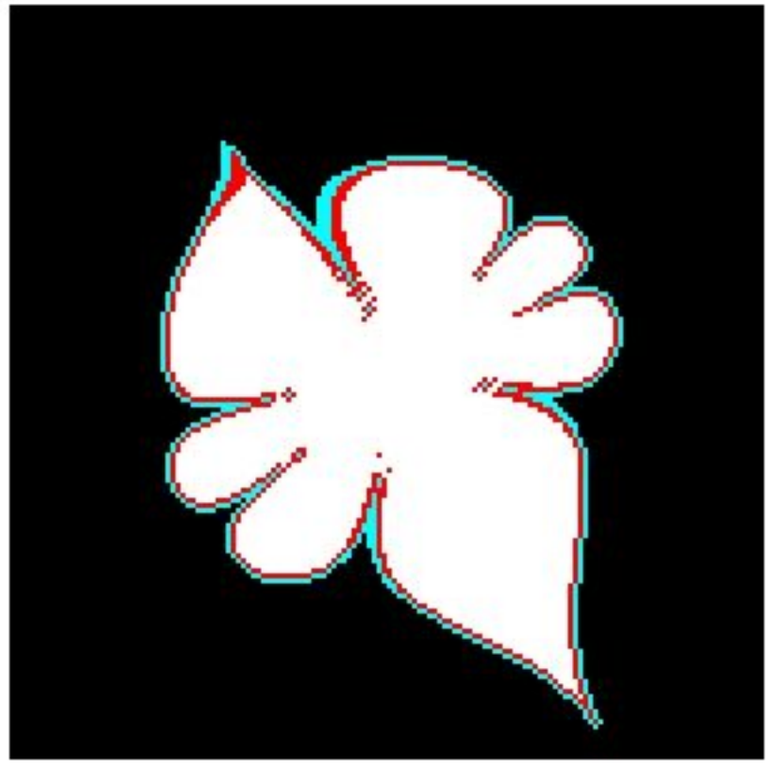
Inside

Transient

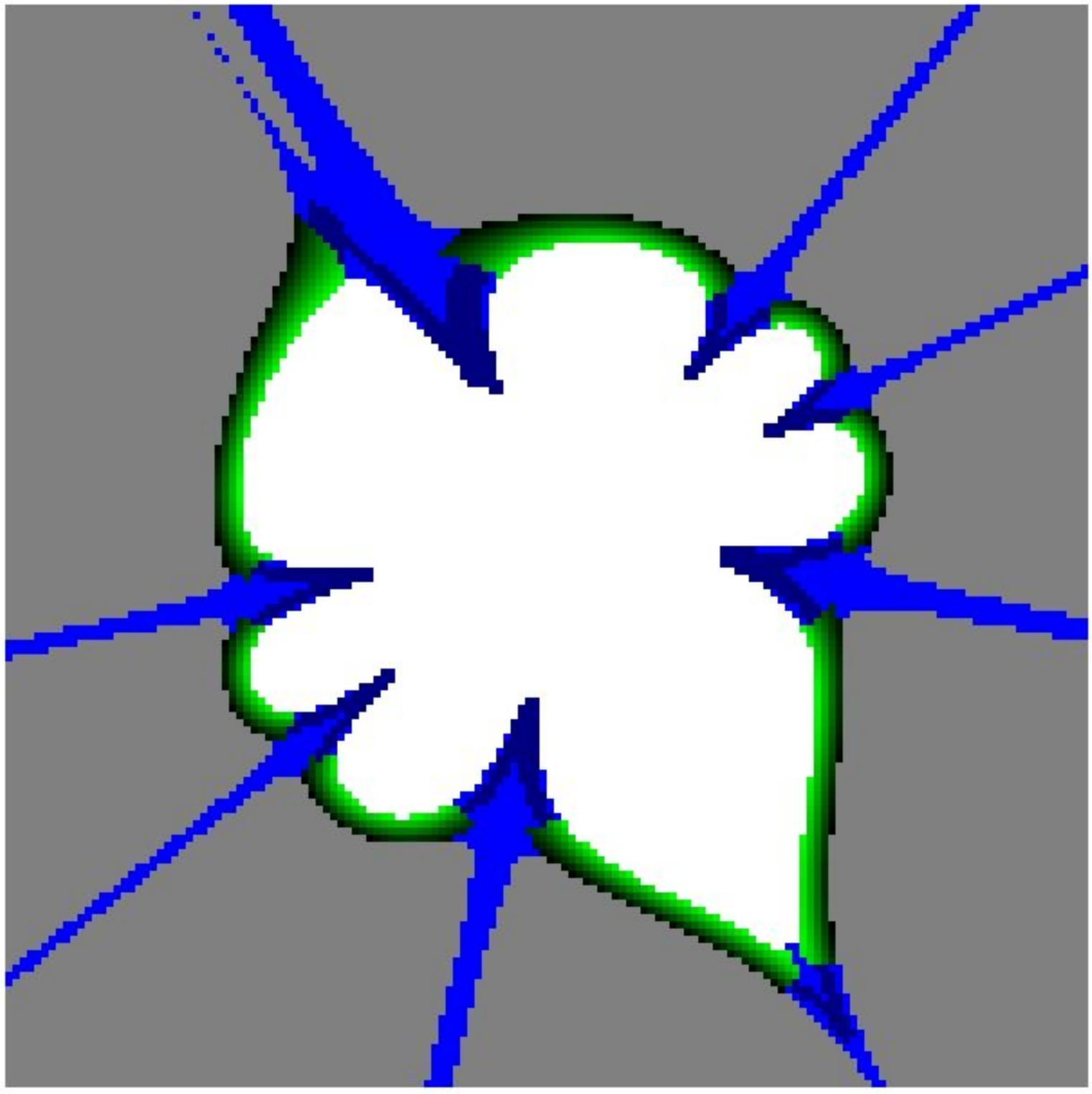
Critical



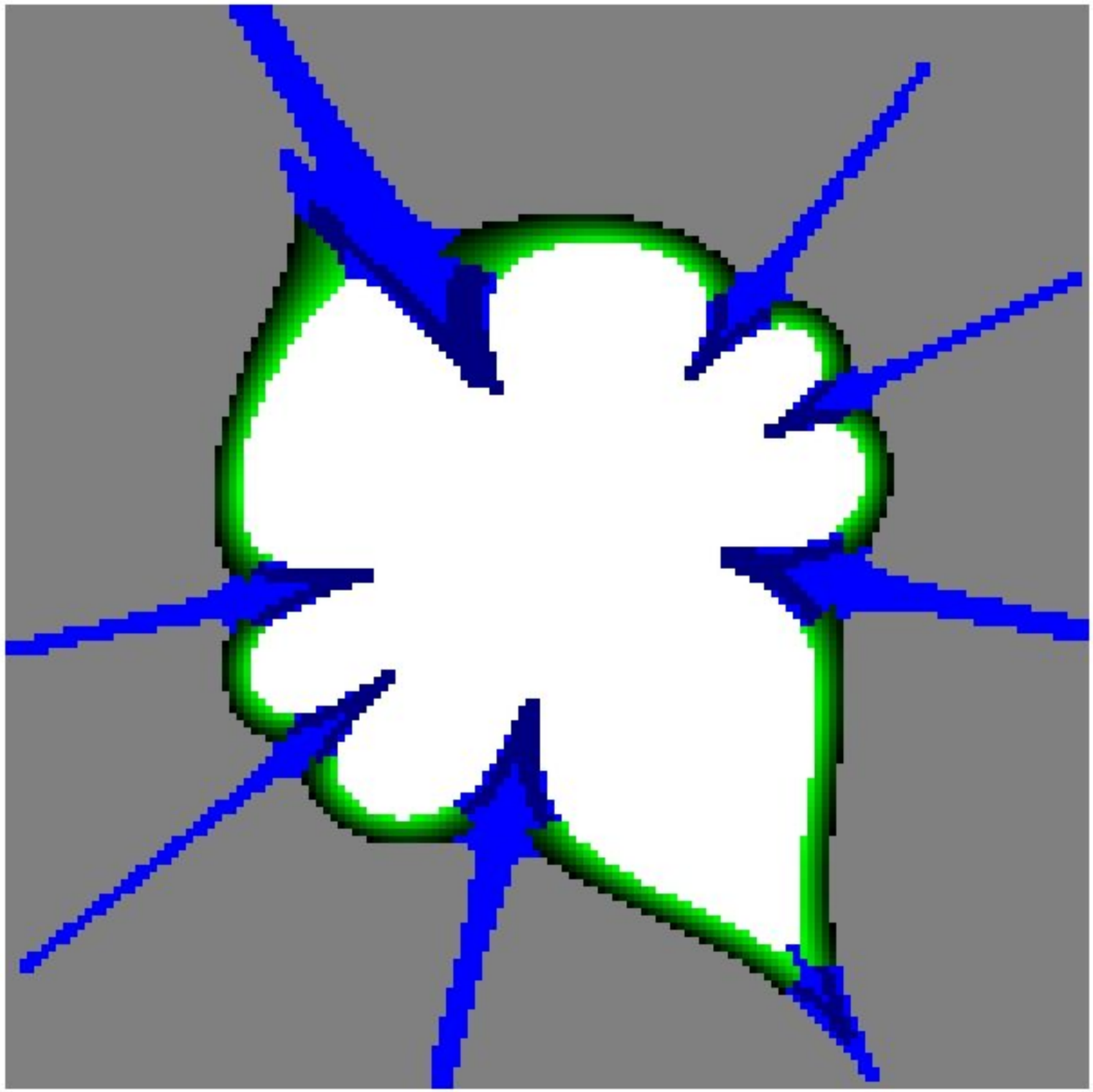
Binary Classification

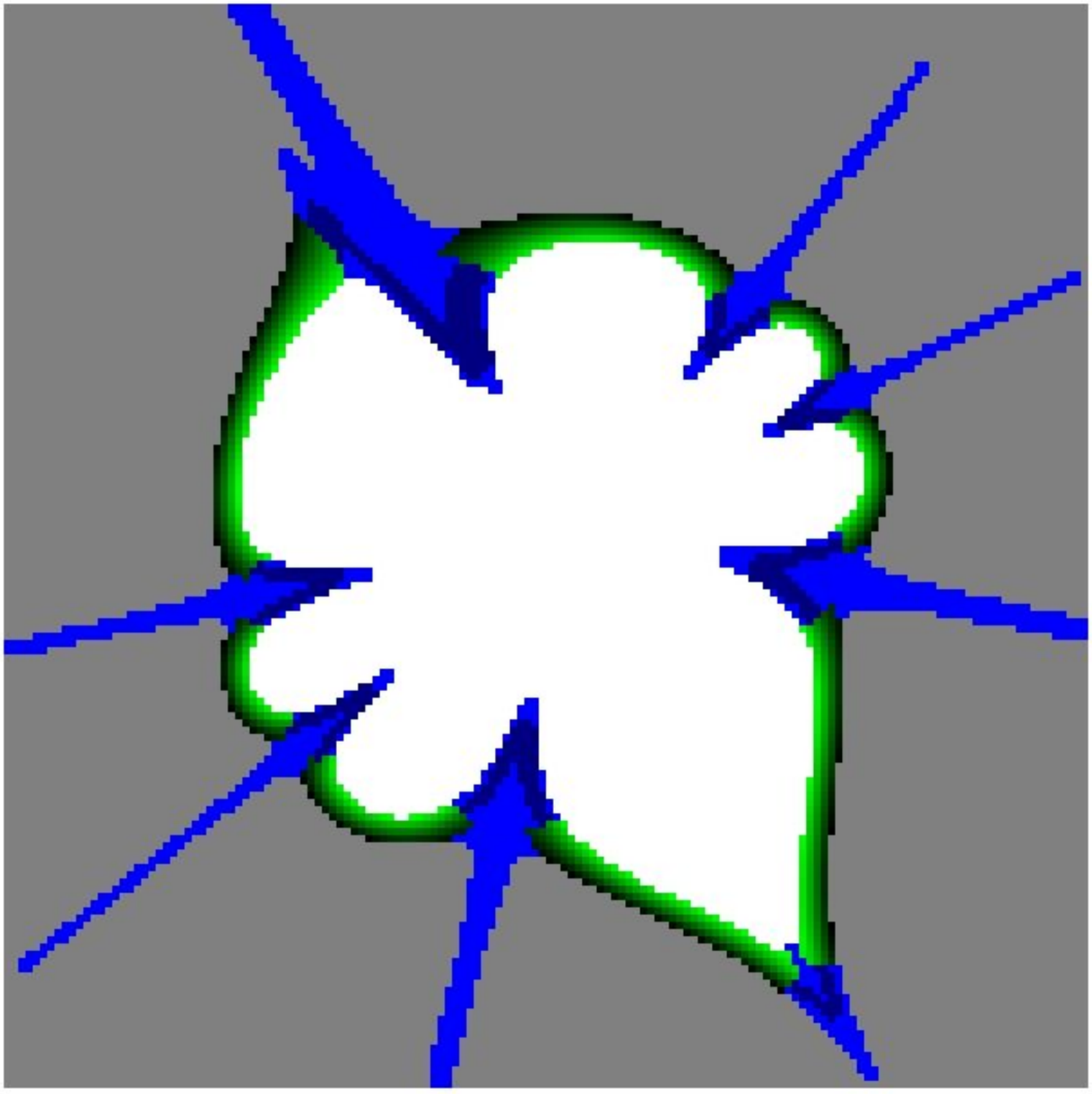


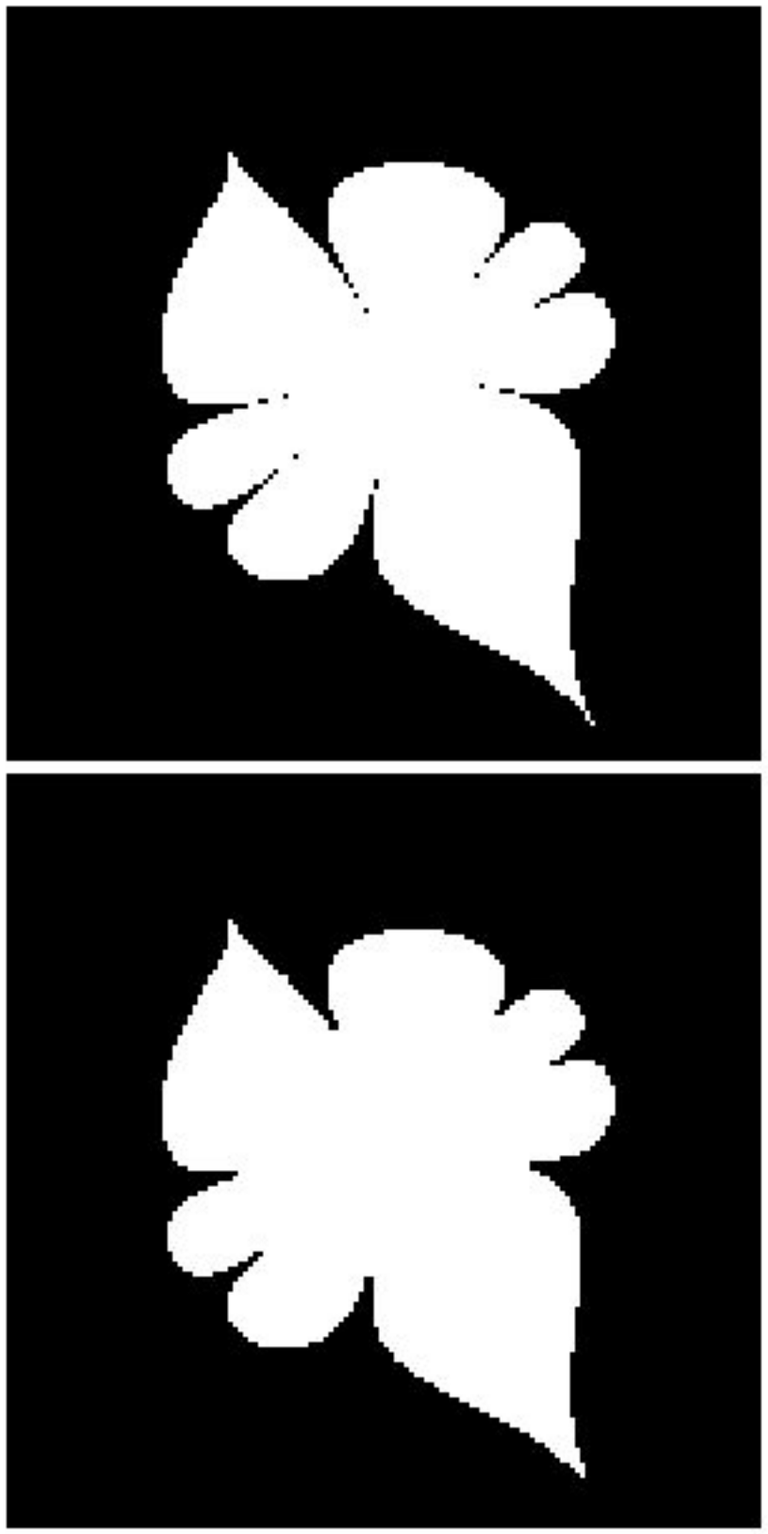
...used to determine Boundary voxels



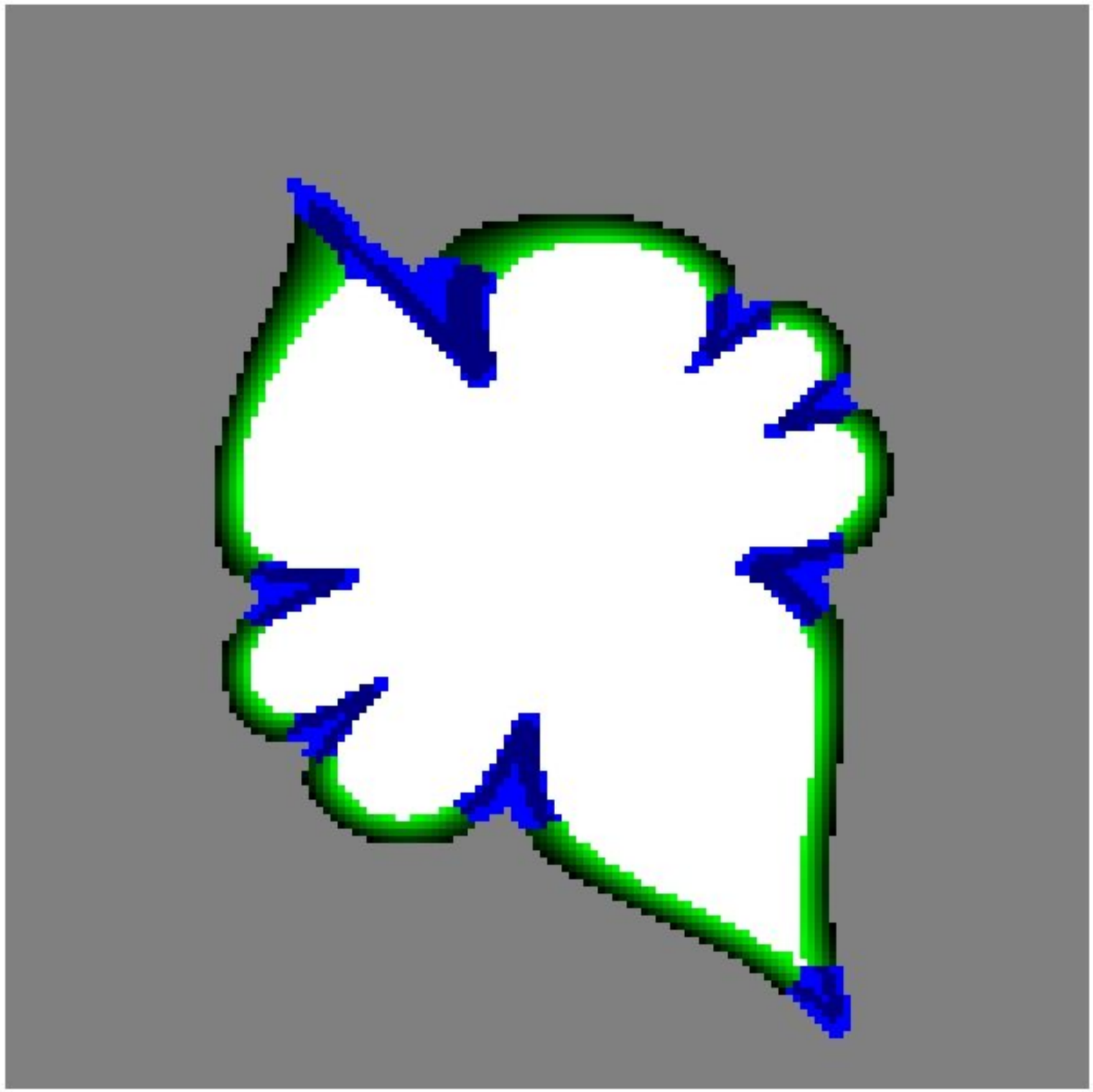
Modified version of the opening operator applied to the critical area



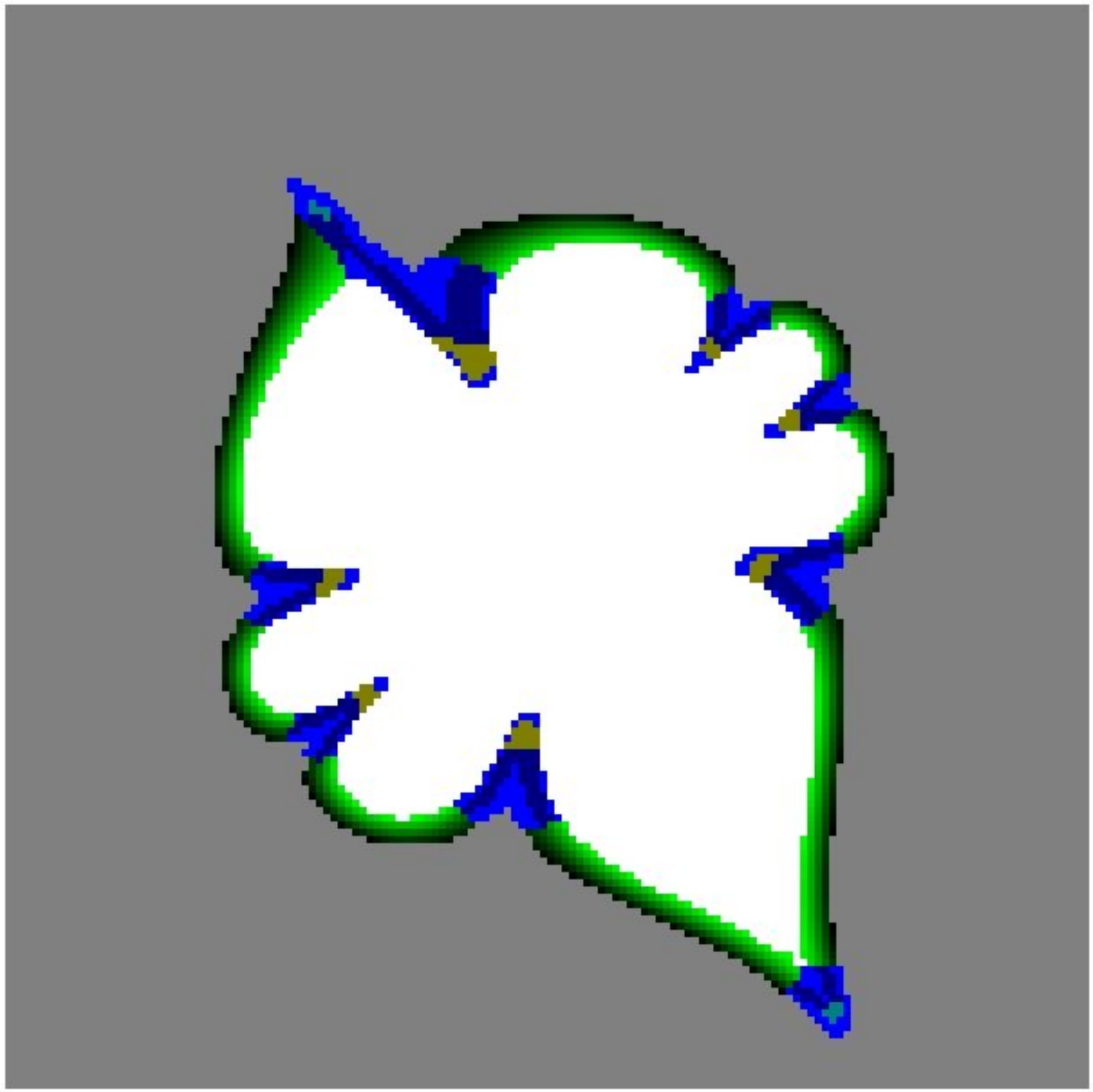




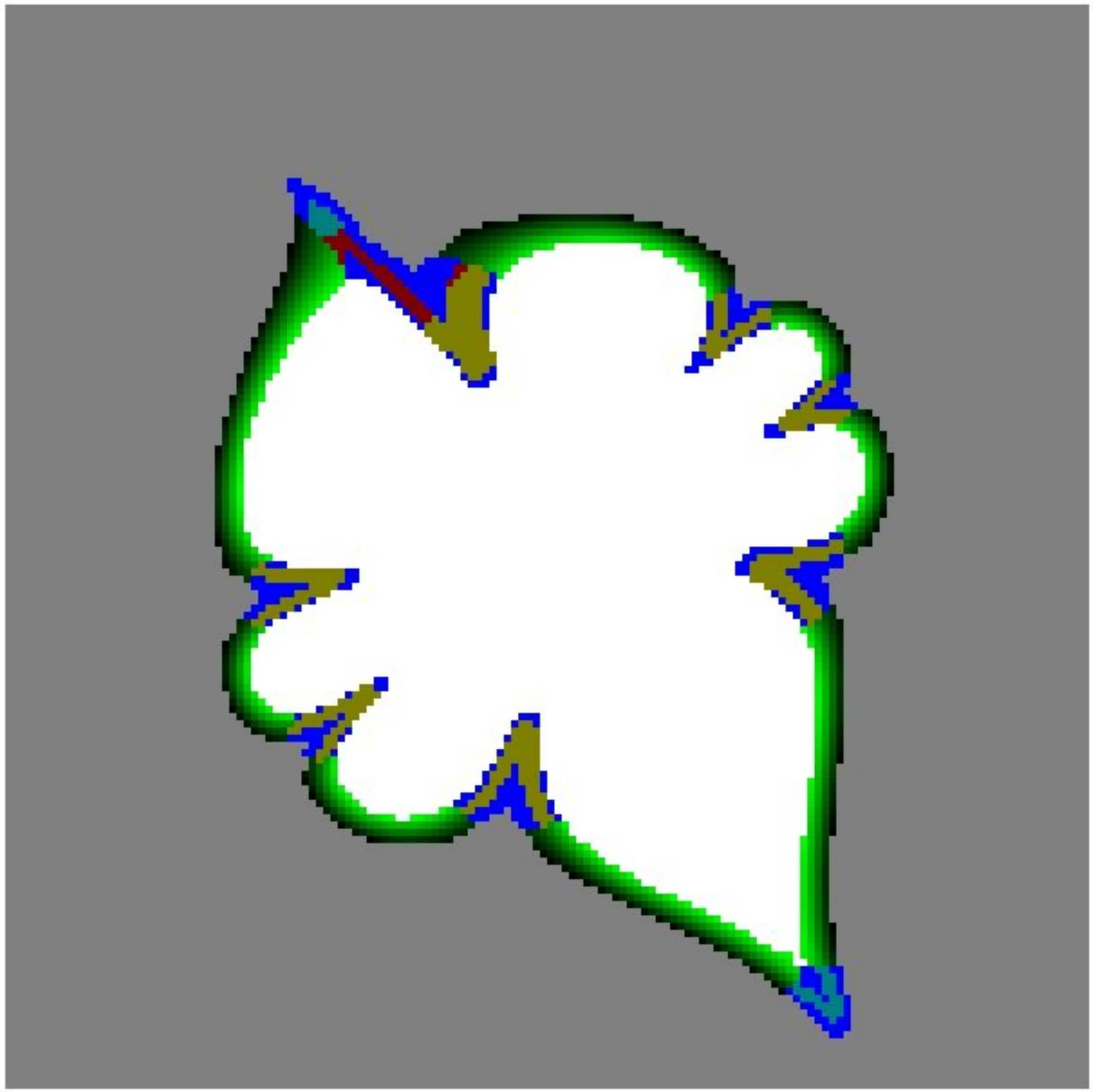
Remove noise from the binary classification



Only areas near to the boundary are "interesting"

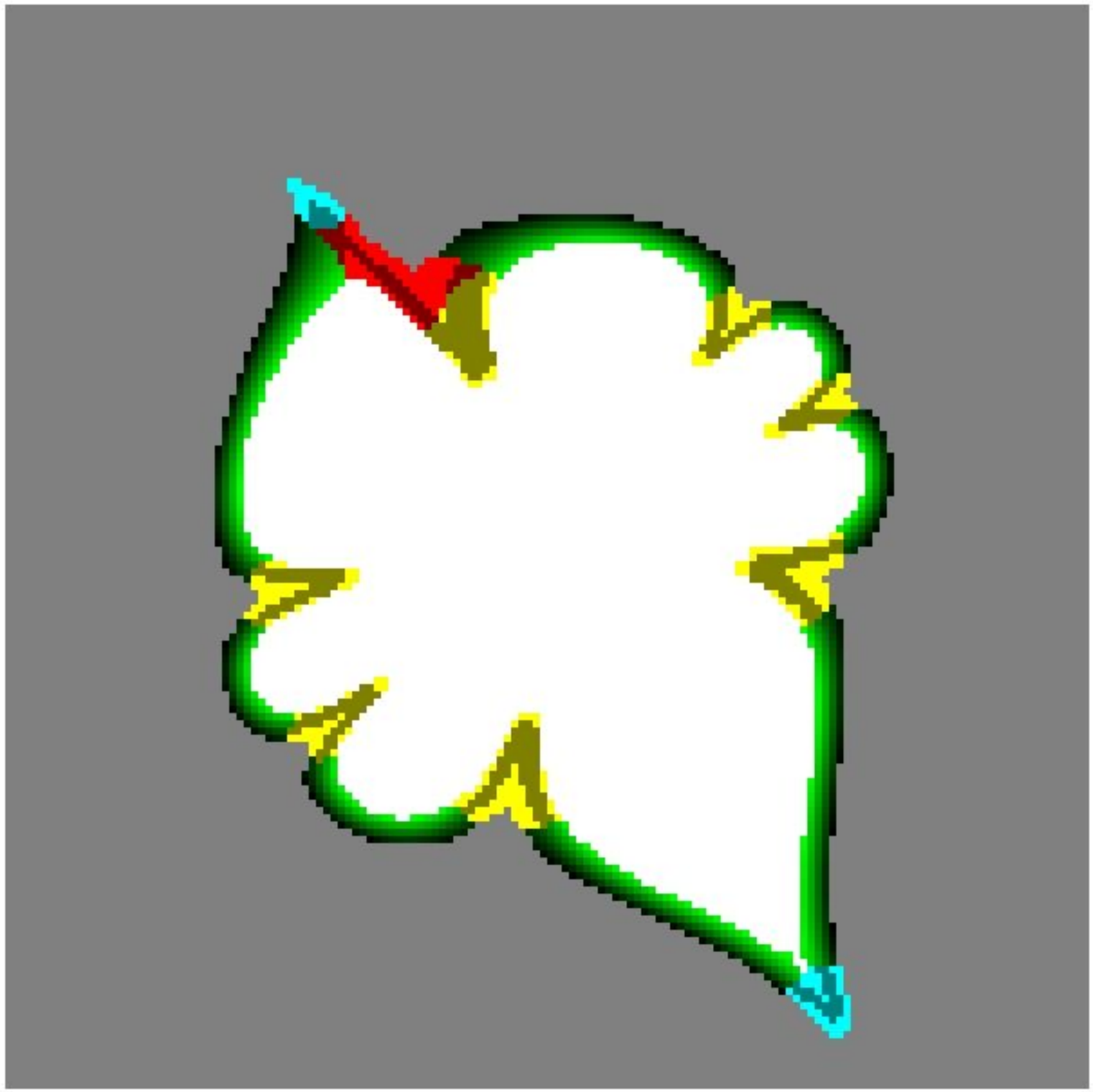


Convex and Concave boundary voxels are determined using binary voxelization

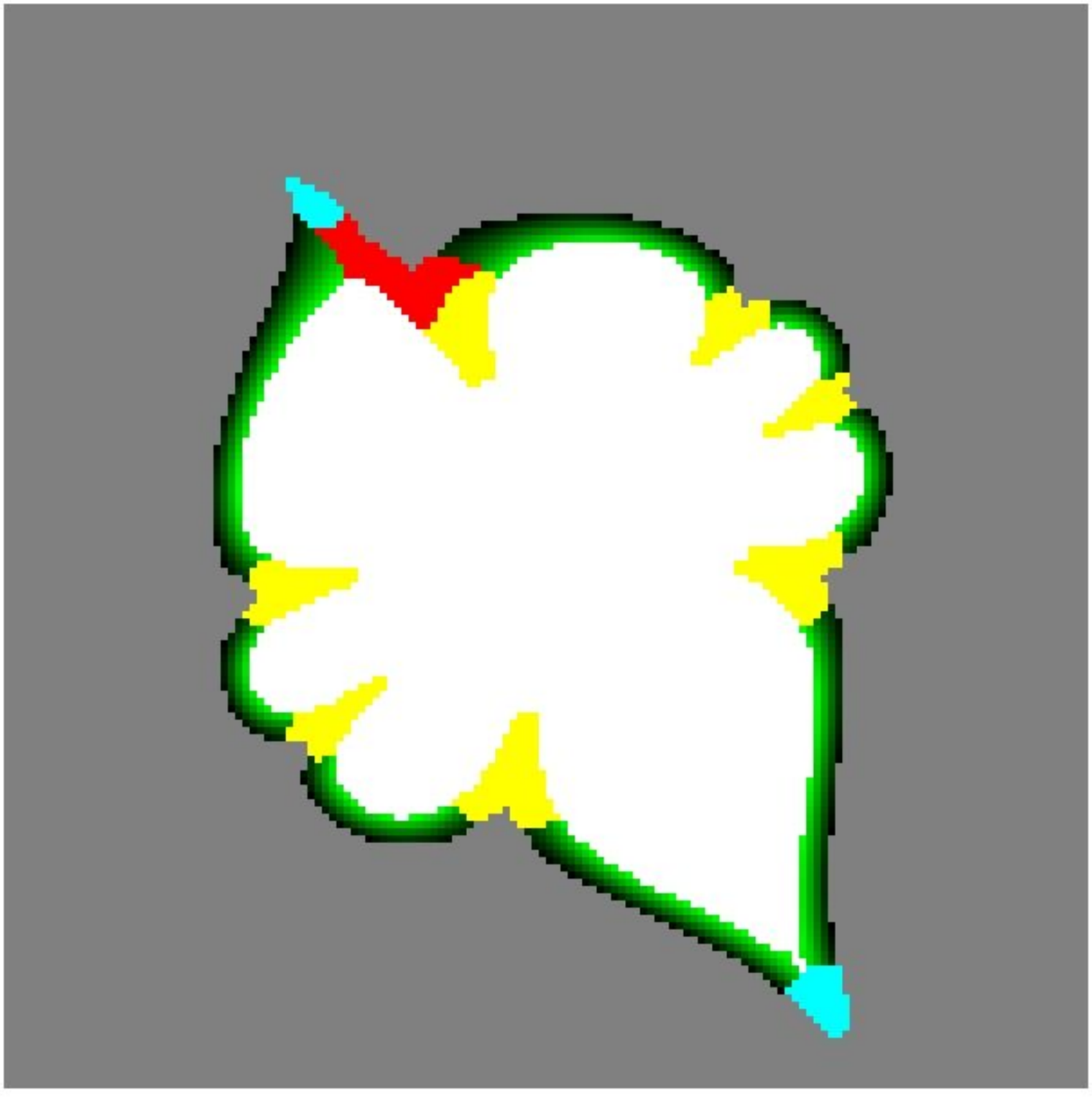


All boundary voxels are classified according to their distance from the original convex and concave voxels

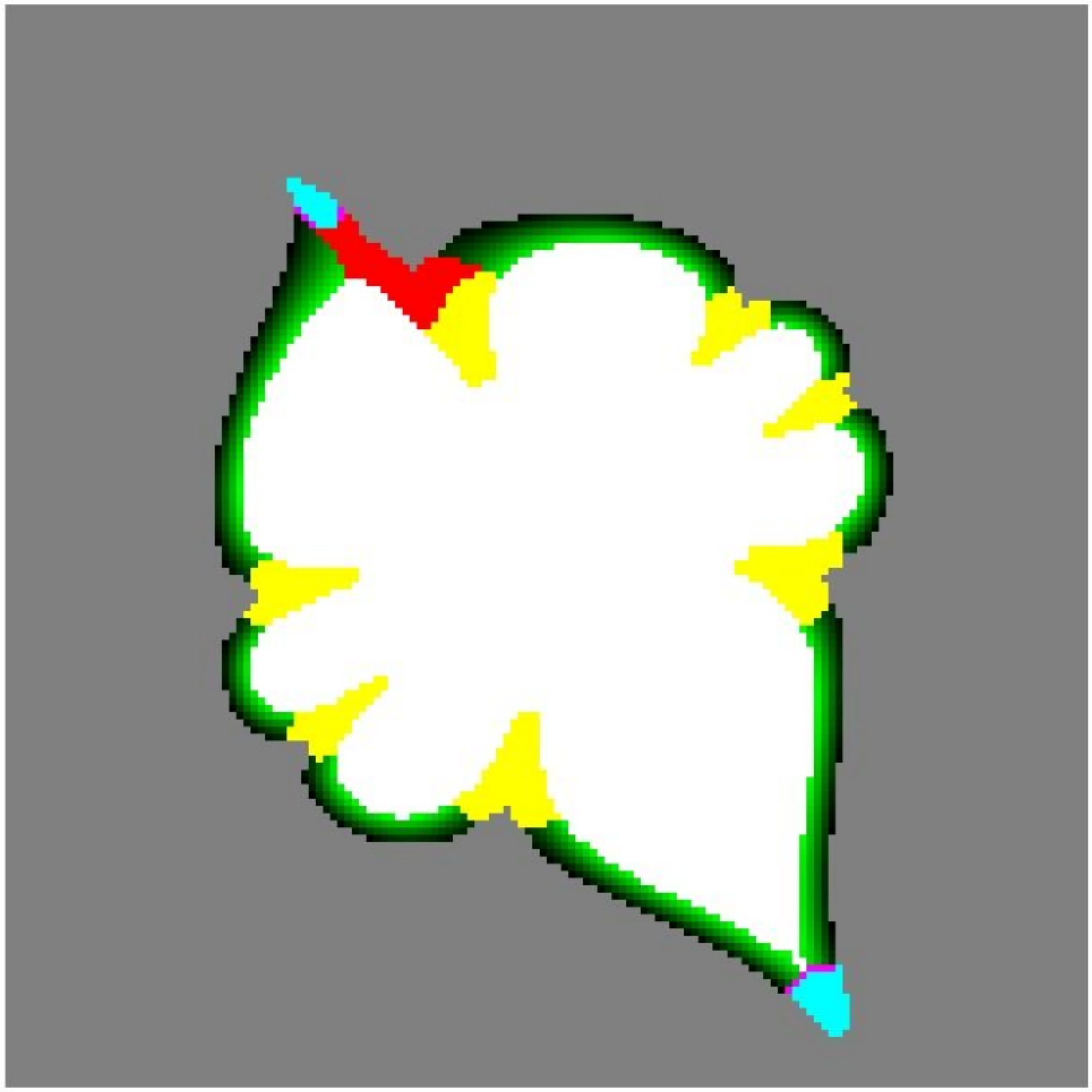
convex inflex concave



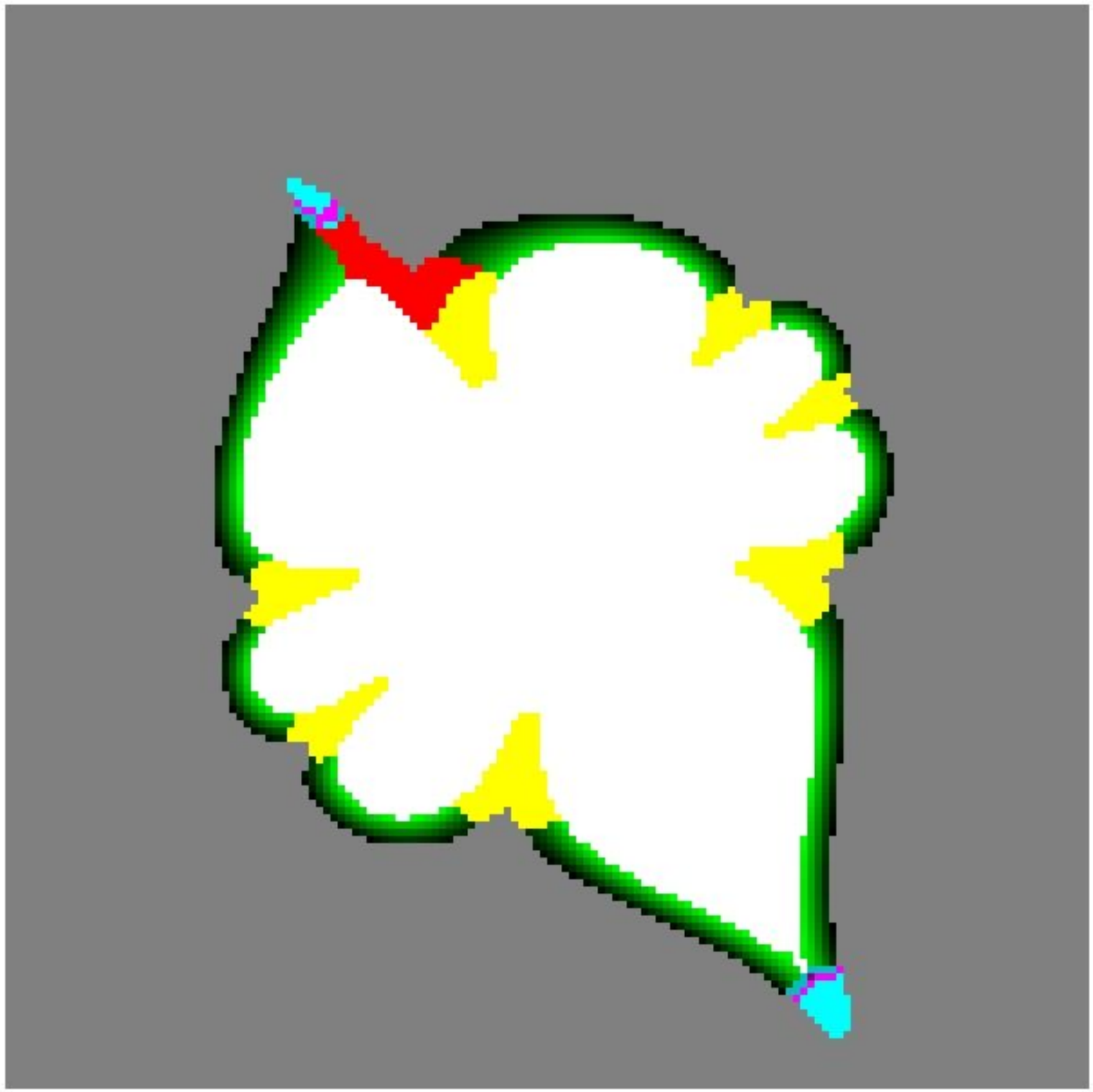
Extension of classification to the rest of the critical area

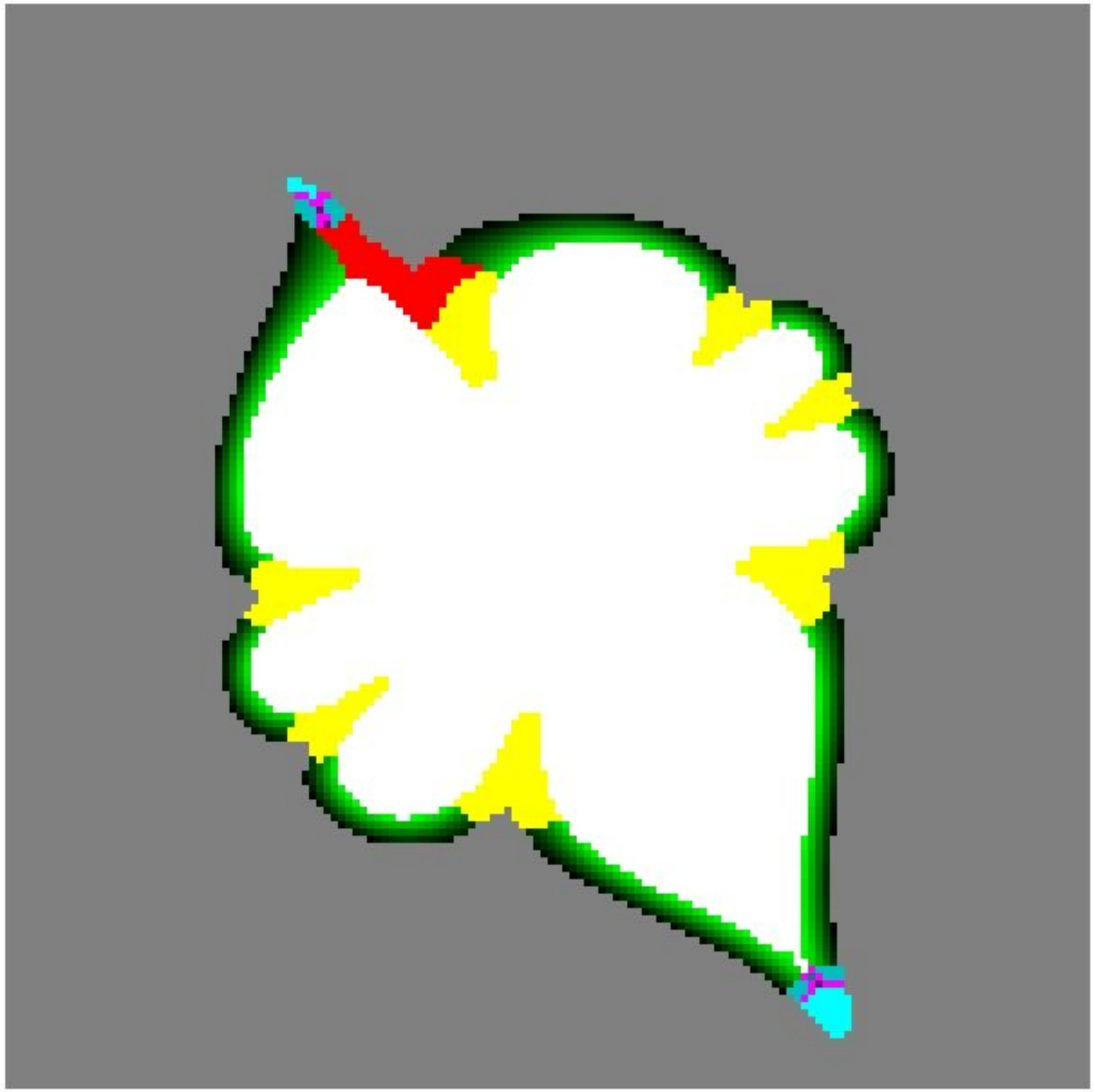


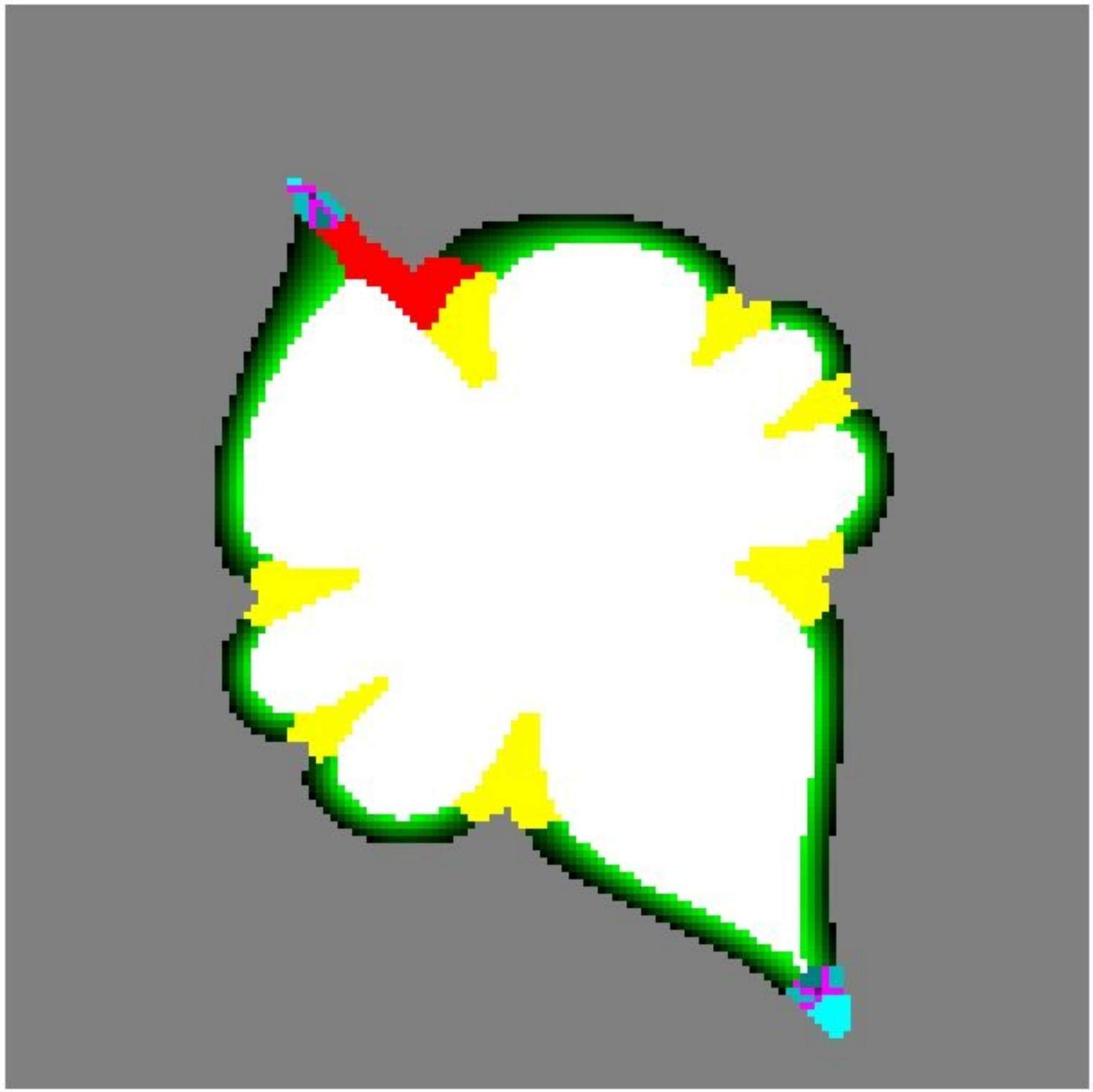
We do not need to know boundary voxels any more.

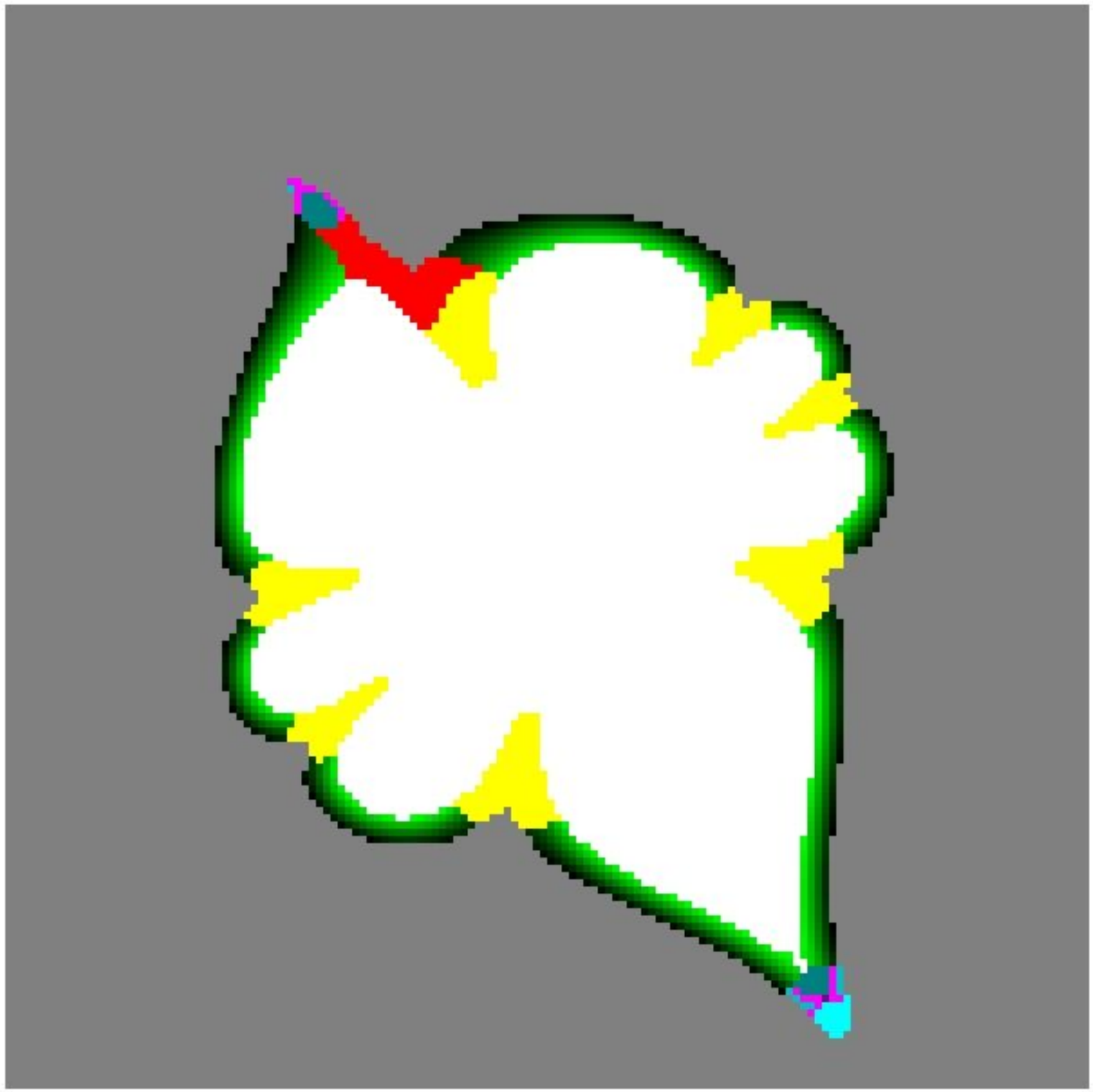


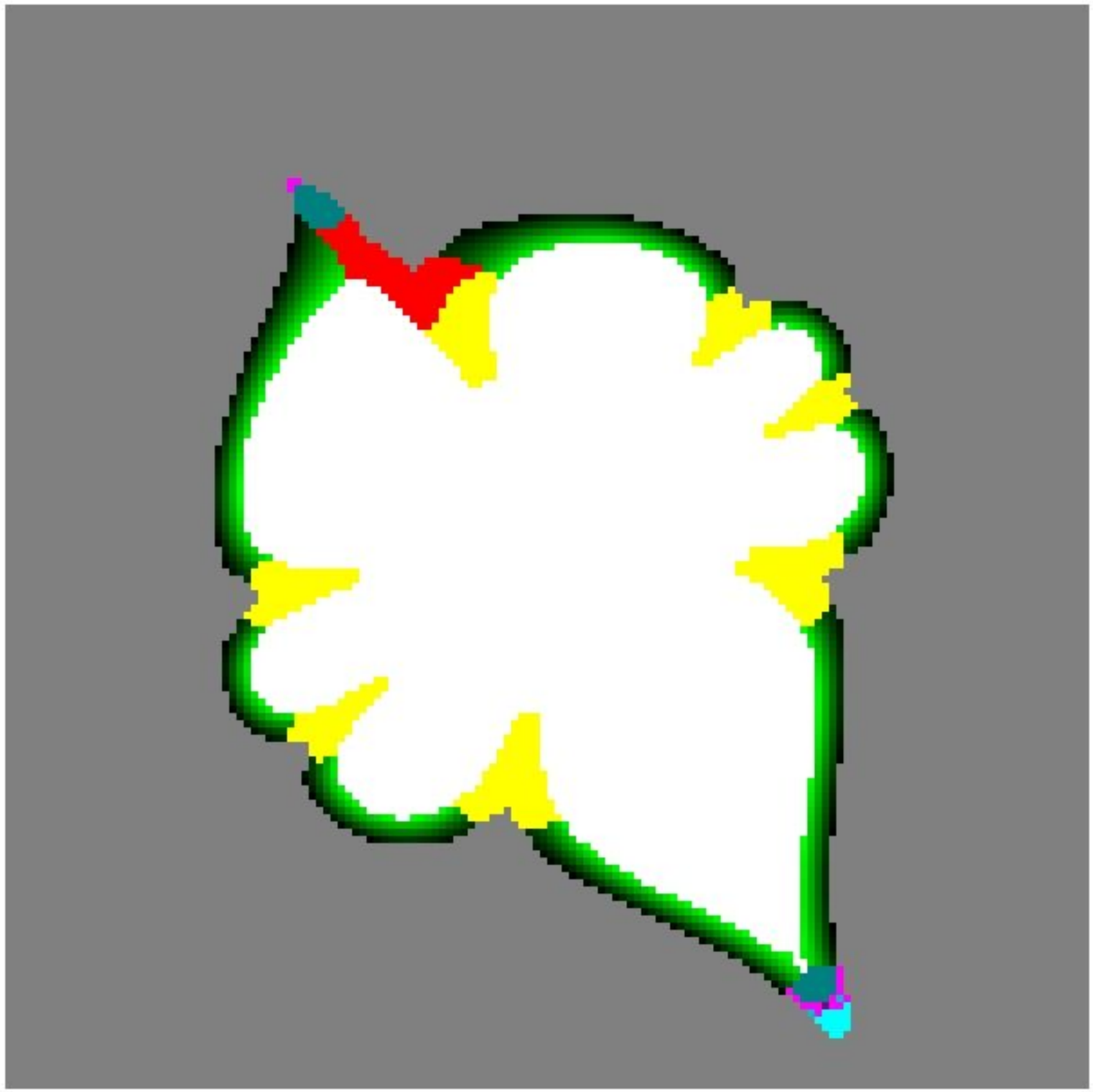
Front propagation in the convex area

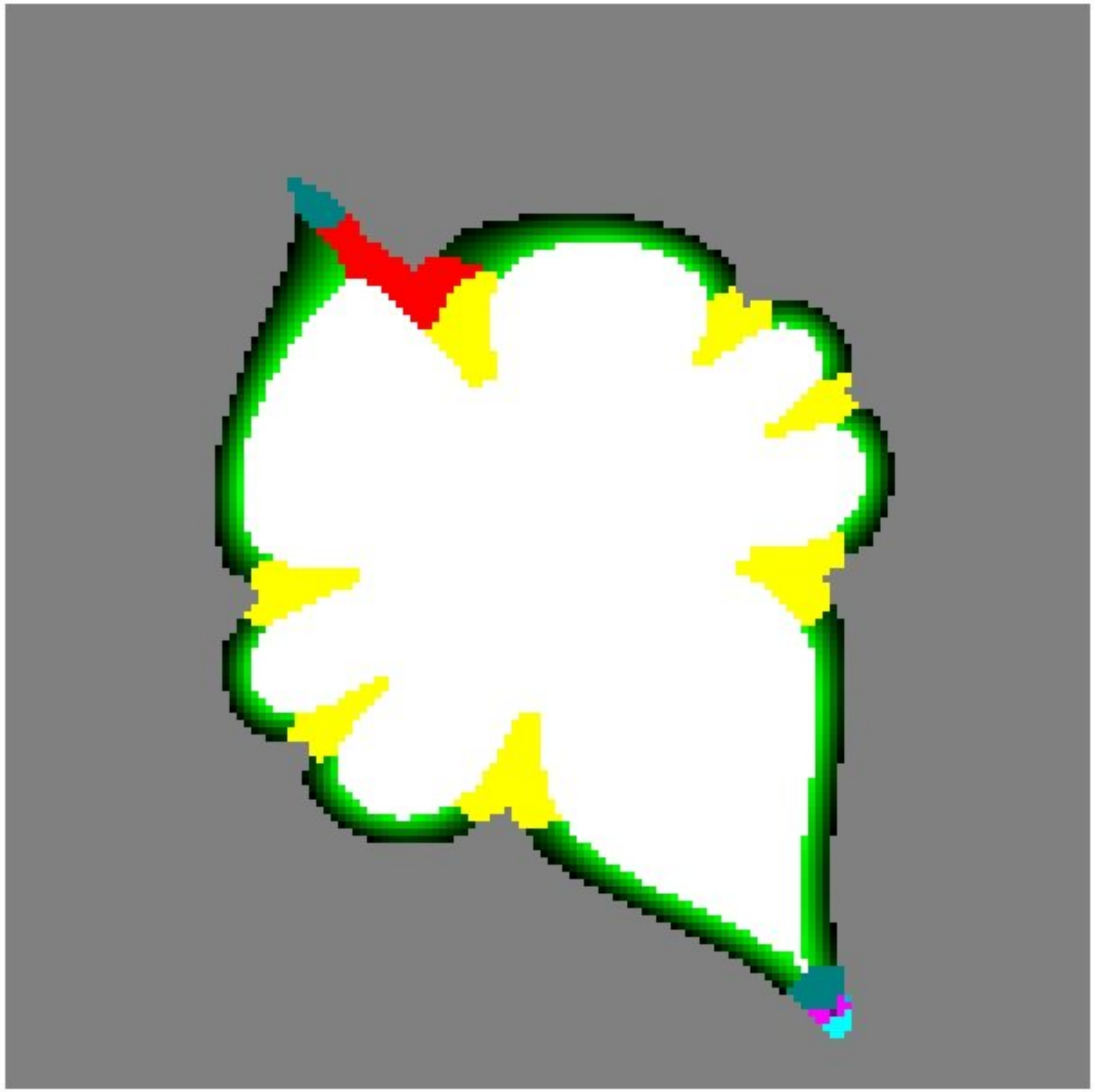


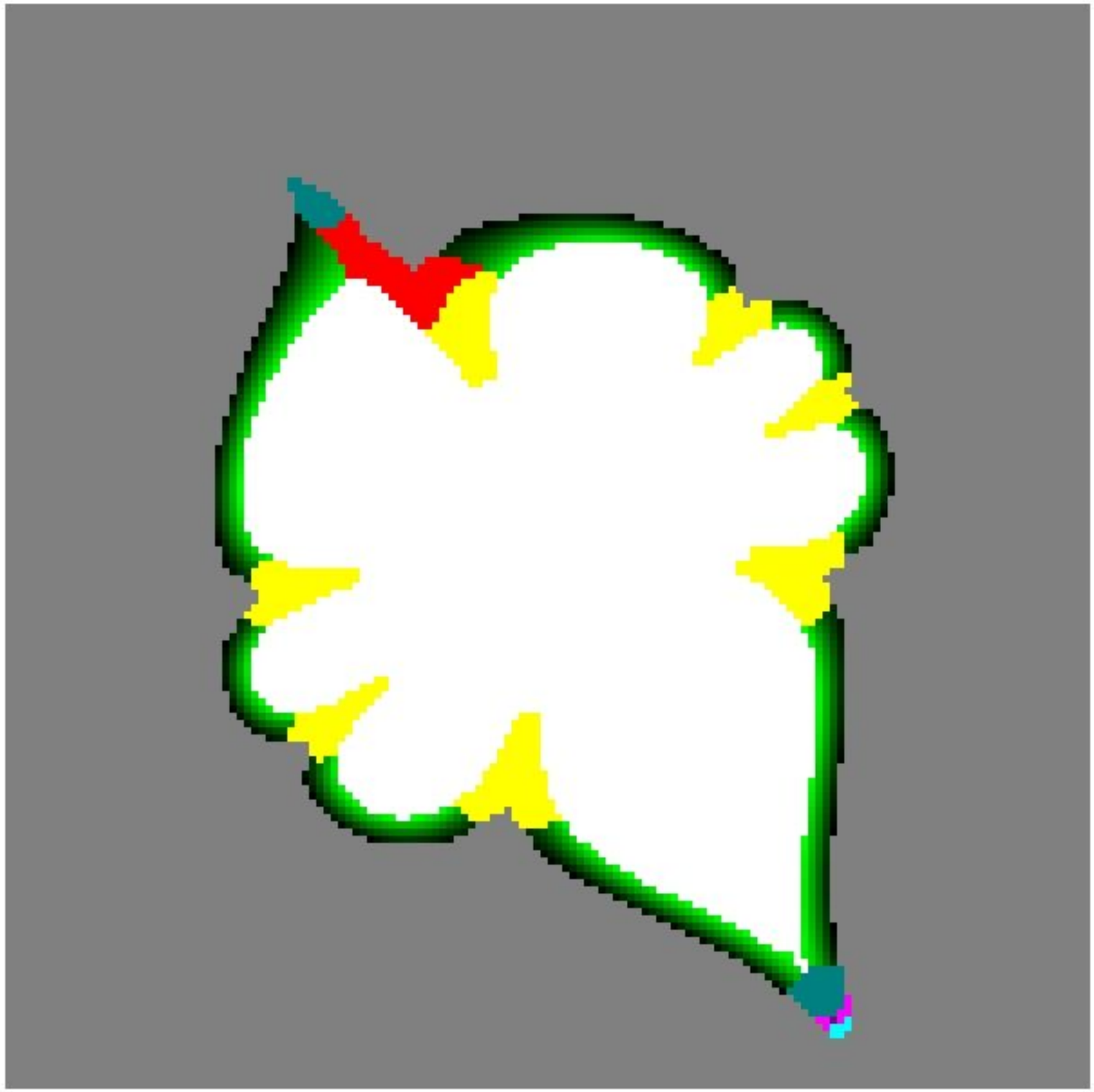


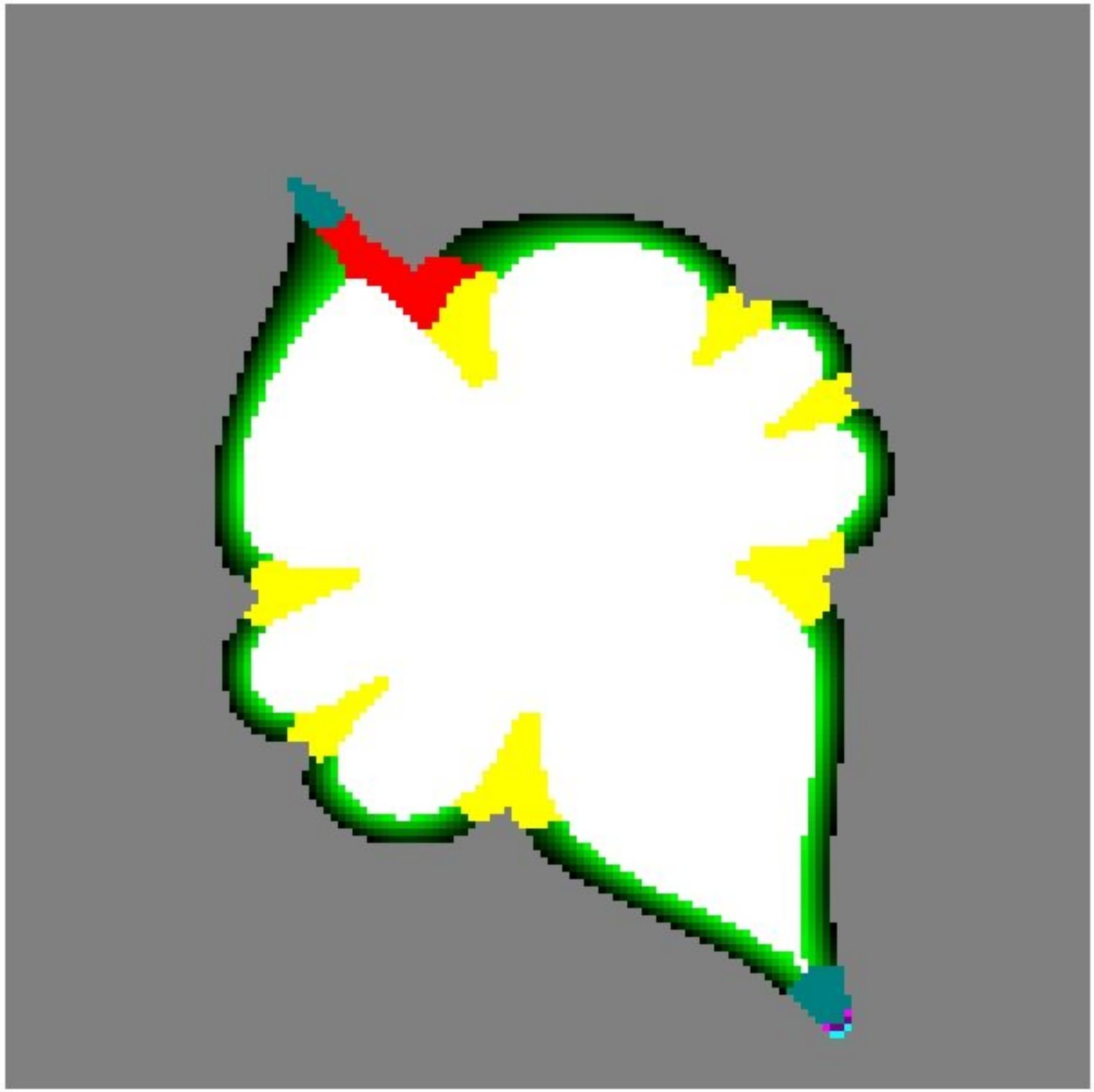


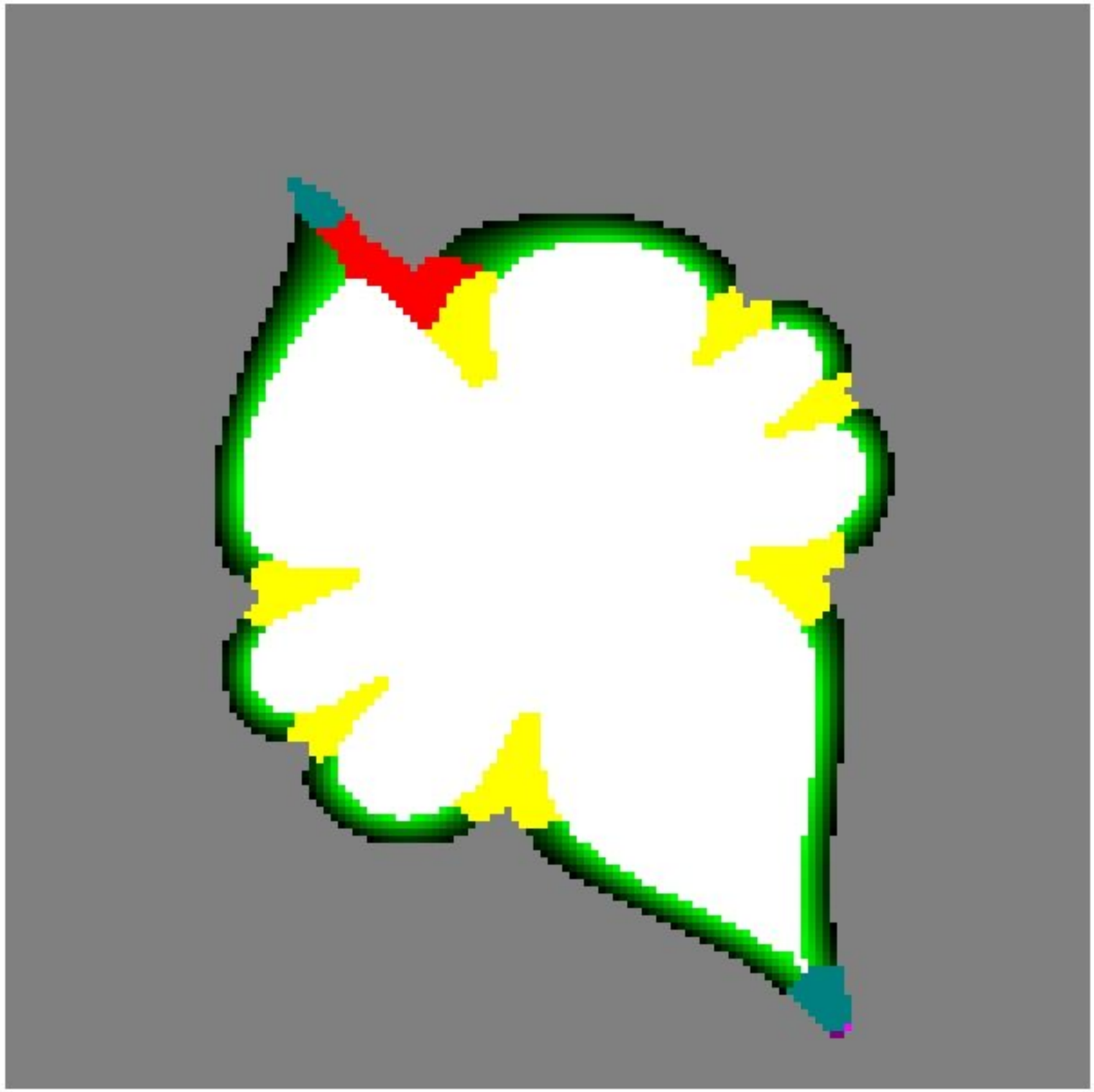


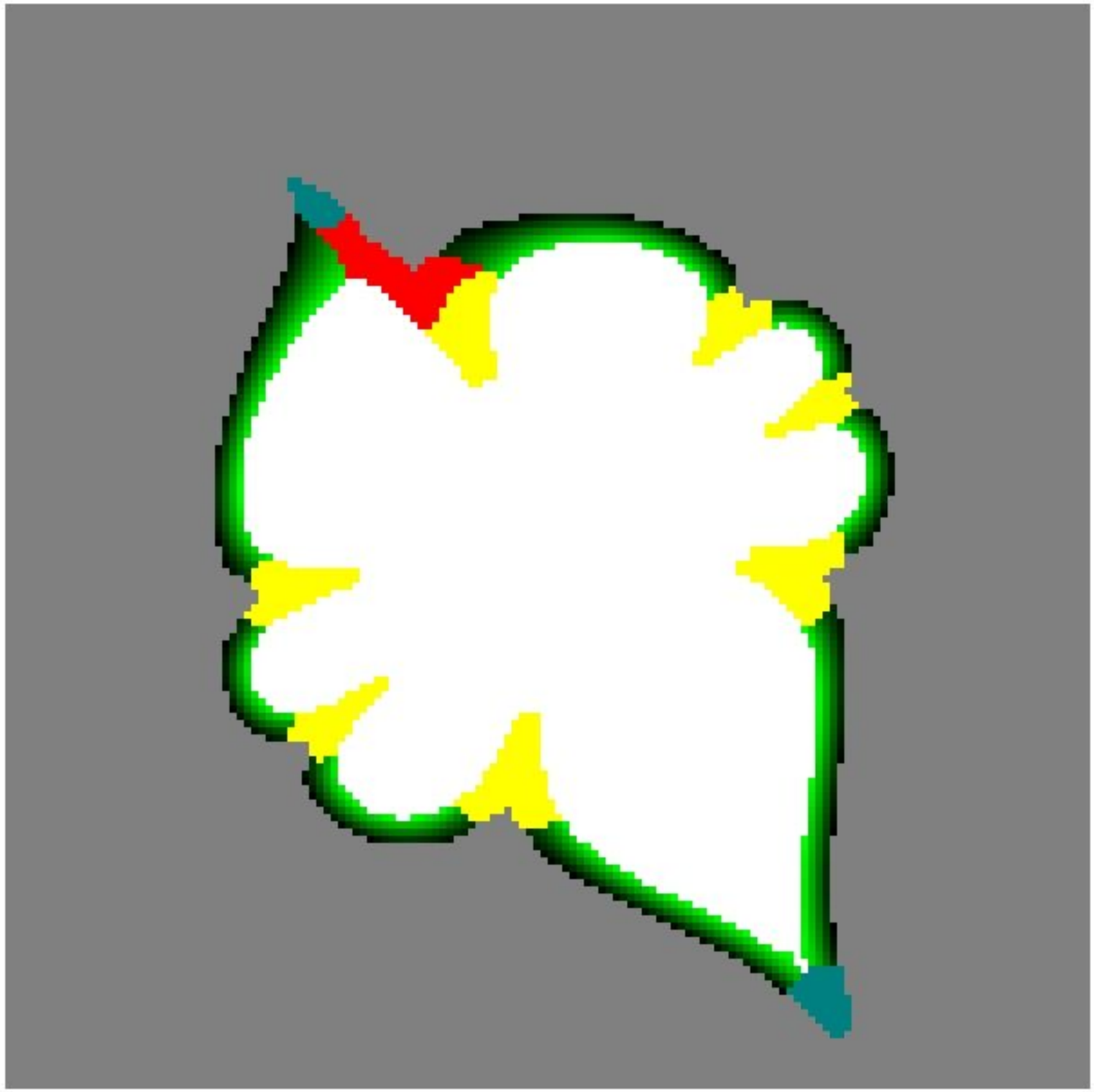


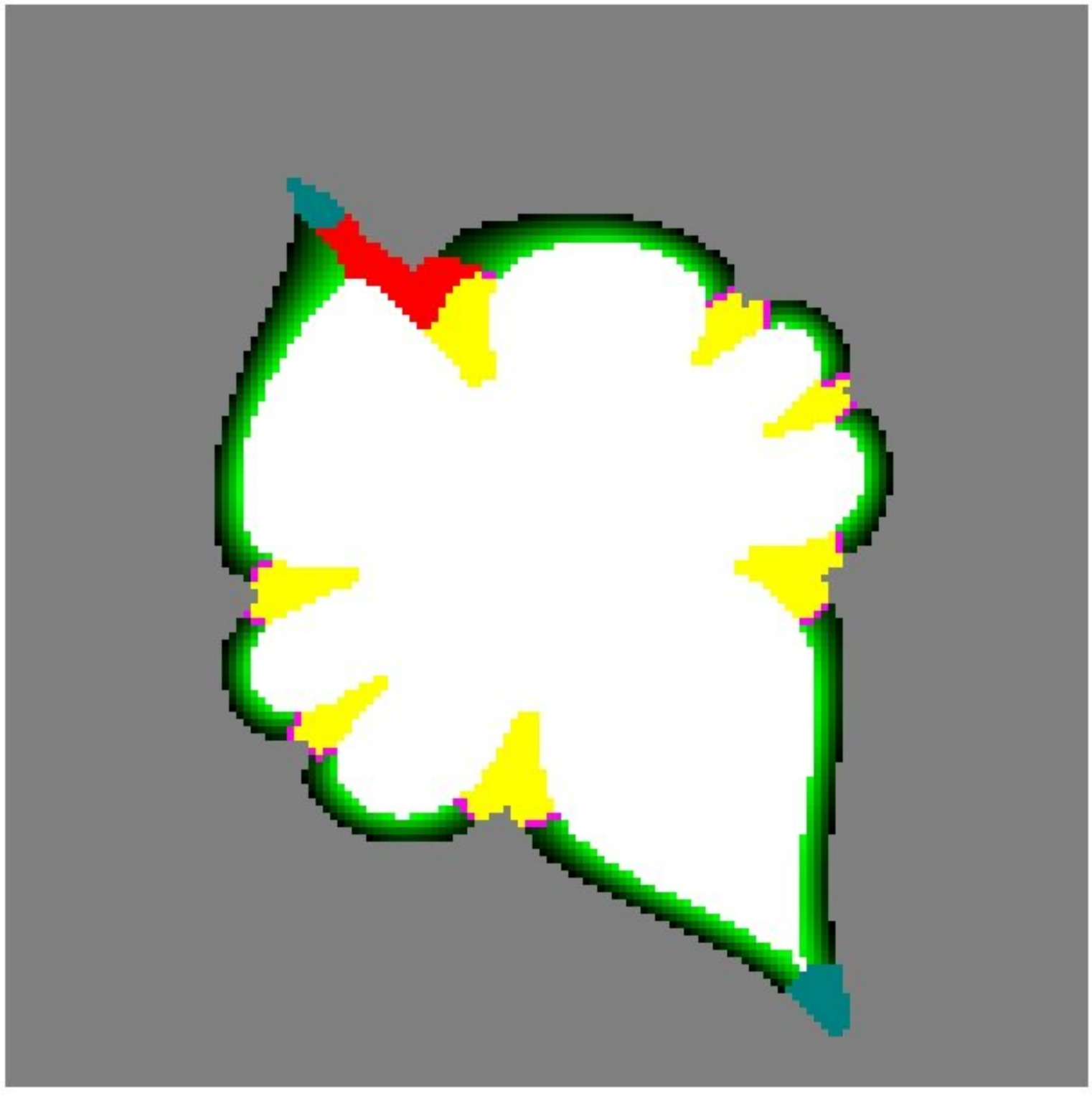




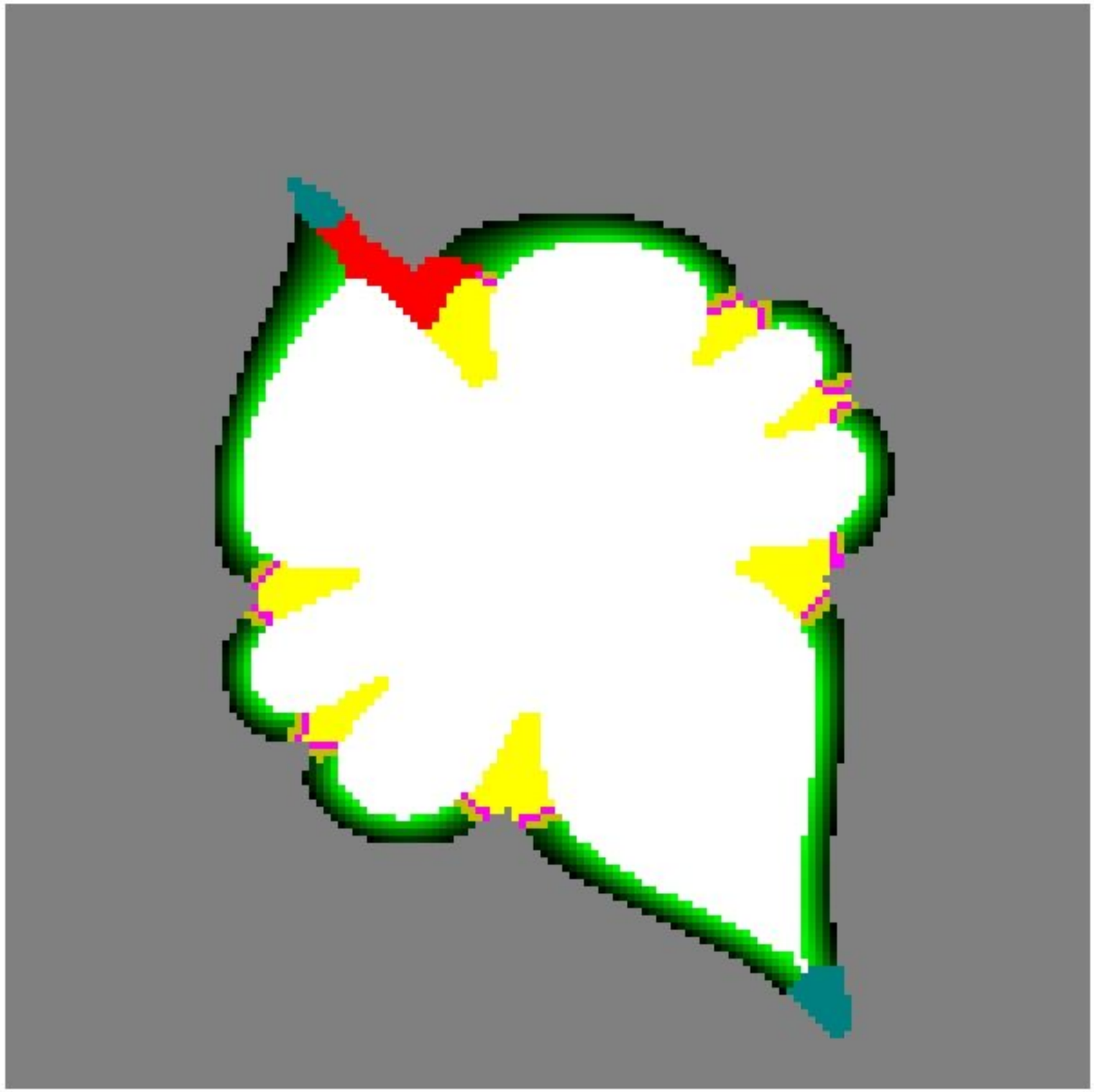


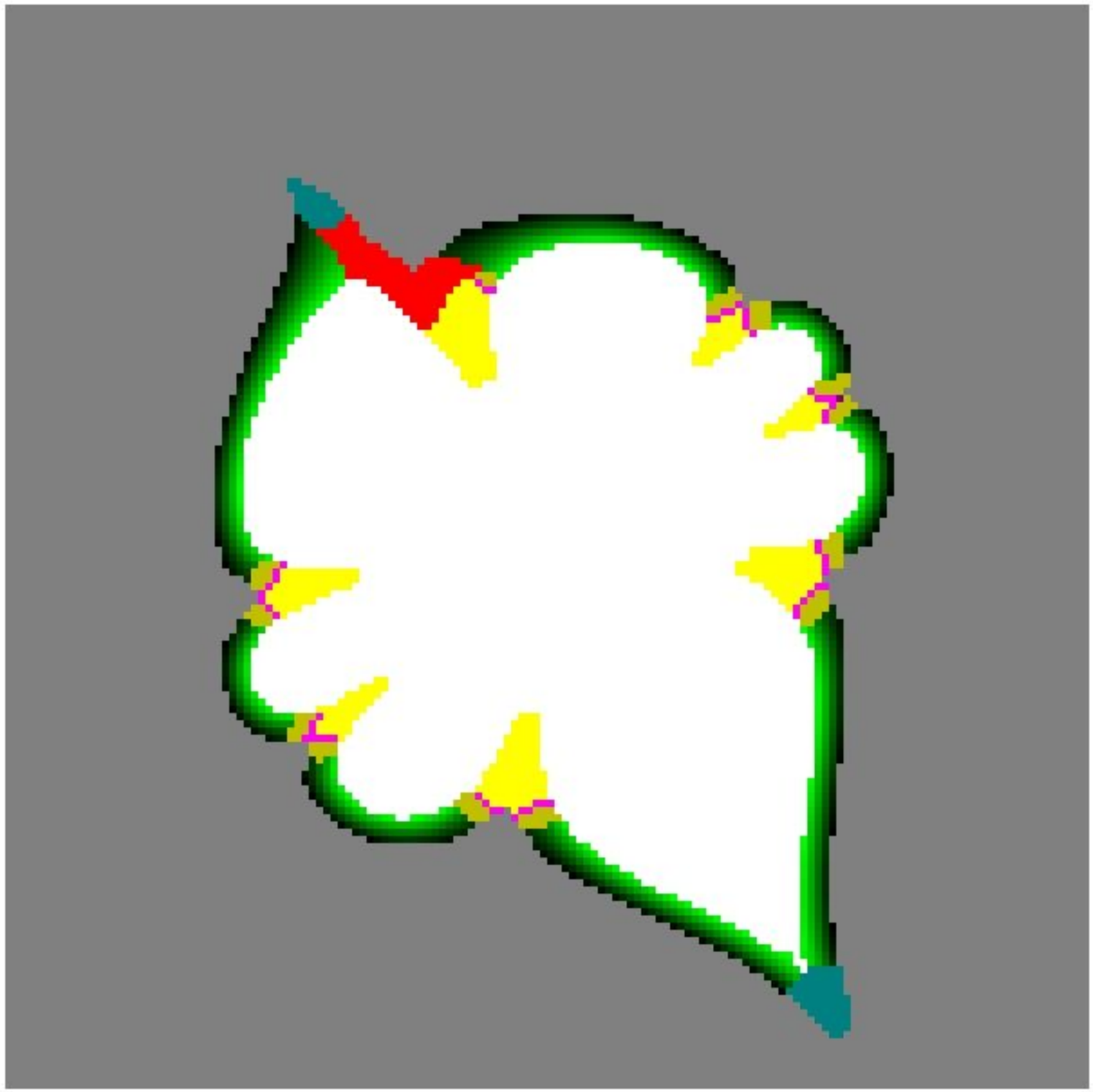


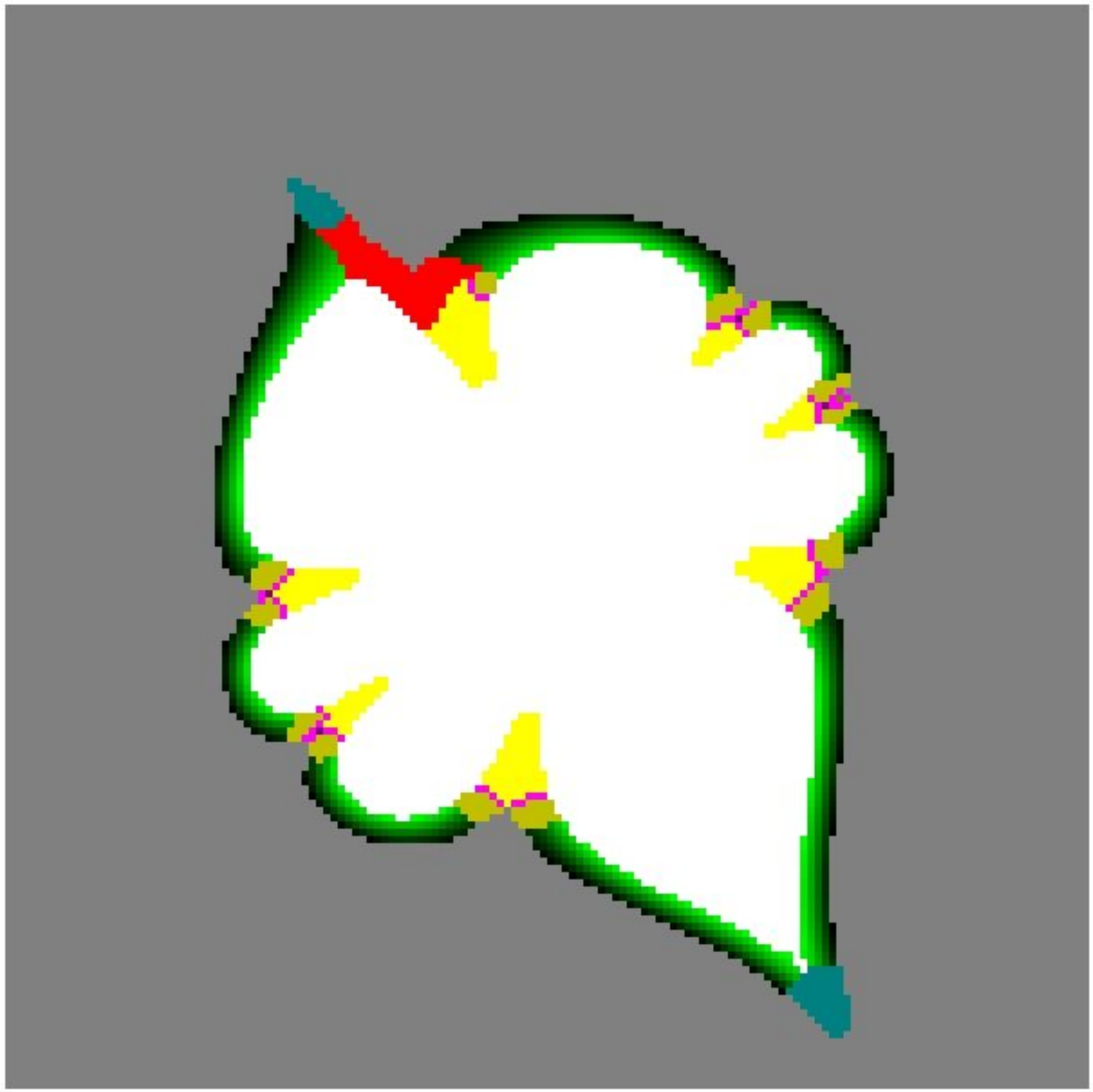


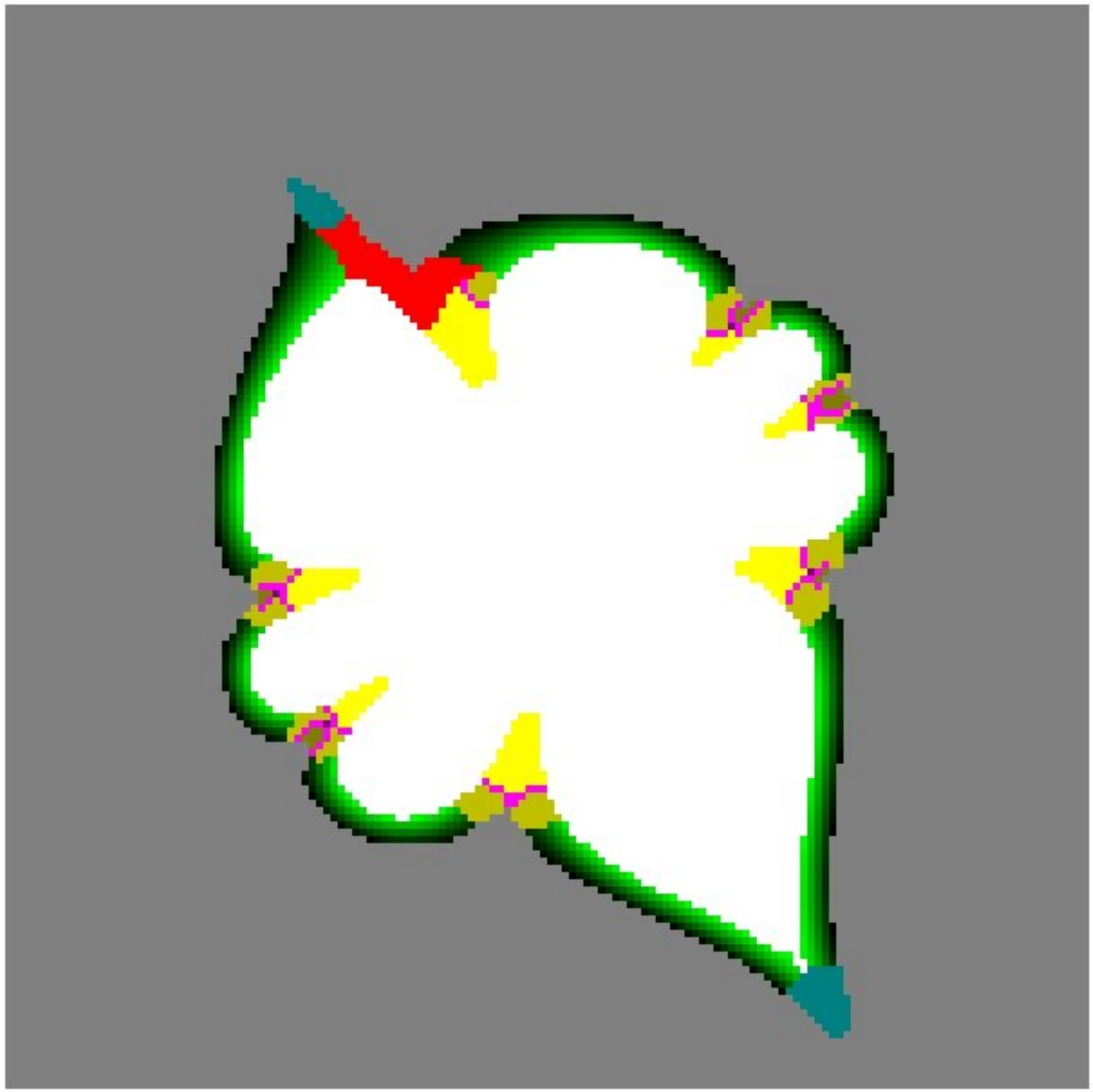


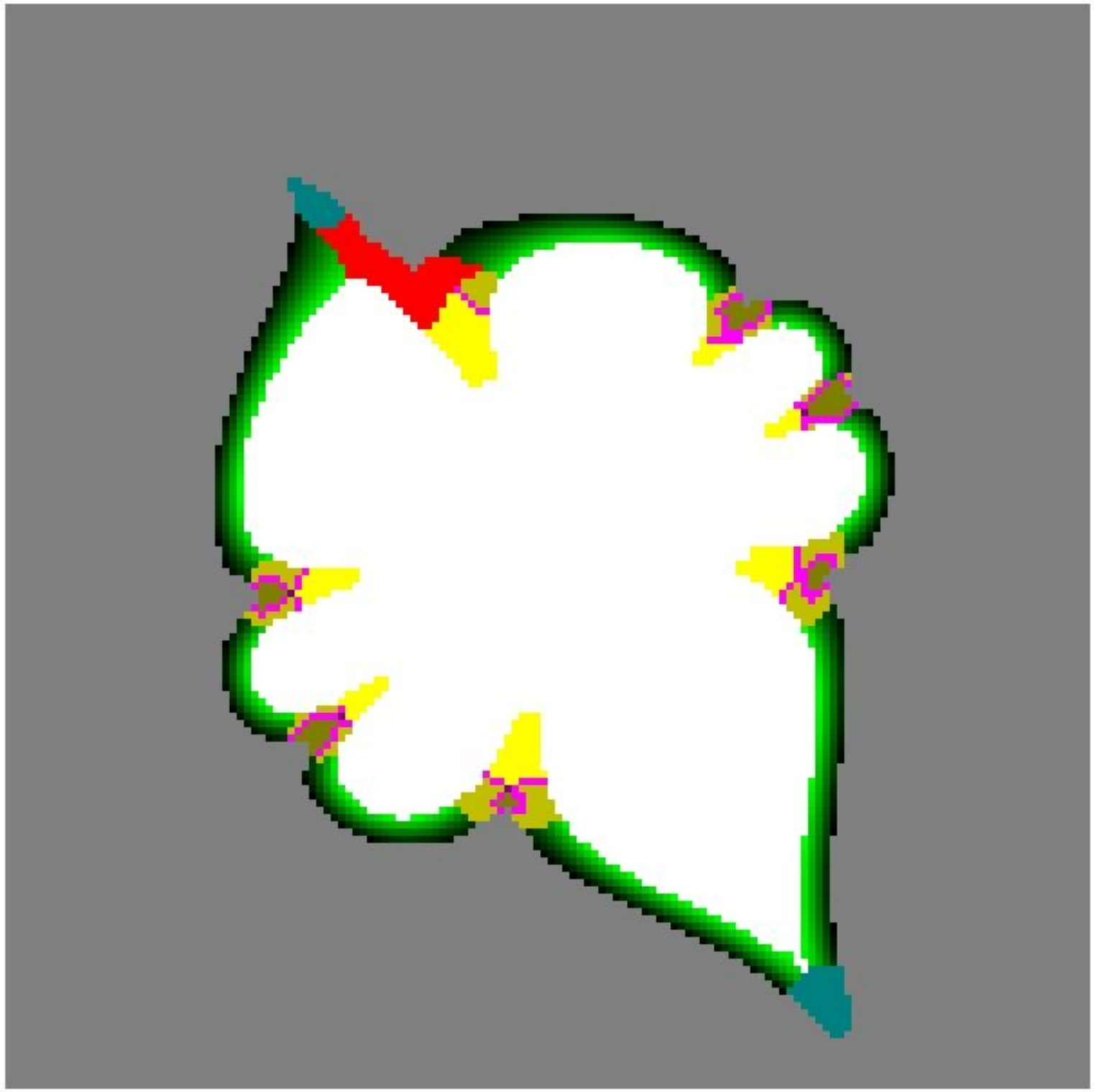
Front propagation in the concave area

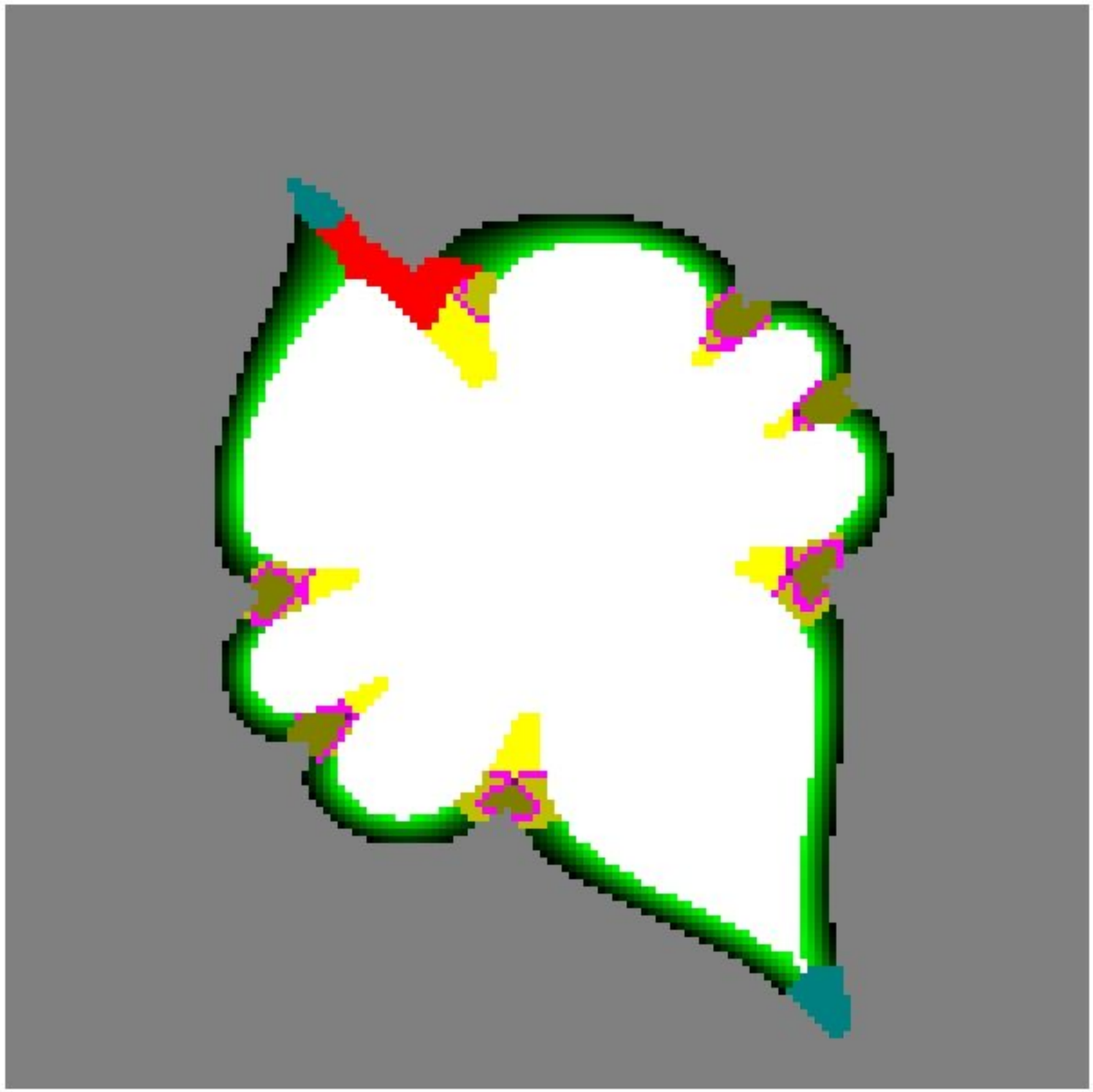


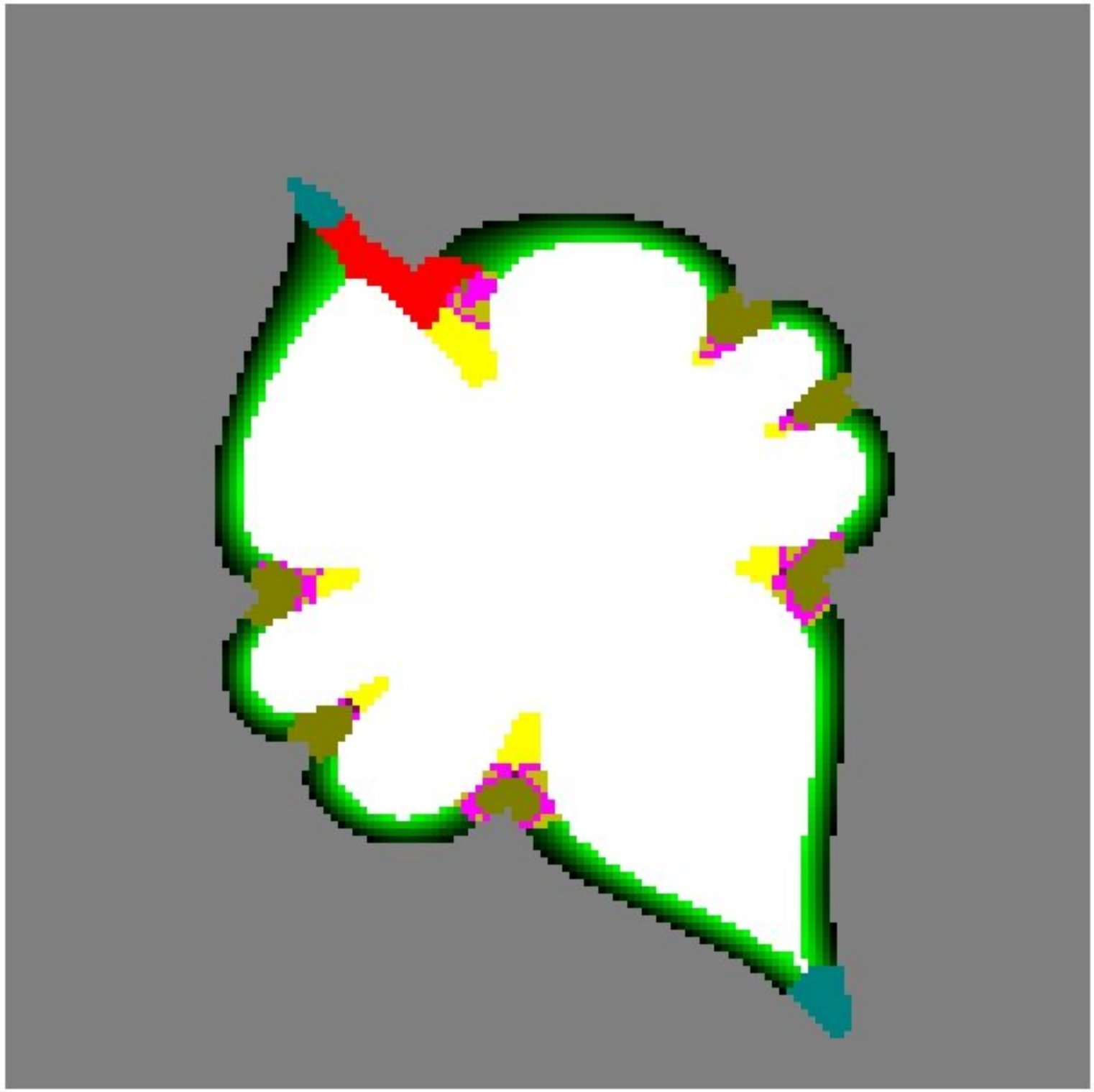


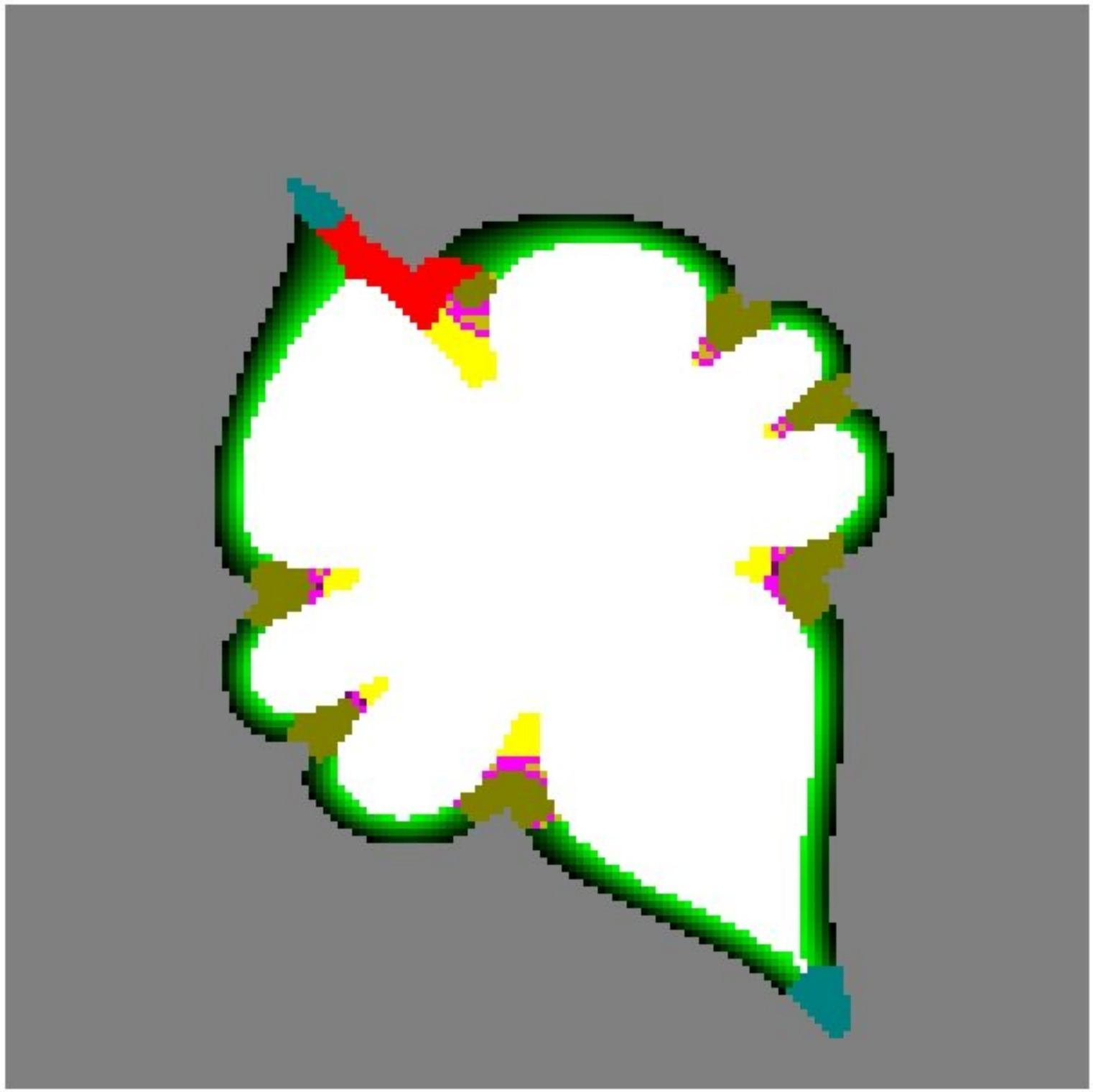


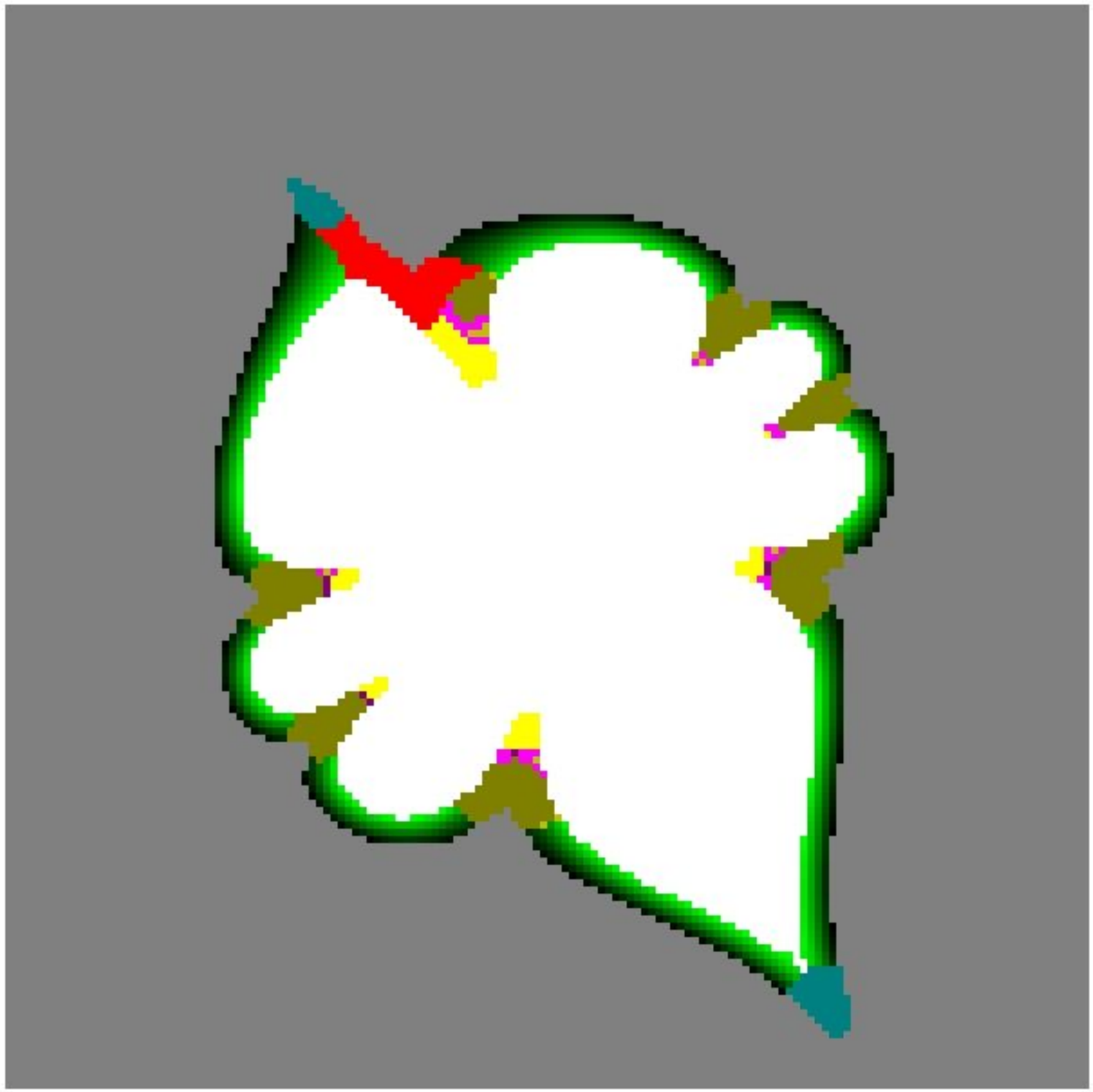


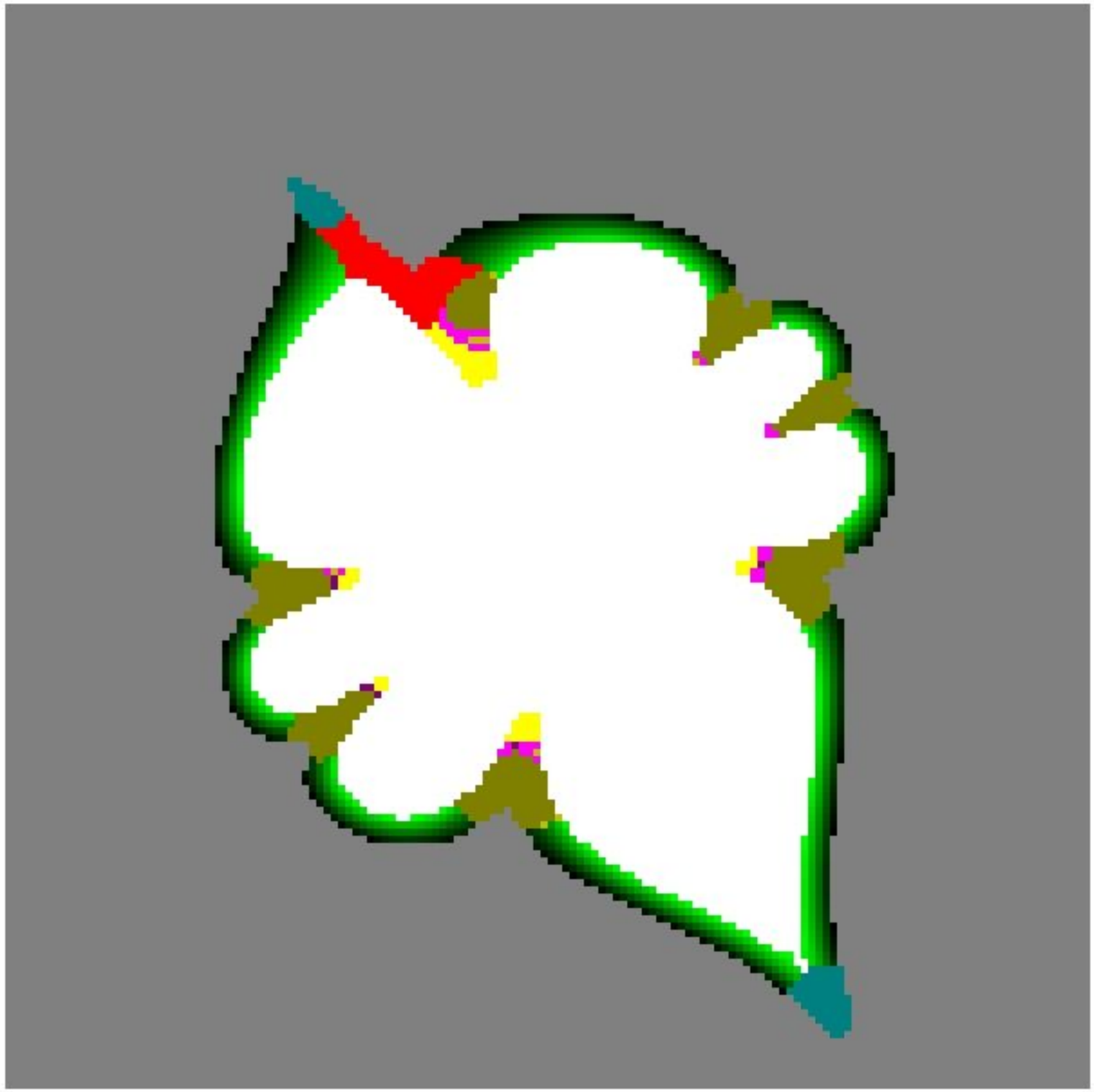


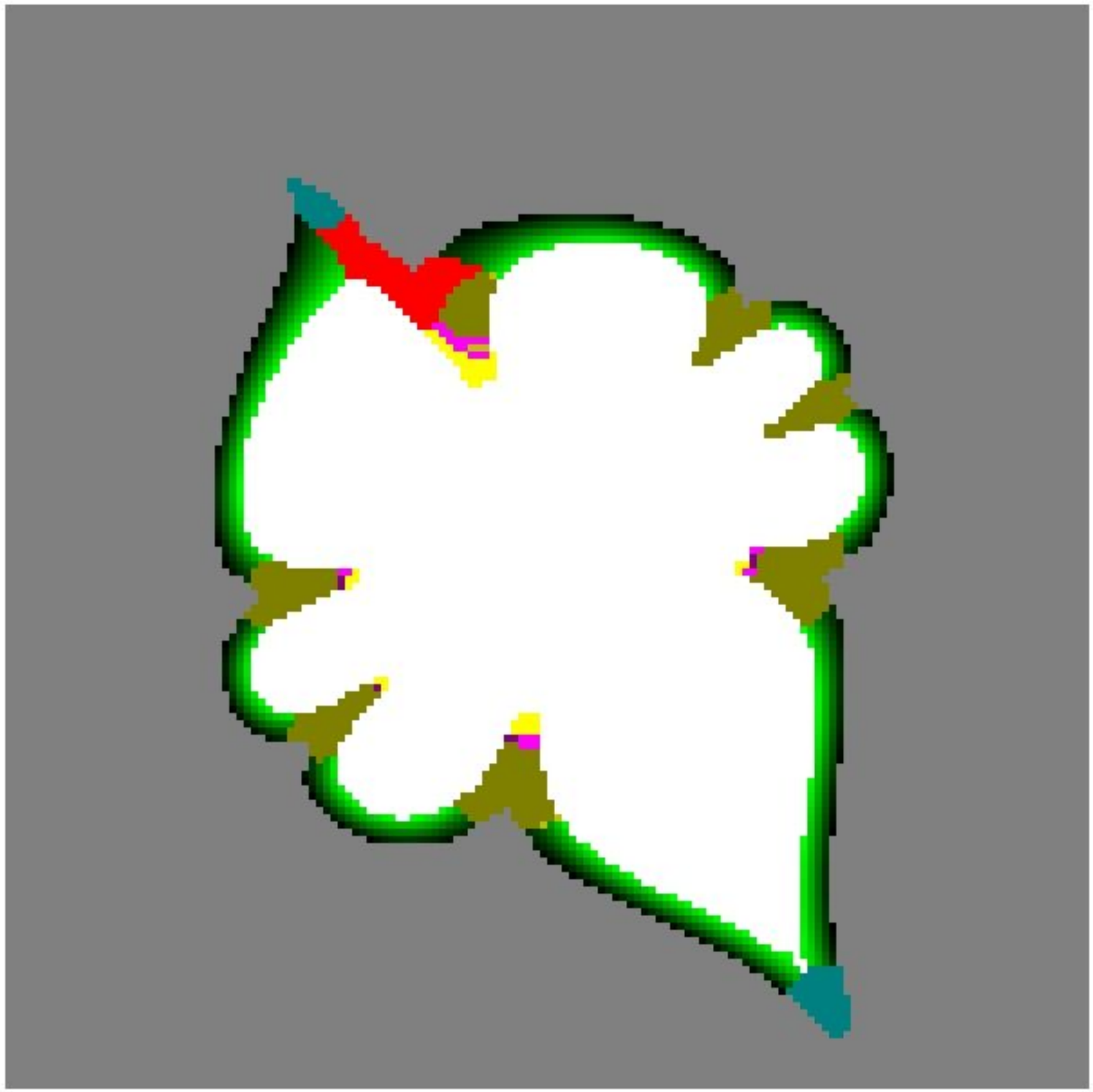


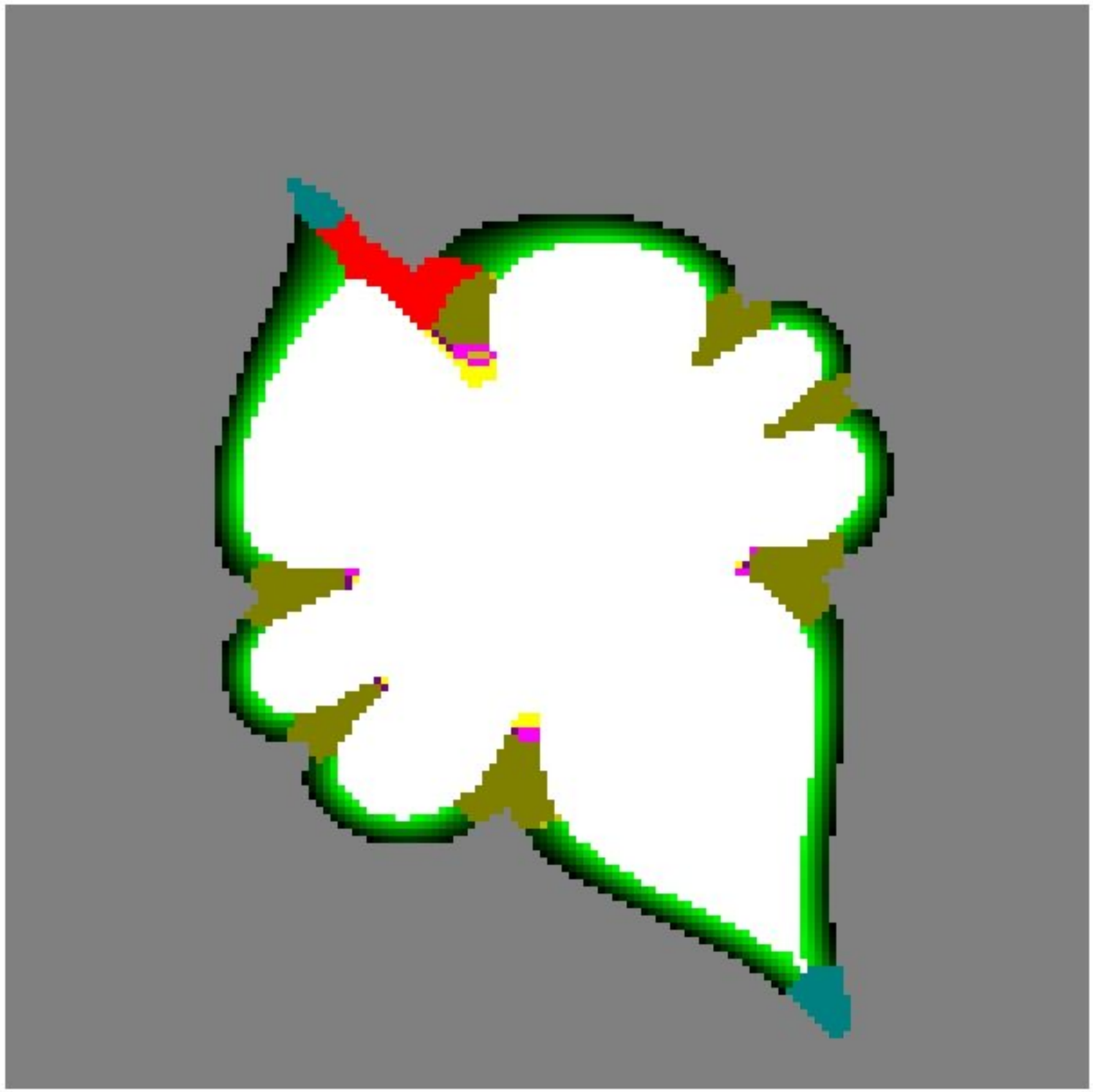


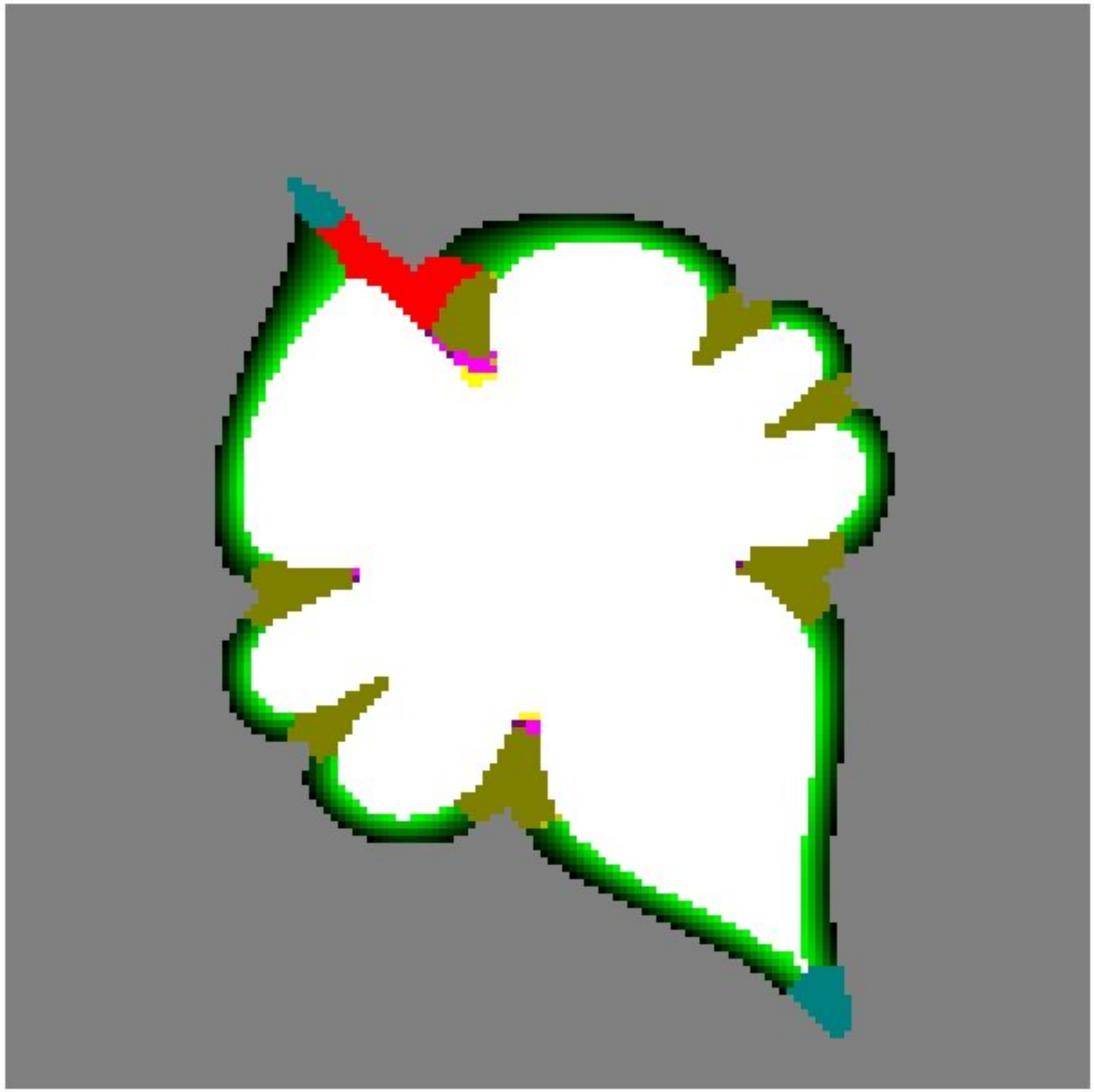


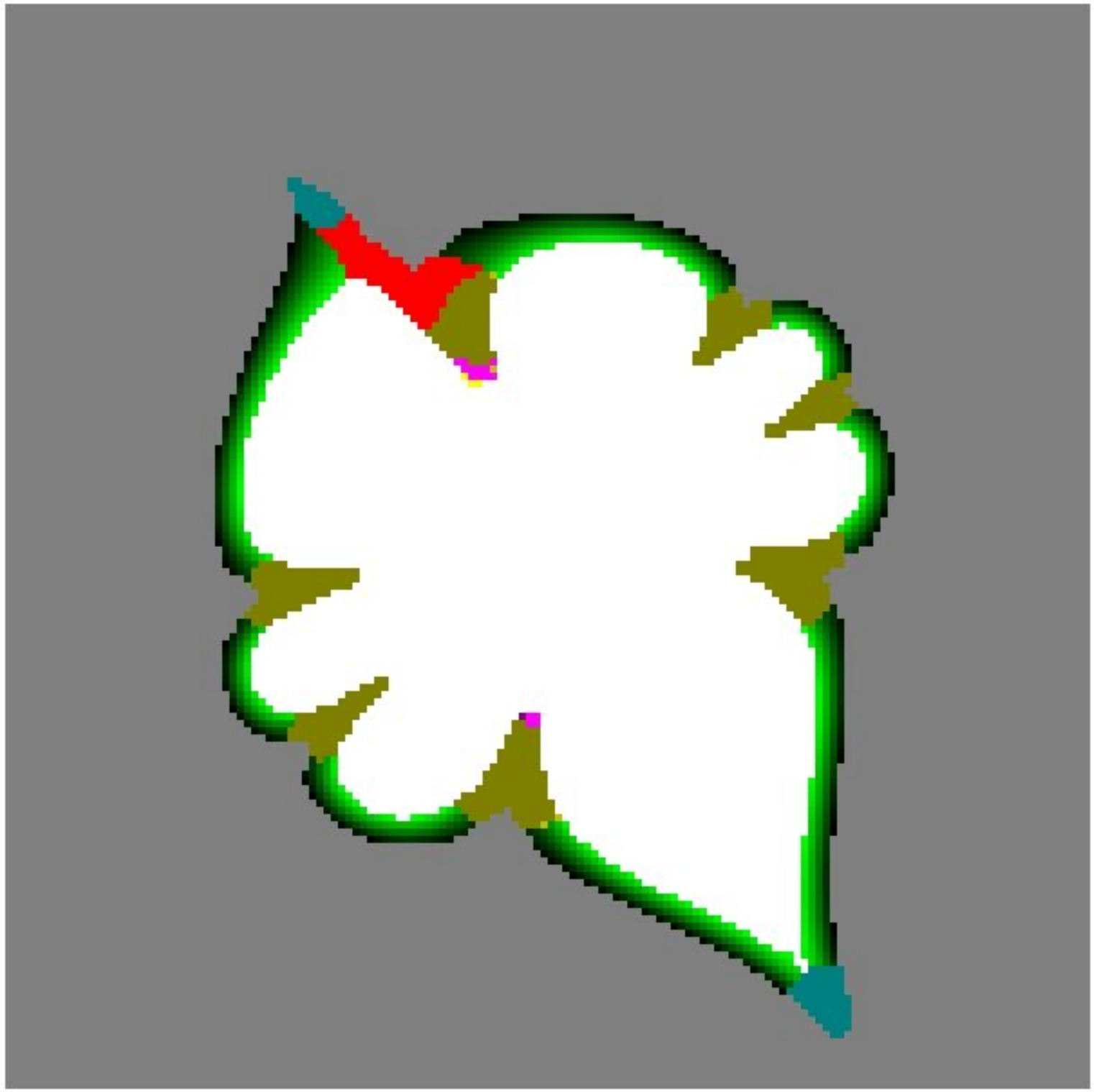


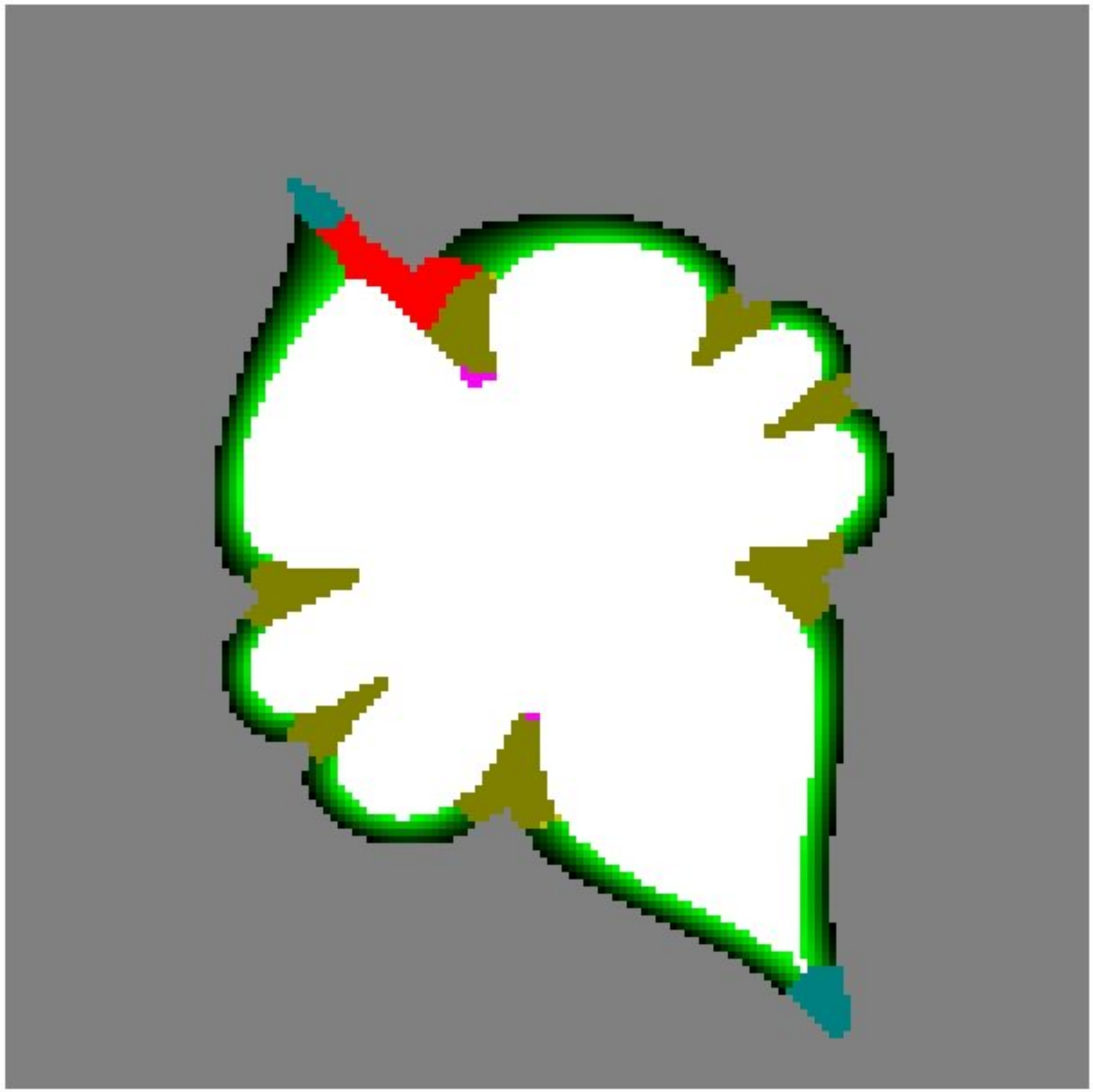


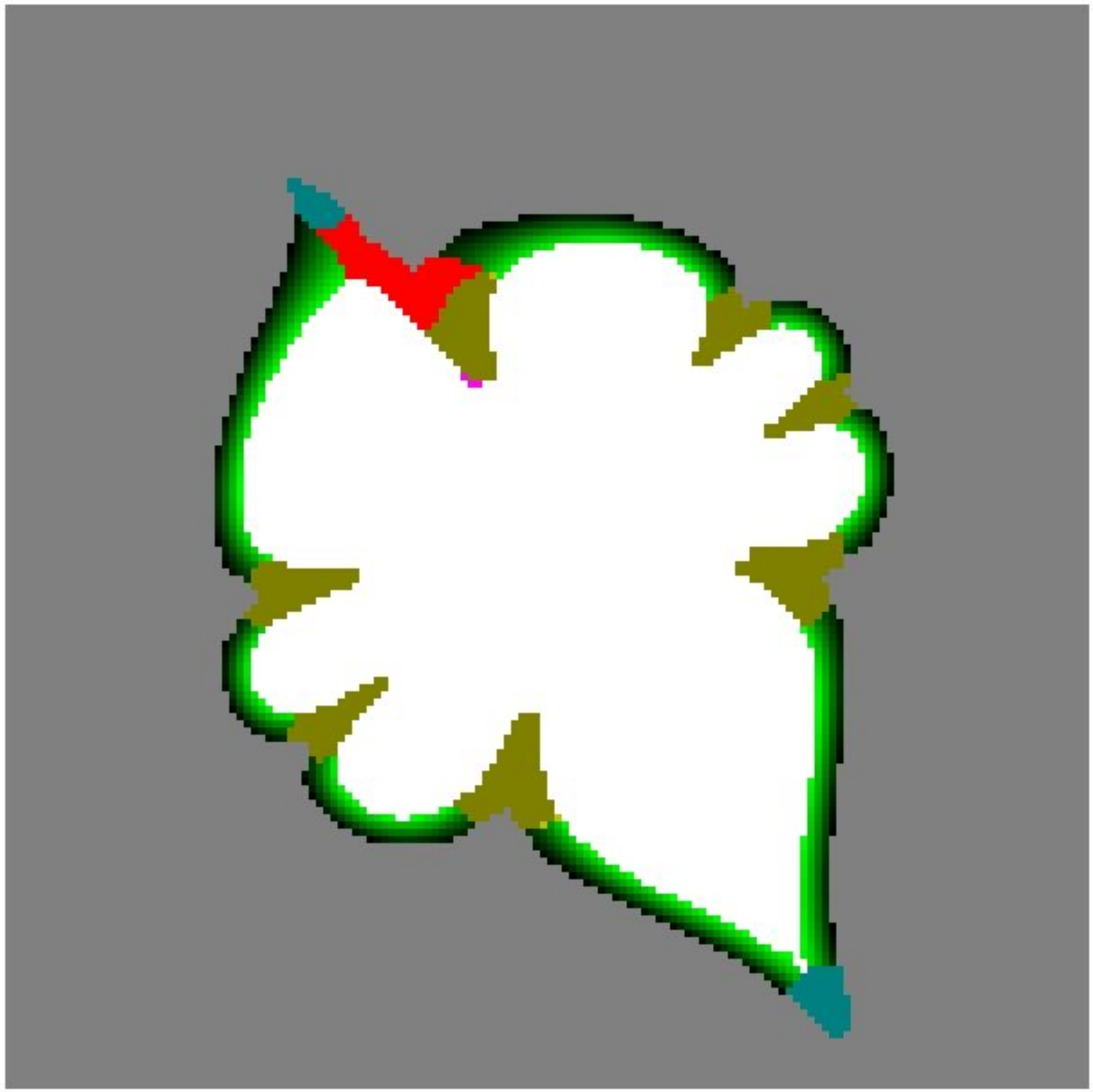


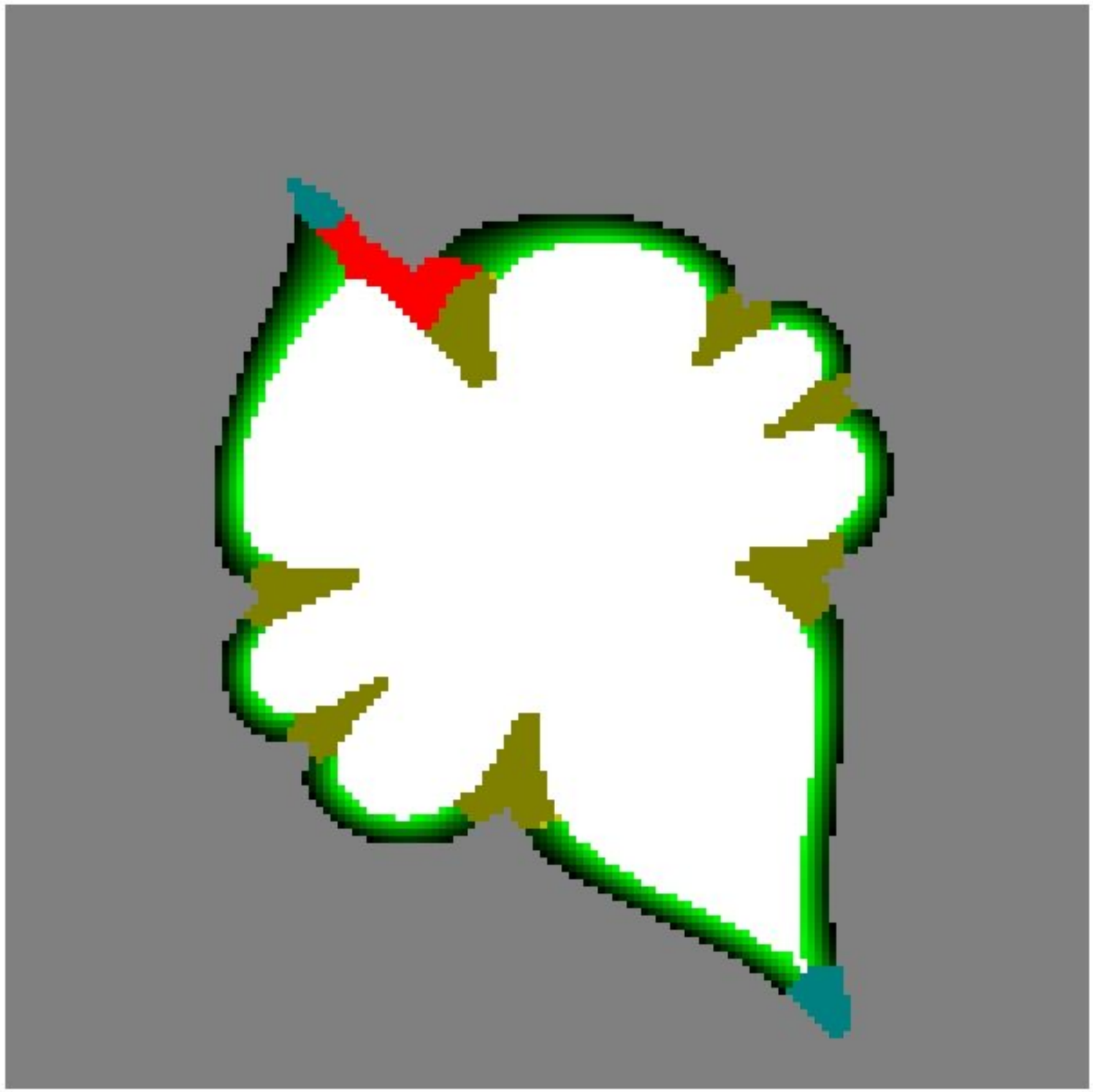


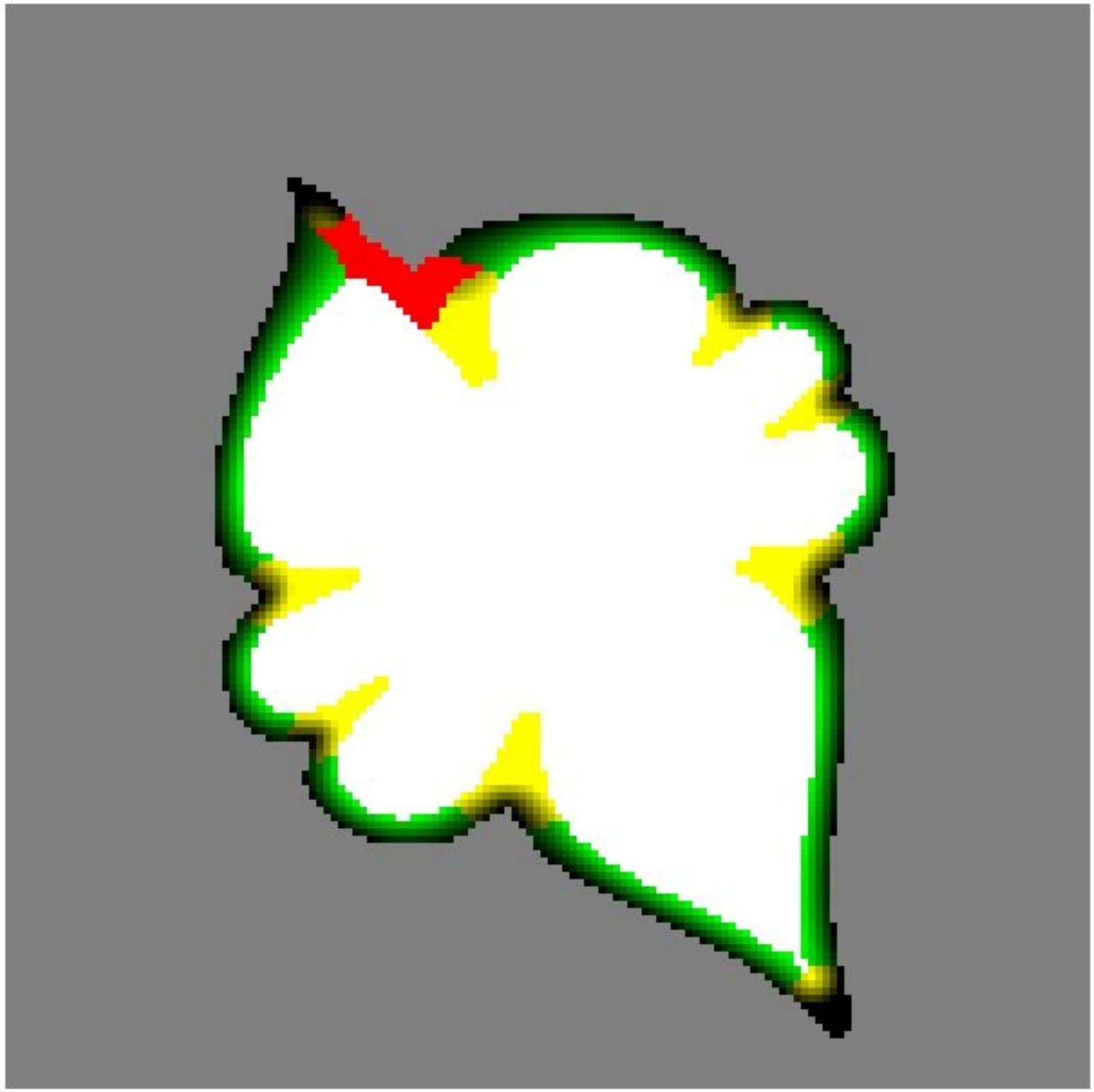




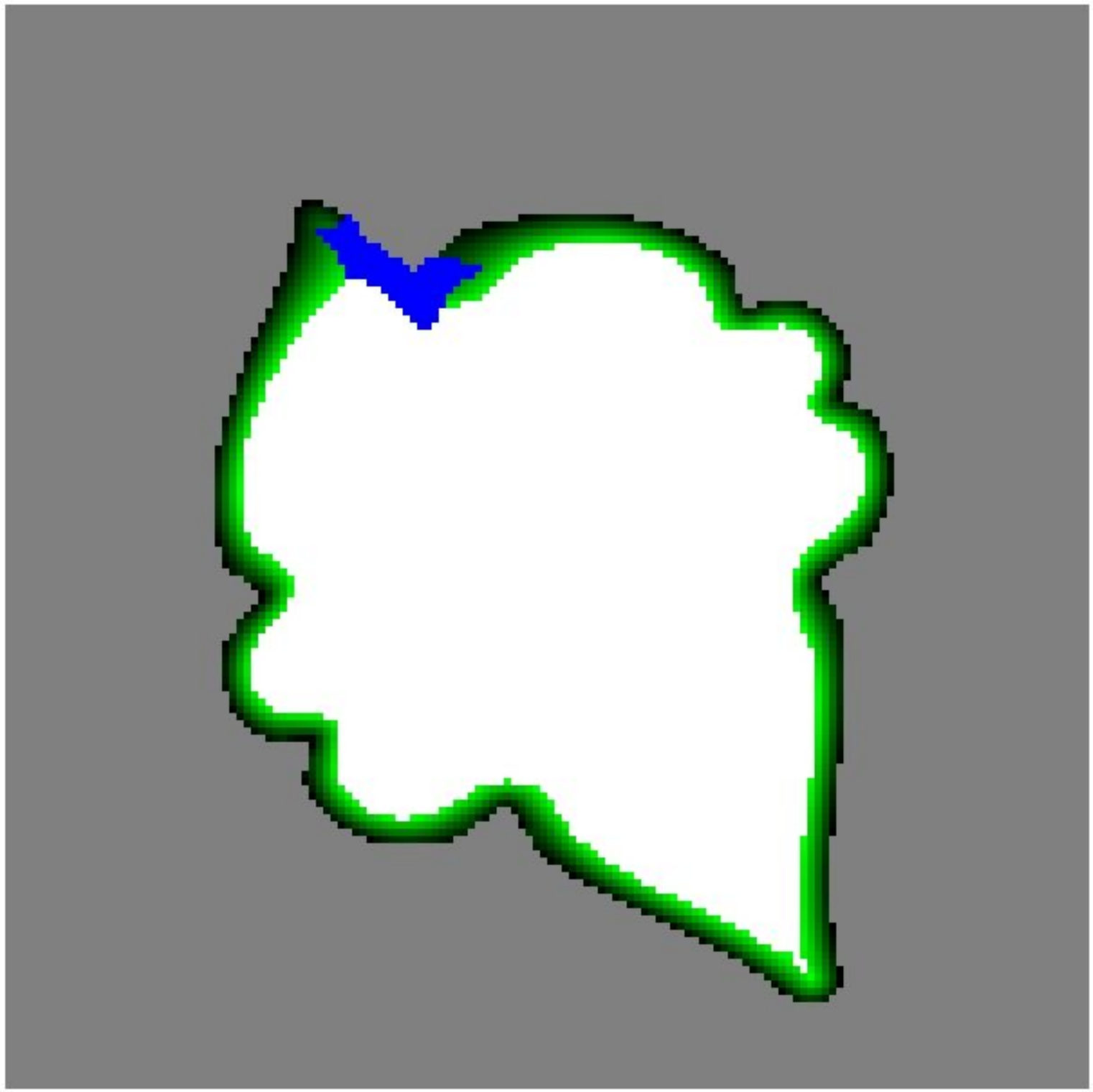




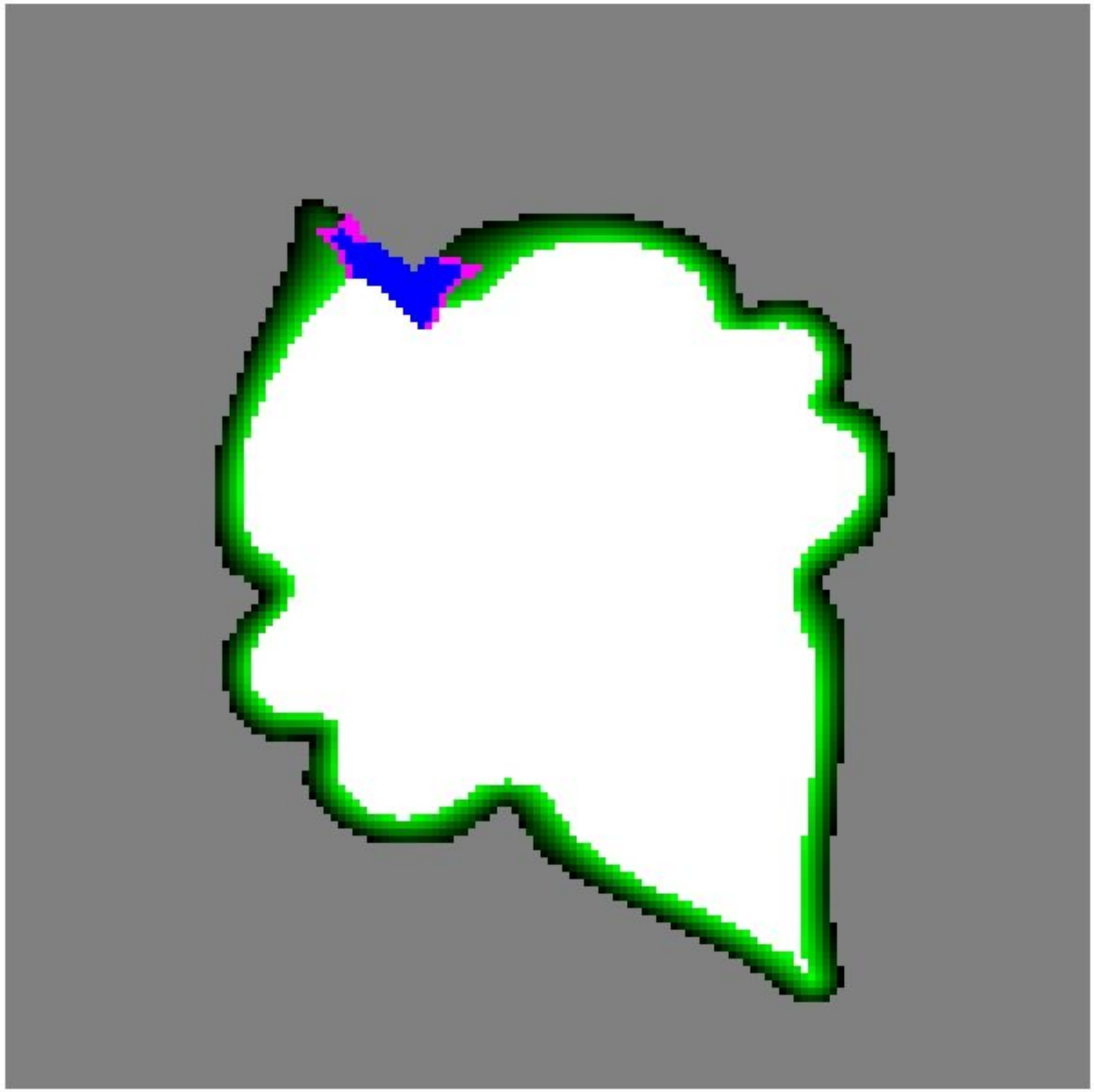




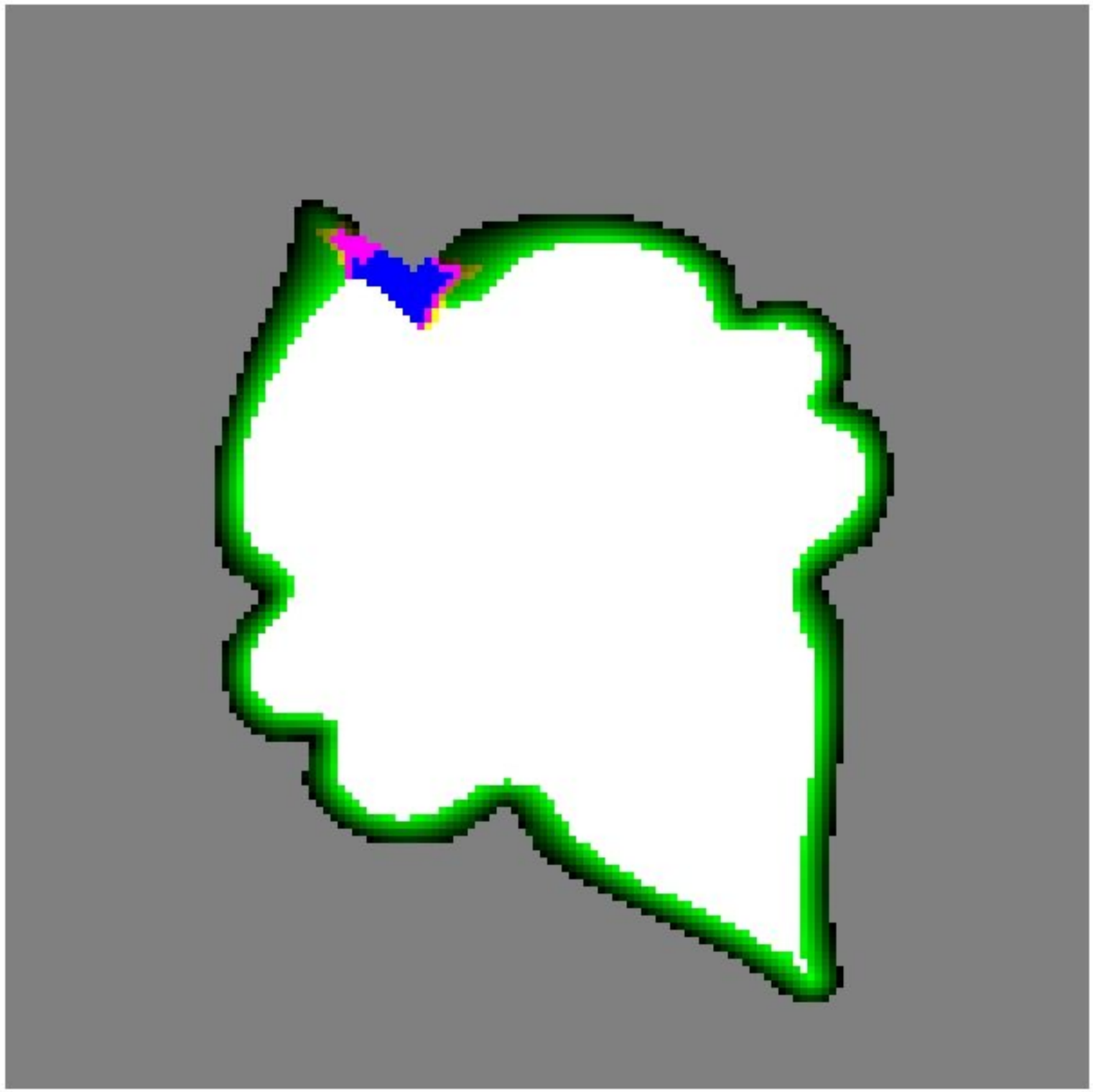
Evaluation of voxels in the convex and concave area

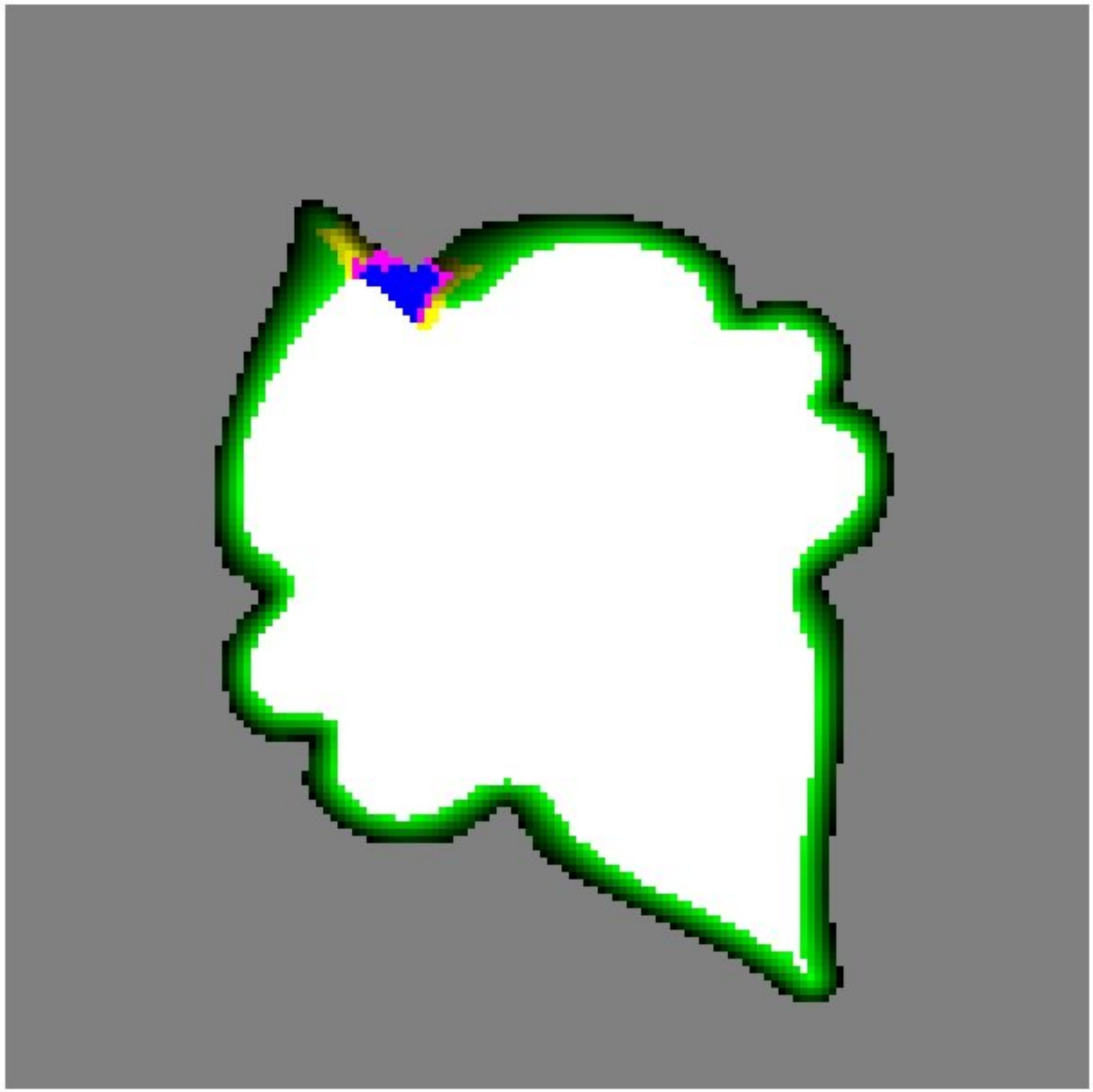


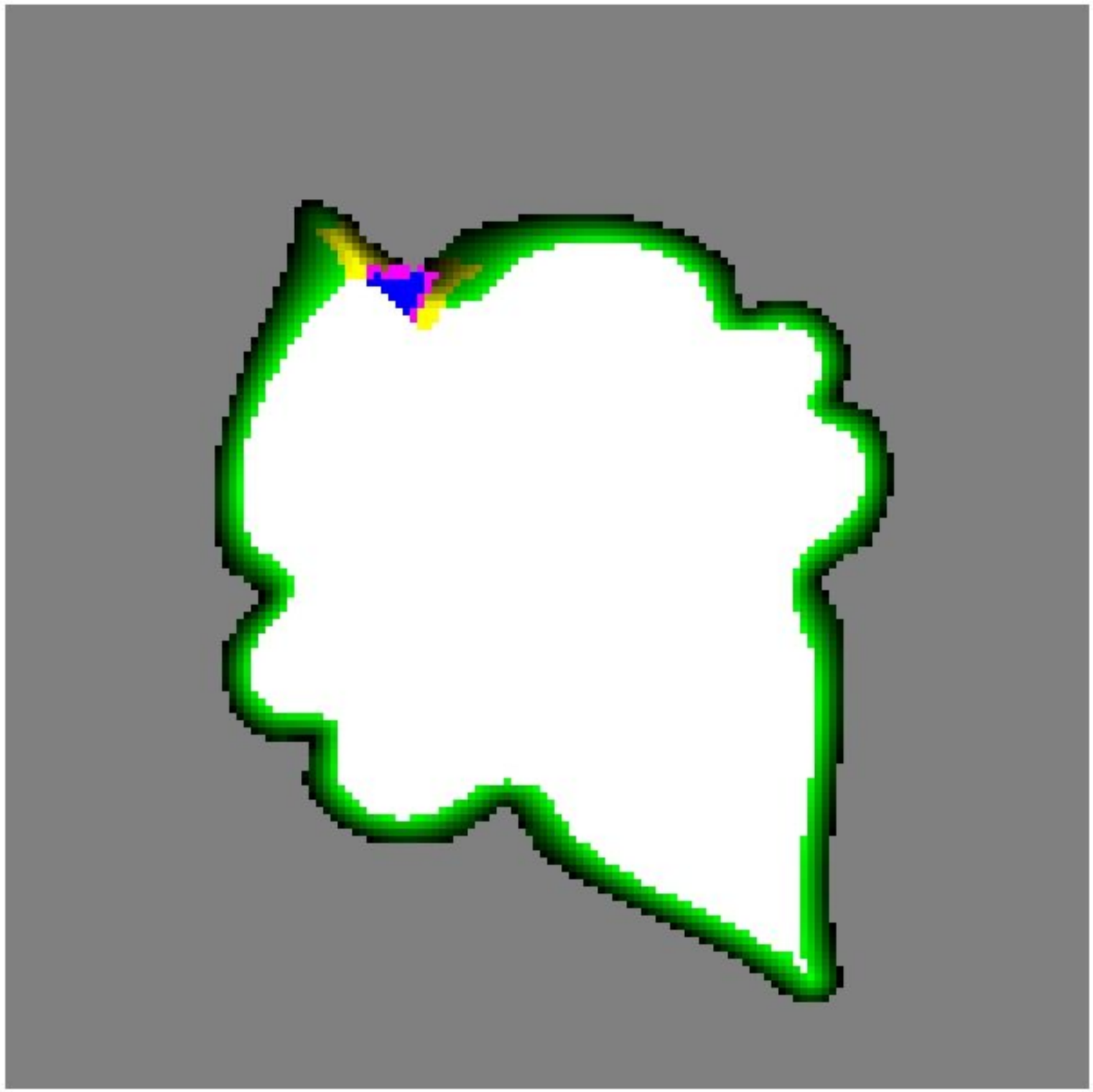
New voxels are classified as transient, outside and inside

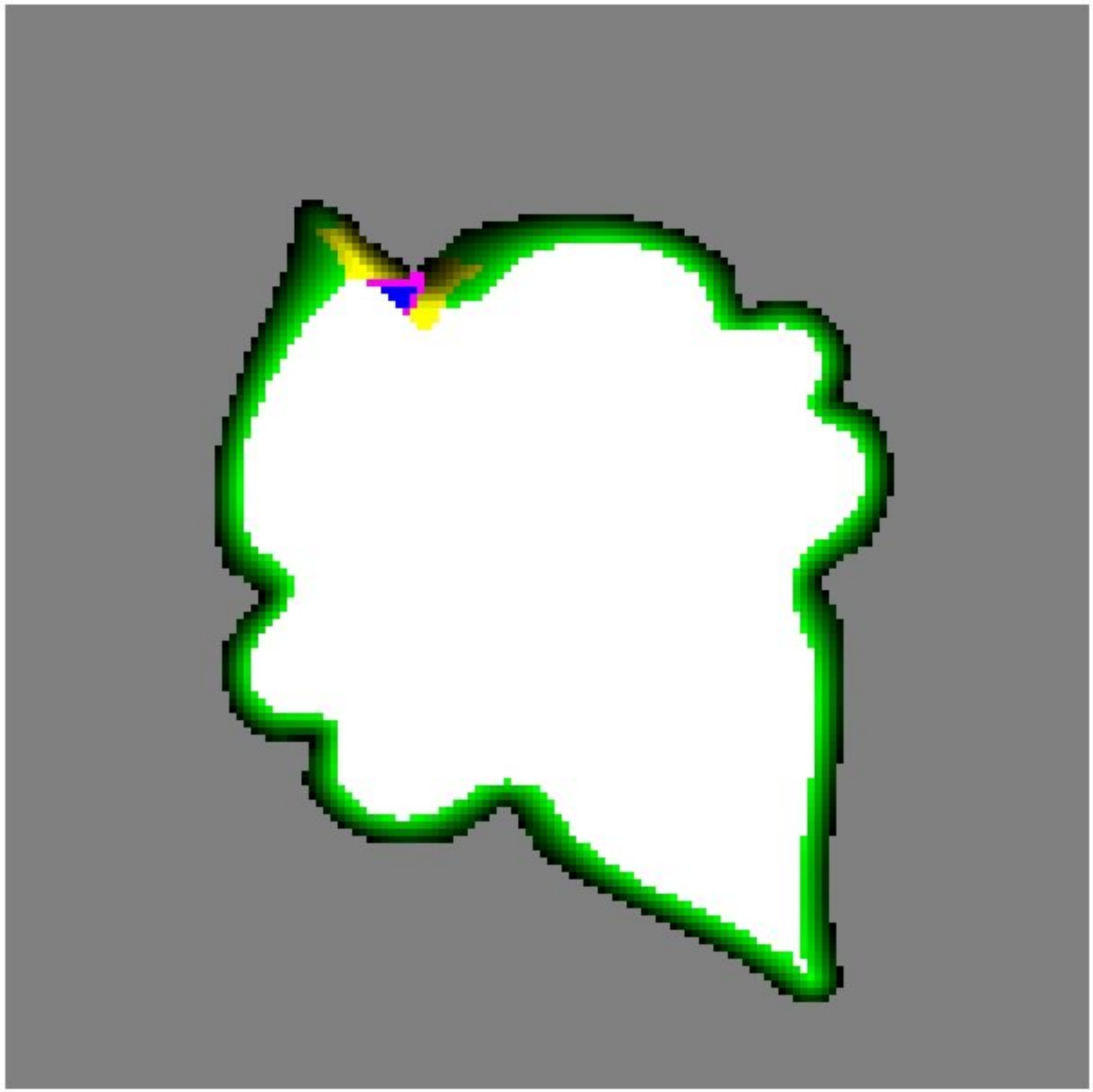


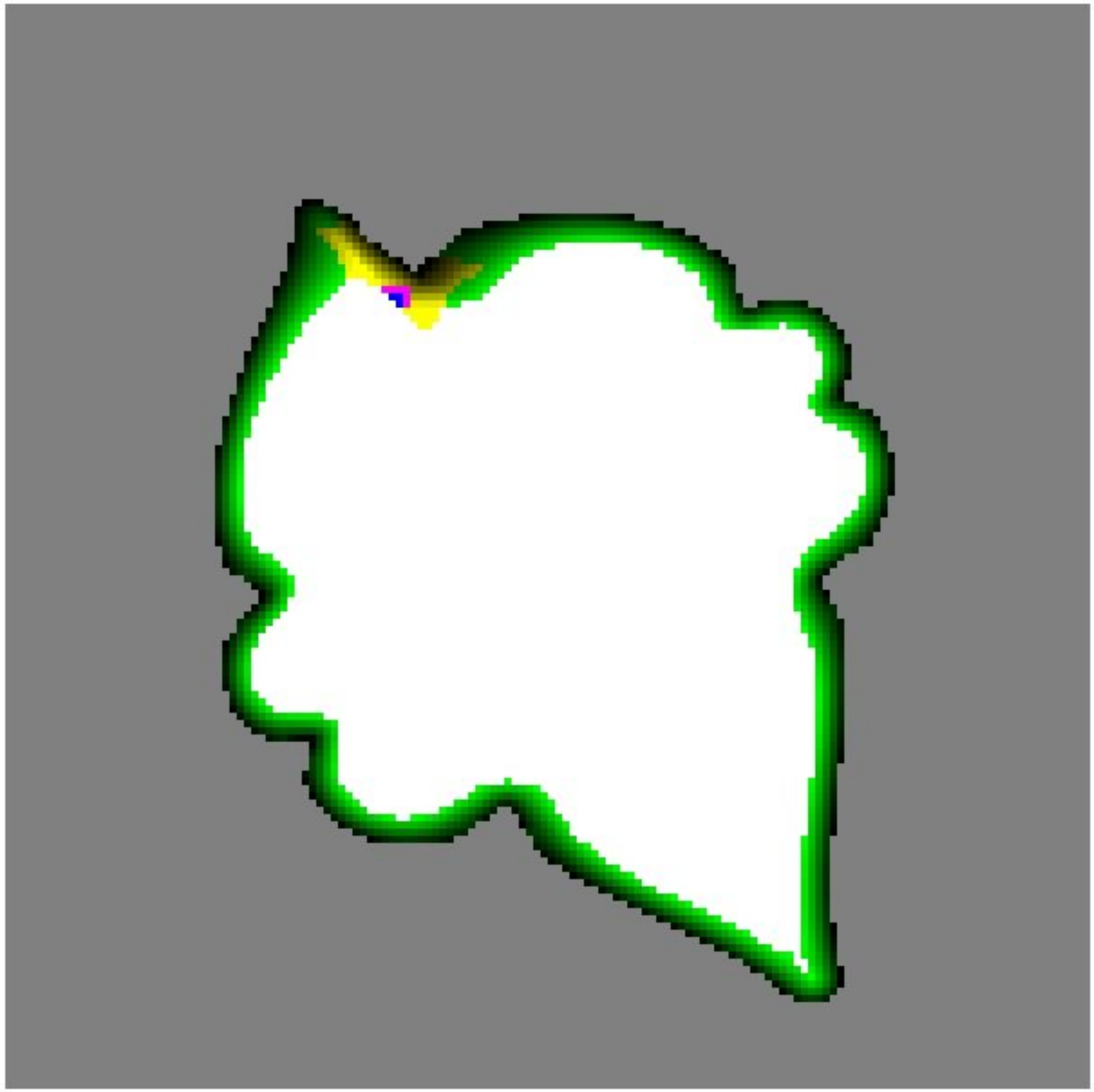
Front propagation in the rest of the critical area...

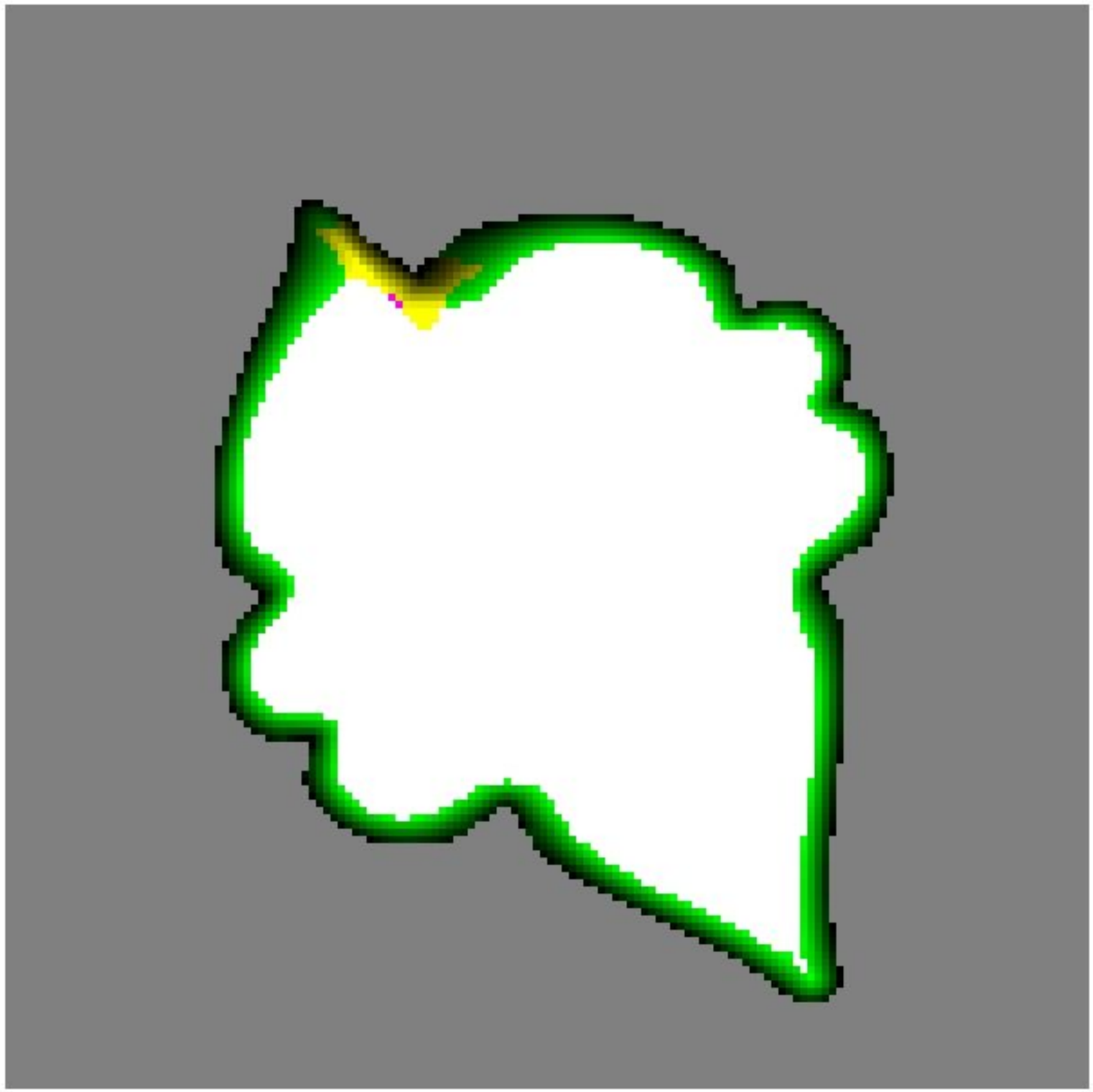


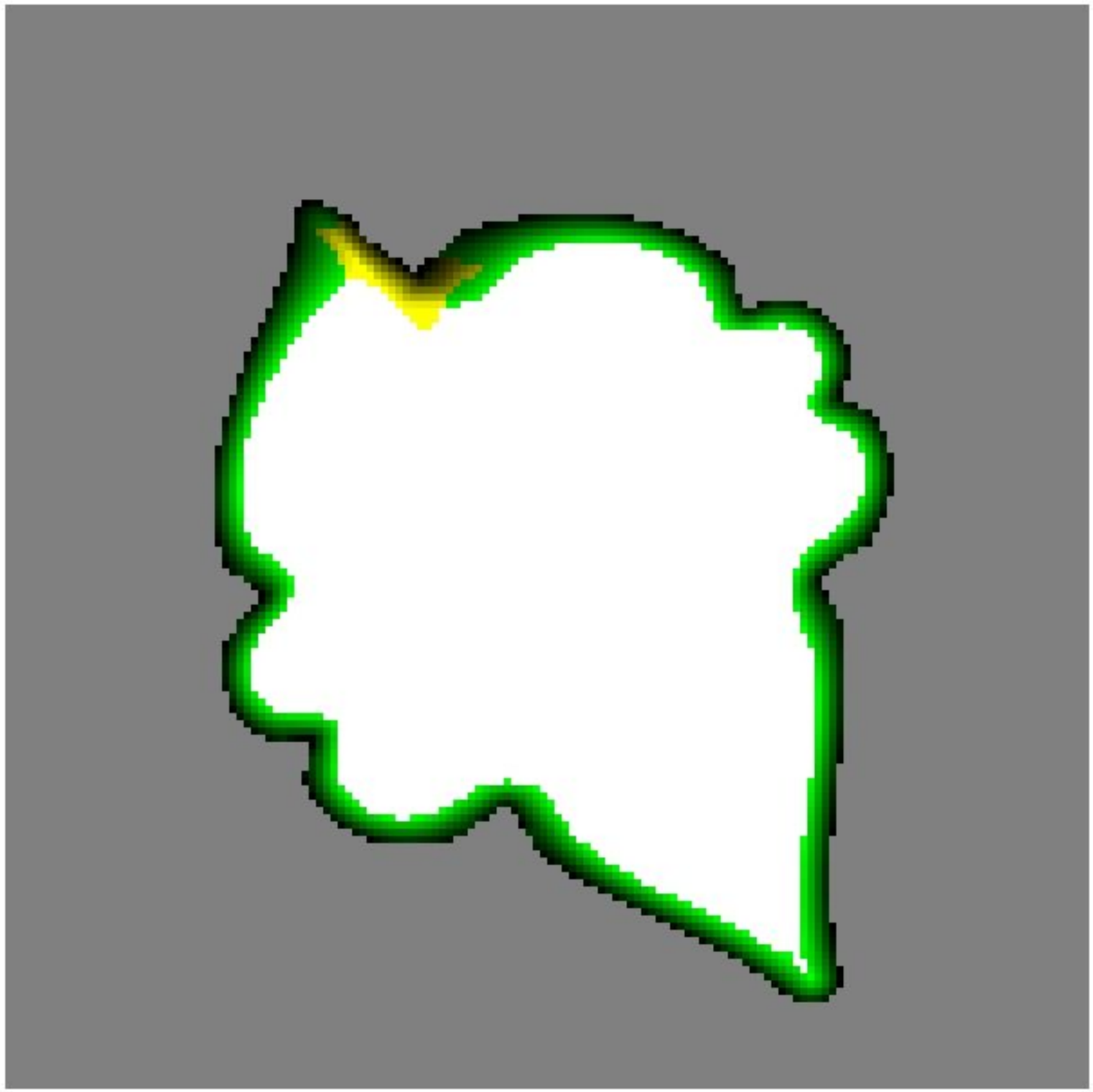


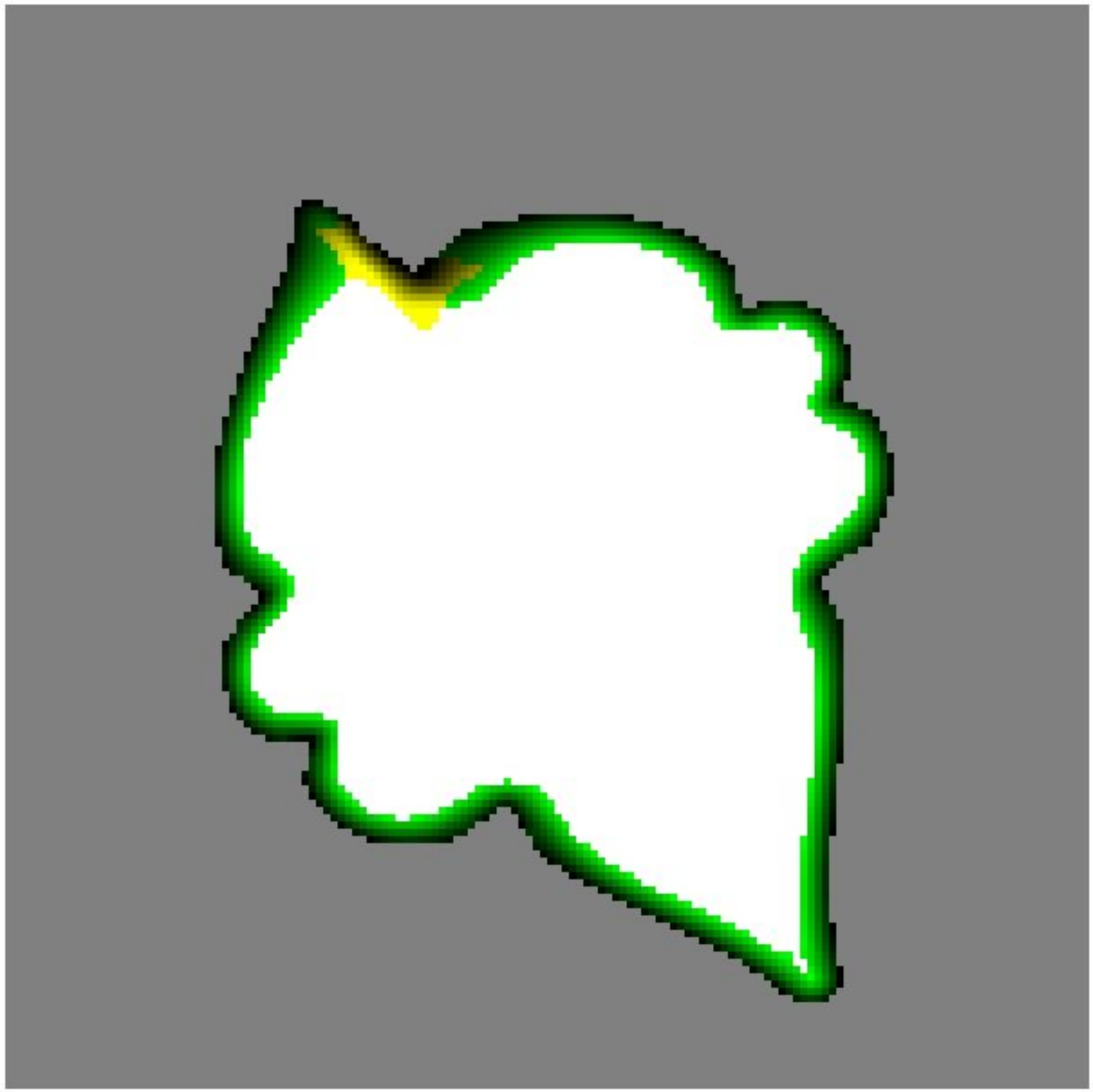




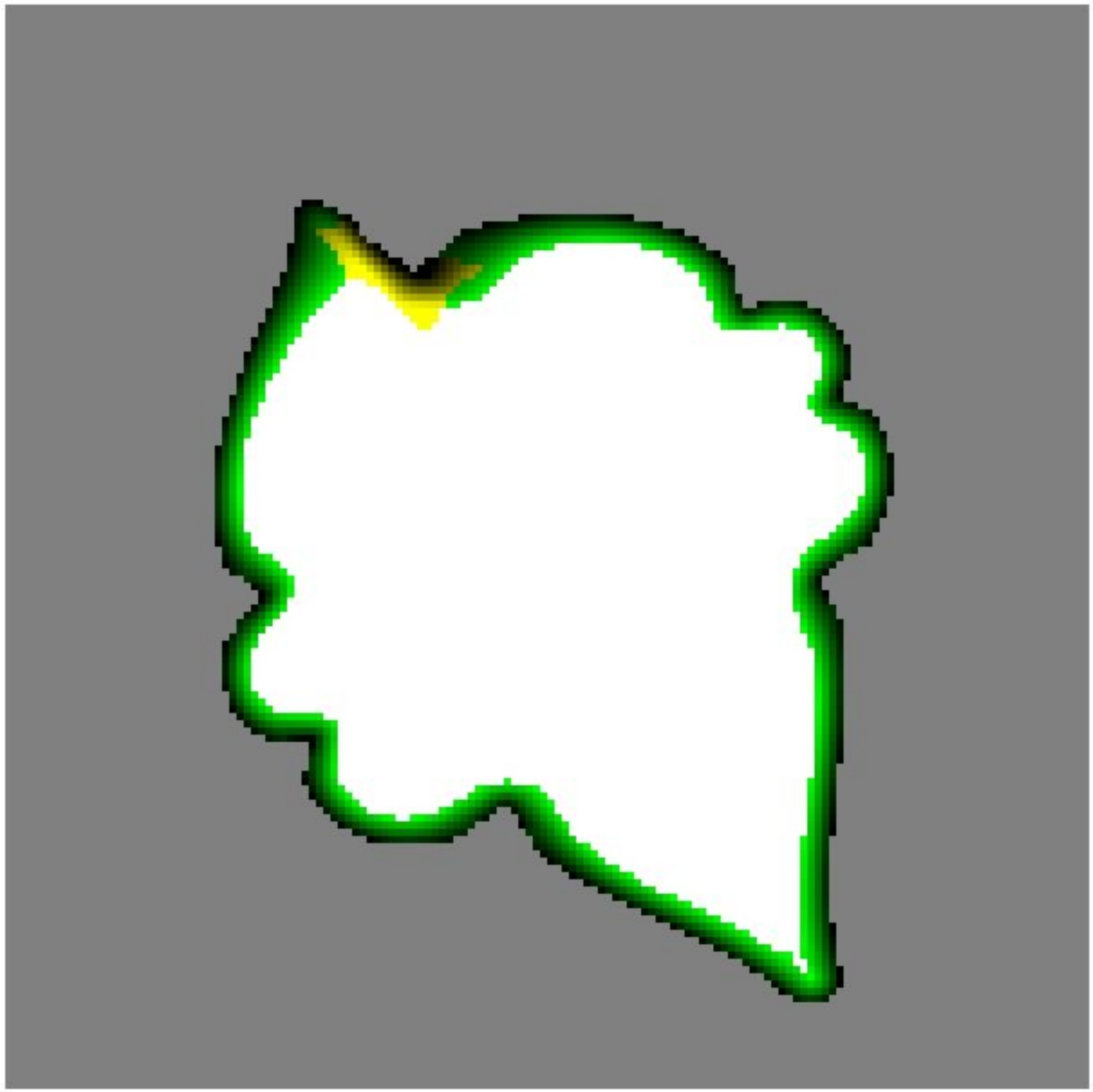


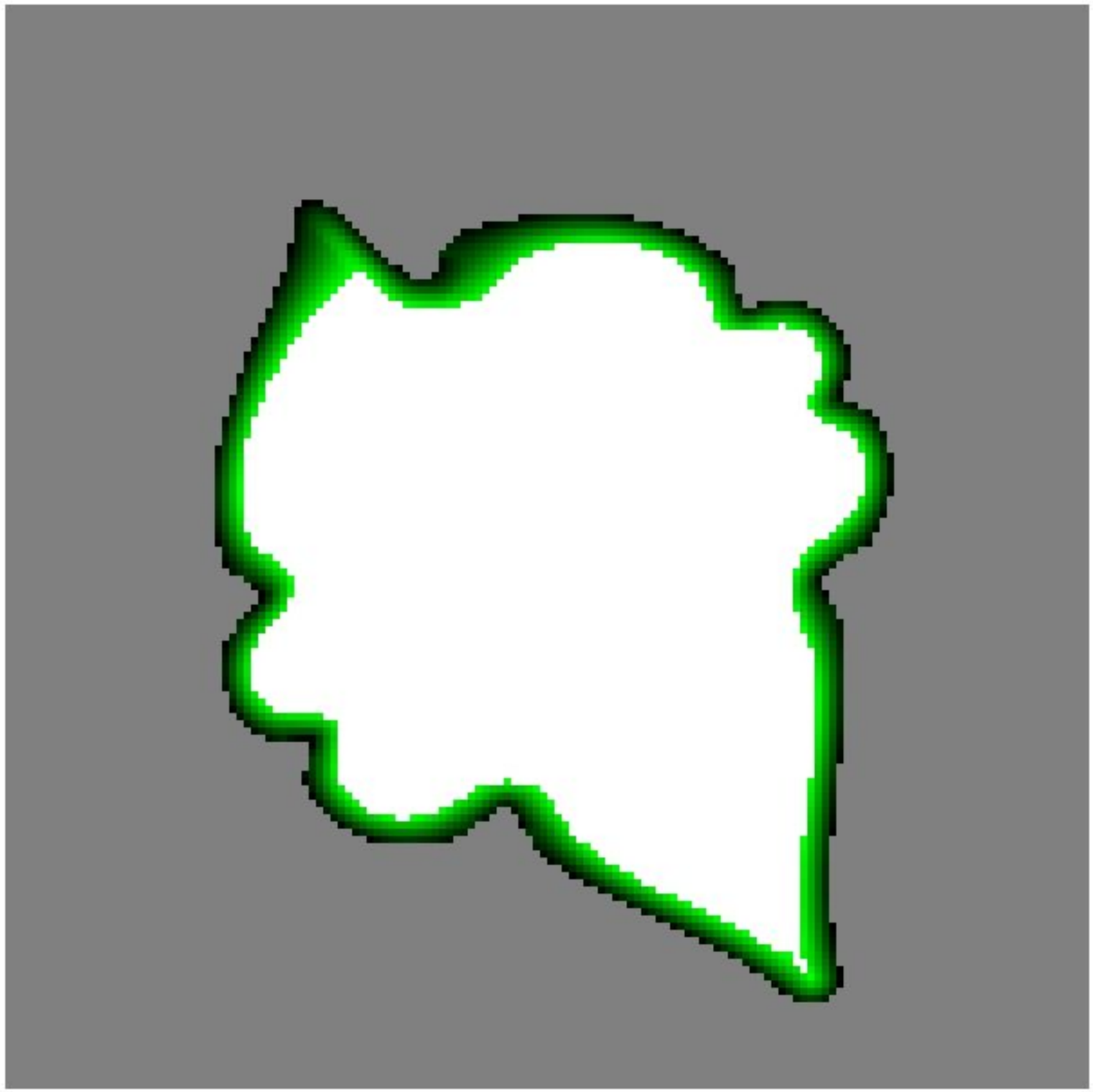






New values have to be recomputed to blur the areas where the front arrived from opposite directions - several steps of averaging...

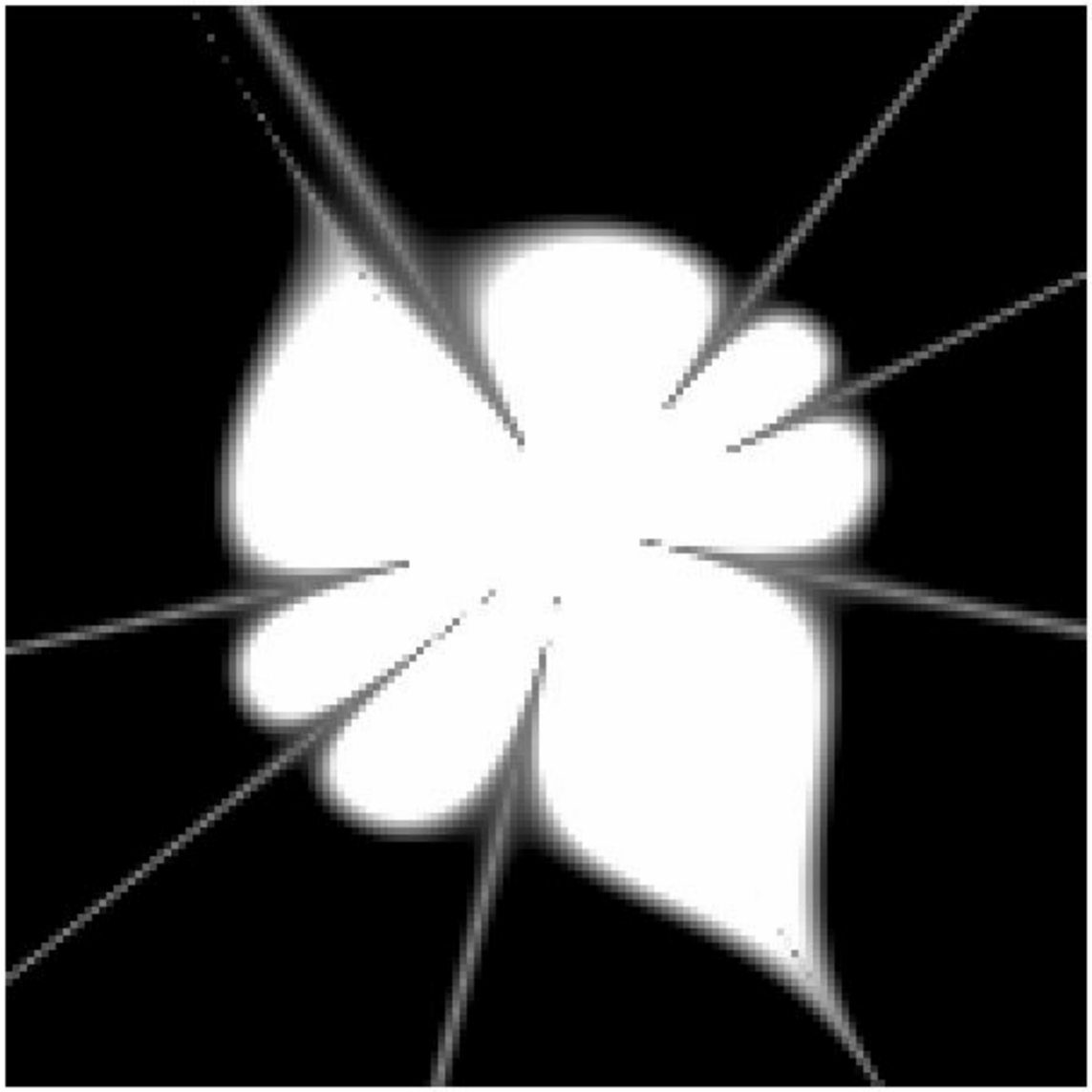




Done.

Final result

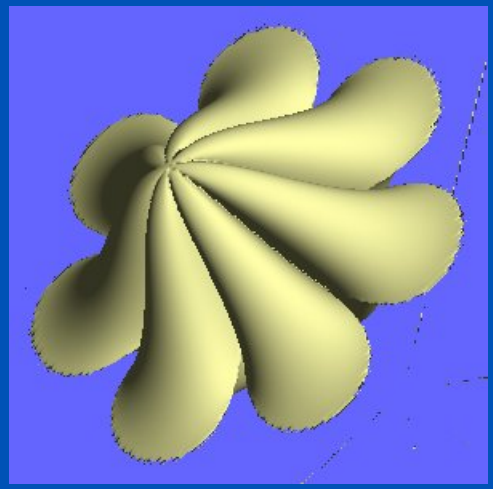
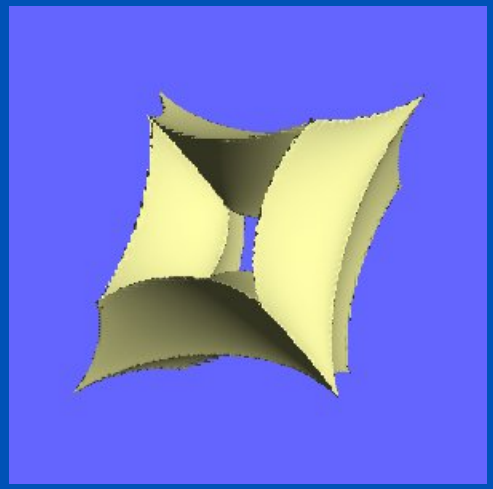
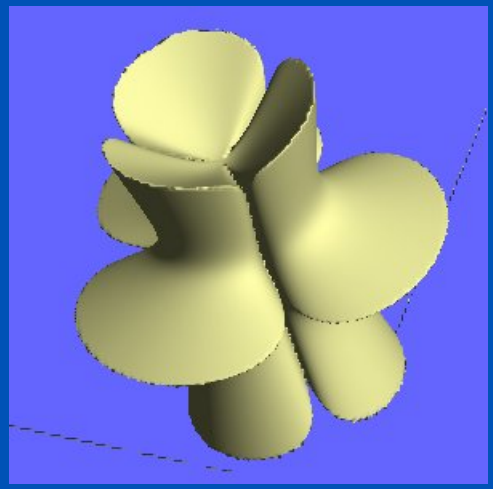
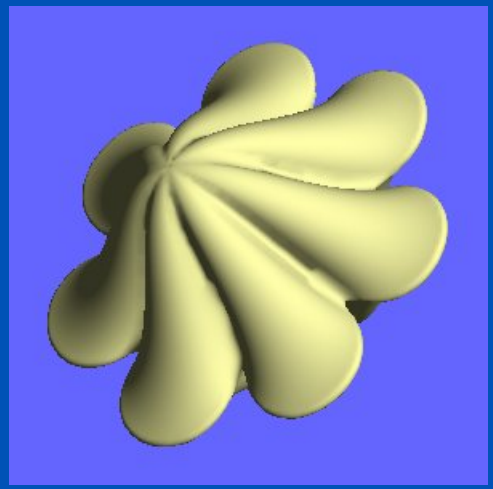
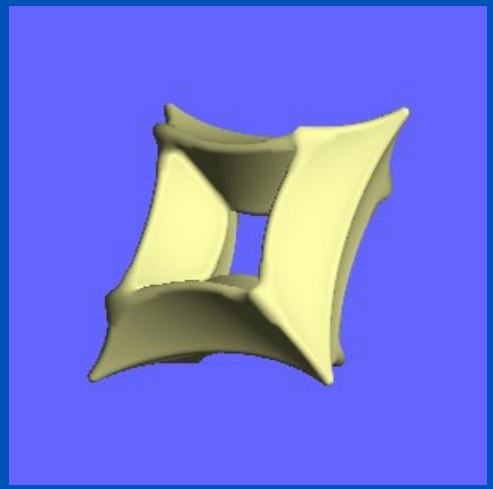
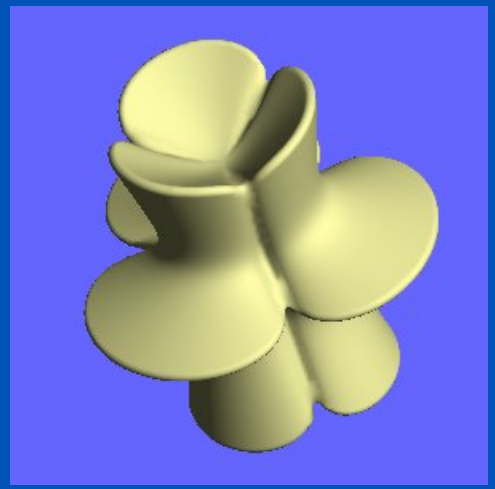
Comparision of results



Trivial Voxelization

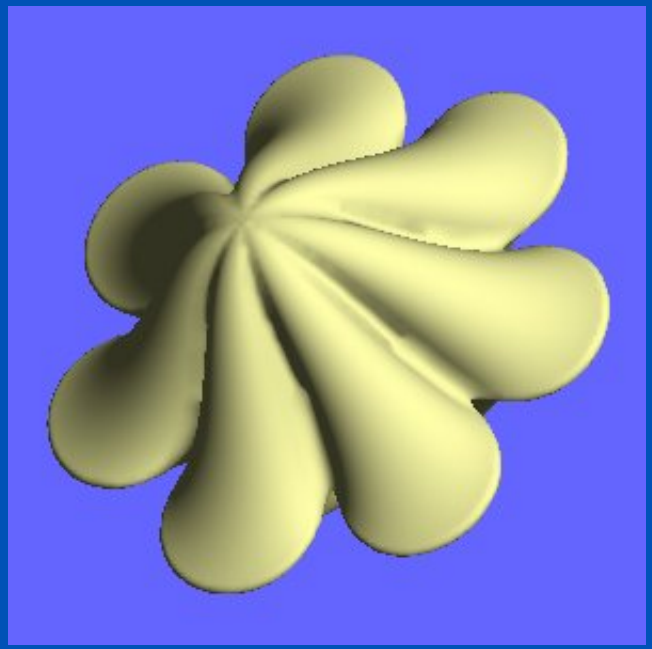
SDC Method

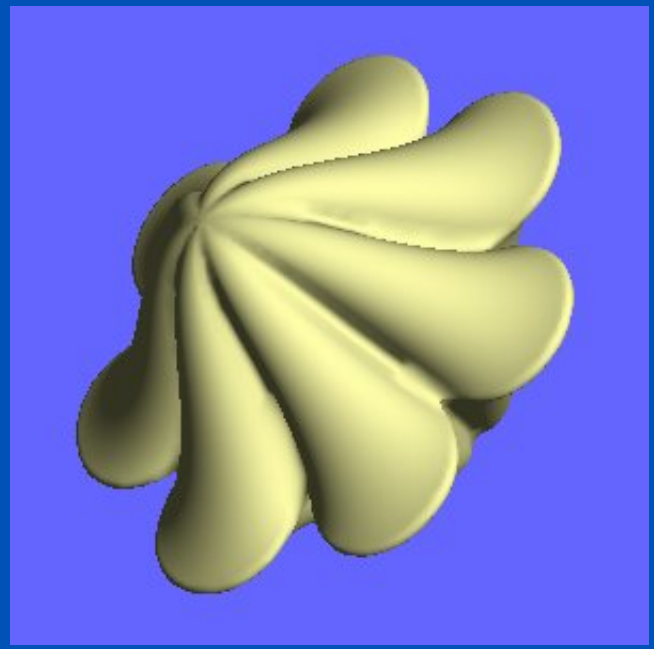
Results

Open Problems

- Exact localization of the inflex area
  - Sensitivity to the location in the grid
  - Especially disturbing in animations





Thank you for attention.