GEOINFO
Brazilian Symposium on GeoInformatics

# Polygon Clipping and Polygon Reconstruction

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# Presentation plan

FIRST CONSIDERATIONS

RELATED WORK

CONTRIBUTIONS

SOME DEFINITIONS

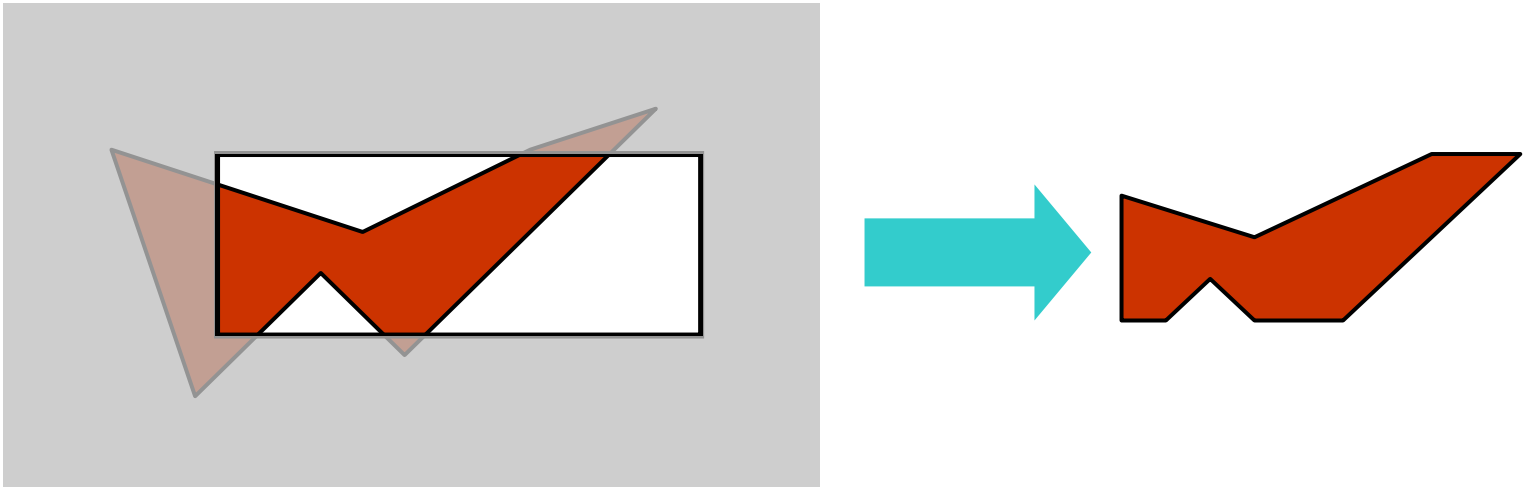
ALGORITHM PROPOSALS

SECONDO

FINAL CONSIDERATIONS

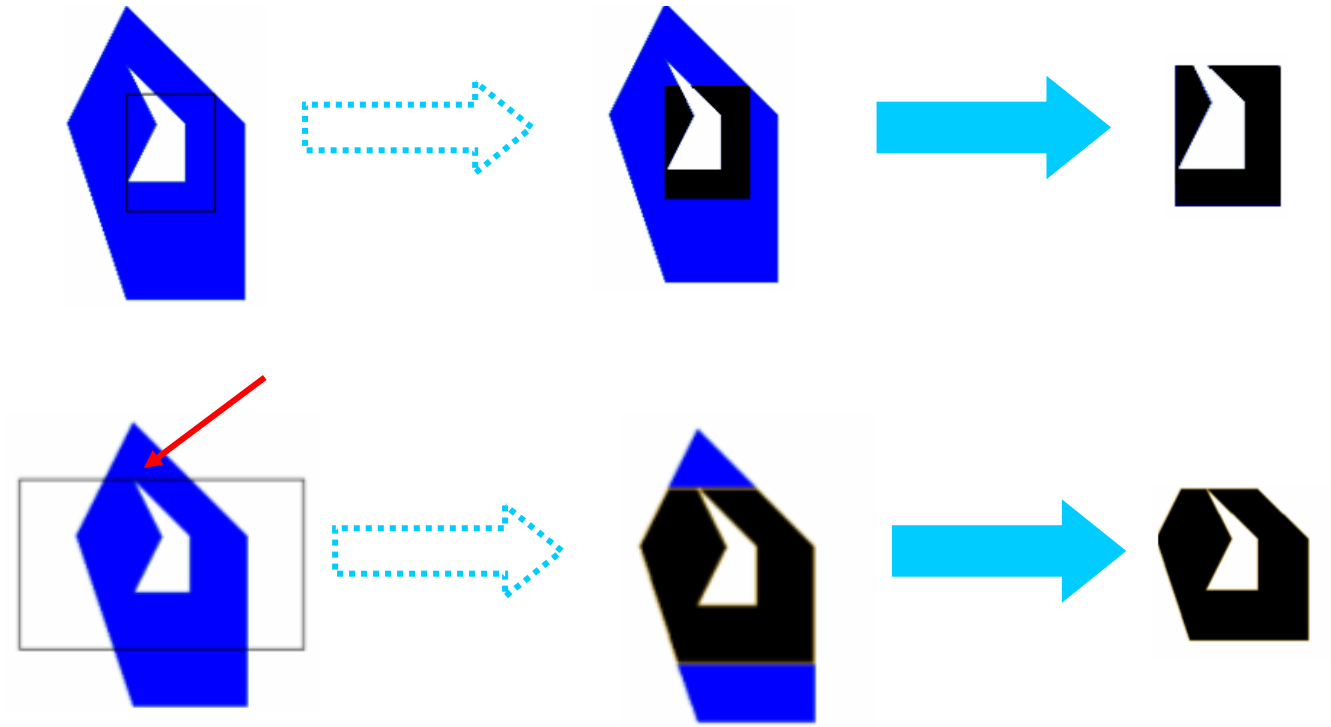
## Polygon clipping

- Polygon clipping is an important operation that computers execute all the time.
- Polygon clipping is the process of removing those parts of a polygon that lie outside a clipping window (Liang and Barsky,1983)



# Polygon clipping

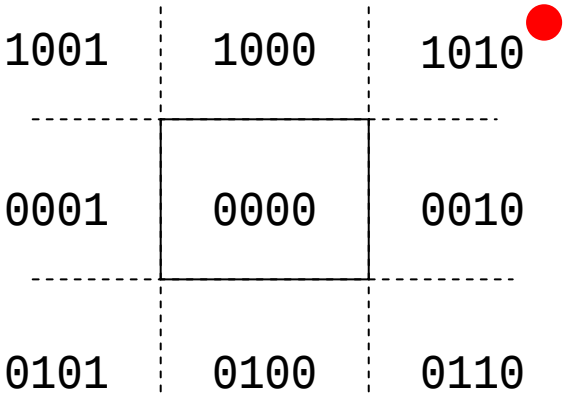
- An algorithm that clips a polygon is rather complex.
- New edges may be added, and existing edges may be discarded, retained, or divided. Multiple polygons may result from clipping a single polygon.



# Cohen-Sutherland line clipping algorithm

- The Cohen-Sutherland algorithm is based on region binary code (*outcode*) related to the window
- The bits in the outcode represent: Top, Bottom, Right, Left.

| T | B | R | L |
|---|---|---|---|

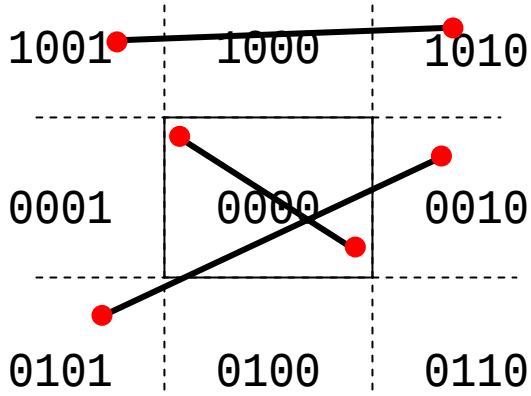



For example the outcode 1010, represents a point that is top-right of the window:

- top: 1
- bottom: 0
- right: 1
- left: 0

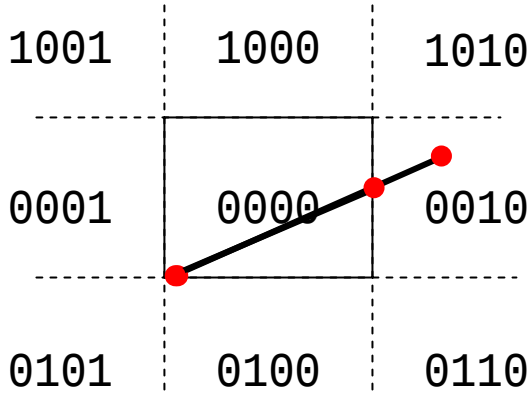
*Based on the outcode, we can perform trivial accept or reject*

# Cohen-Sutherland line clipping algorithm




- Both ending points are in the window
  - (bitwise OR of ending points outcodes == 0): trivial accept
- Both ending points are in the same part, which is not visible
  - (bitwise AND of ending points outcodes != 0): trivial reject
- Both ending points are in different parts (non trivial situation )
  - the intersection of the outpoint and window border is then calculated (i.e. with the parametric equation for the line)
  - this new point replaces the outpoint.
  - the algorithm repeats until a trivial accept or reject occurs.

# Cohen-Sutherland line clipping algorithm

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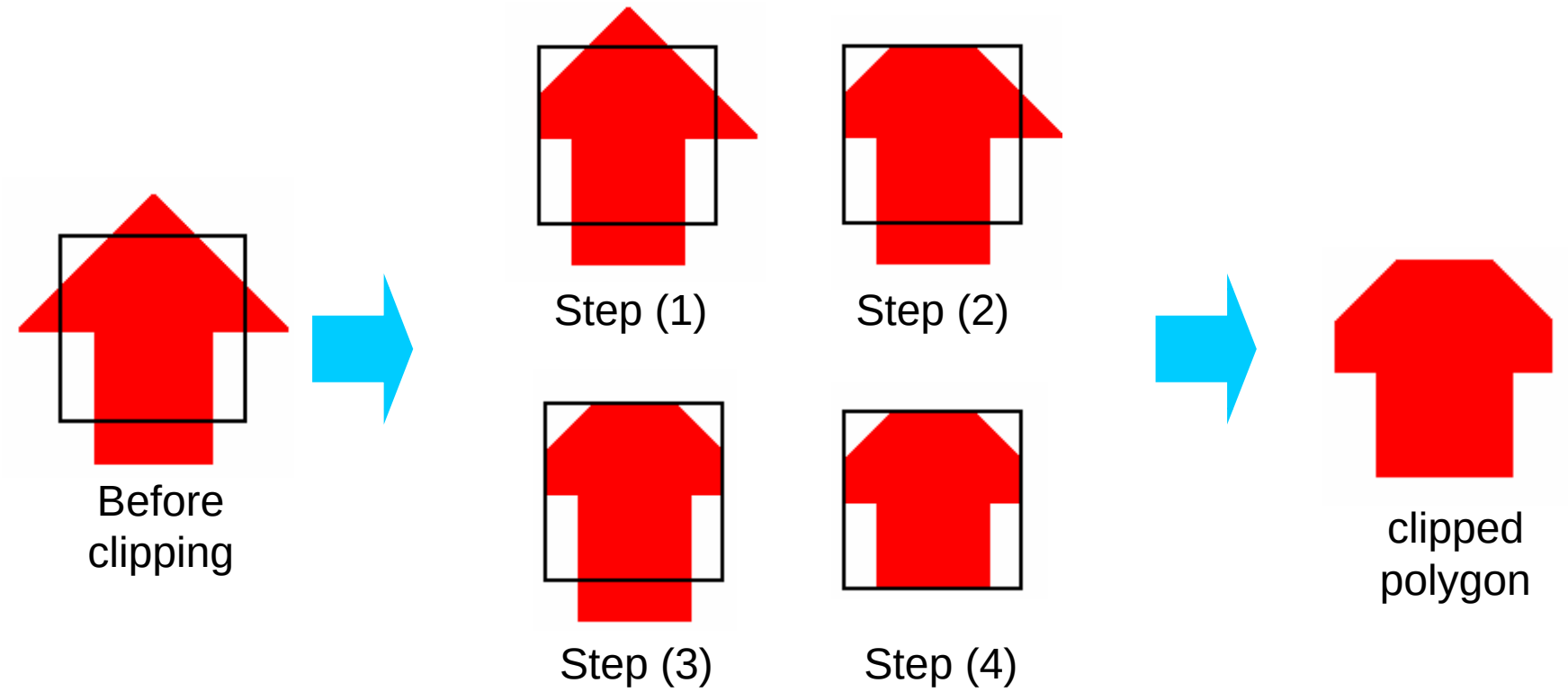
# Sutherland-Hodgman polygon clipping algorithm

- There are several well-known polygon clipping algorithms, each having its strengths and weaknesses.
- Sutherland-Hodgman algorithm is the oldest one (from 1974)
- It performs a clipping of a polygon against each window edge in turn. It accepts an ordered sequence of vertices v1, v2, v3, ..., vn and puts out a set of vertices defining the clipped polygon.

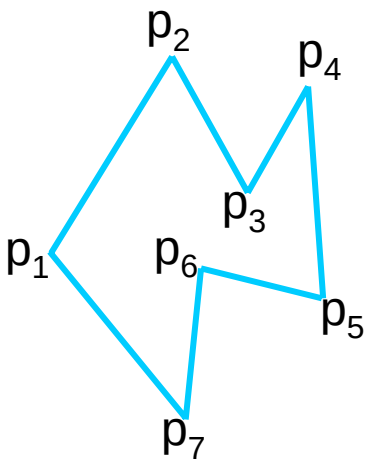


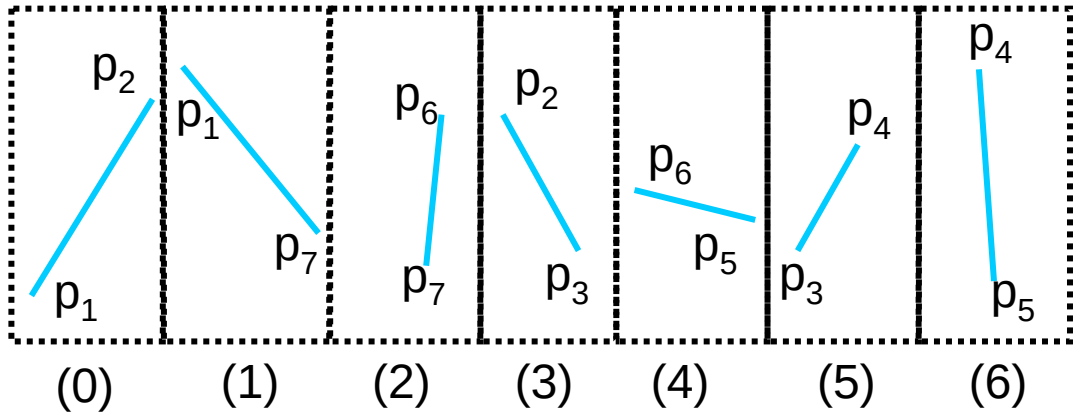
# Polygon clipping algorithms

- Some problems of Sutherland-Hodgman algorithm:
  - It does not work if the clip window is not convex.
  - If the polygon is not also convex, there may be some dangling edges.
- Liang-Barsky algorithm
  - more complicated,
  - but in certain cases fewer intersections need to be calculated than for Sutherland-Hodgman algorithm
- Weiler and Atherton algorithm
  - more complicated.
  - it allows clipping of a subject polygon by an arbitrarily shaped clip polygon.
  - applicable only in 2D.
- Even more ways to clip a polygon exist. None of them is totally perfect
  - vertices may disappear
  - a ghost vertex may be created.
- Therefore, the hunt for the perfect clipping algorithm is still open

# Polygon reconstruction

- Polygon reconstruction is the process of reconstructing a polygon from a set of segments those are not in any specific order.
- For example, polygon's segments may be stored in a list where one segment that follows another one does not have a common point.



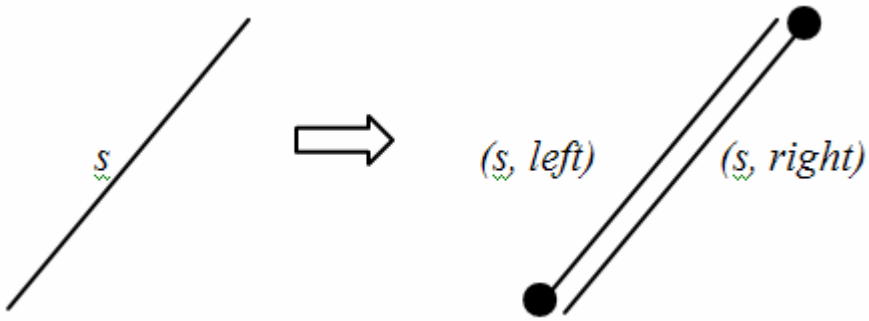



# Algorithm Proposals

- In this work we propose new algorithms
  - an algorithm for polygon clipping by a rectangle window
  - an algorithm for polygon reconstruction from a set of “disconnected” segments
- The algorithms
  - do not assume any specific orientation of polygon’s segments
  - do not rely on the computation of parity or wrap numbers of a reference point.
  - each segment can be processed independent from the others
  - handle polygons that have multiple boundaries and polygons with holes.
- The algorithms were implemented in SECONDO a platform for implementing and experimenting with various kinds of data models
  - It is developed as a research prototype at Fernuniversität in Hagen (Germany)

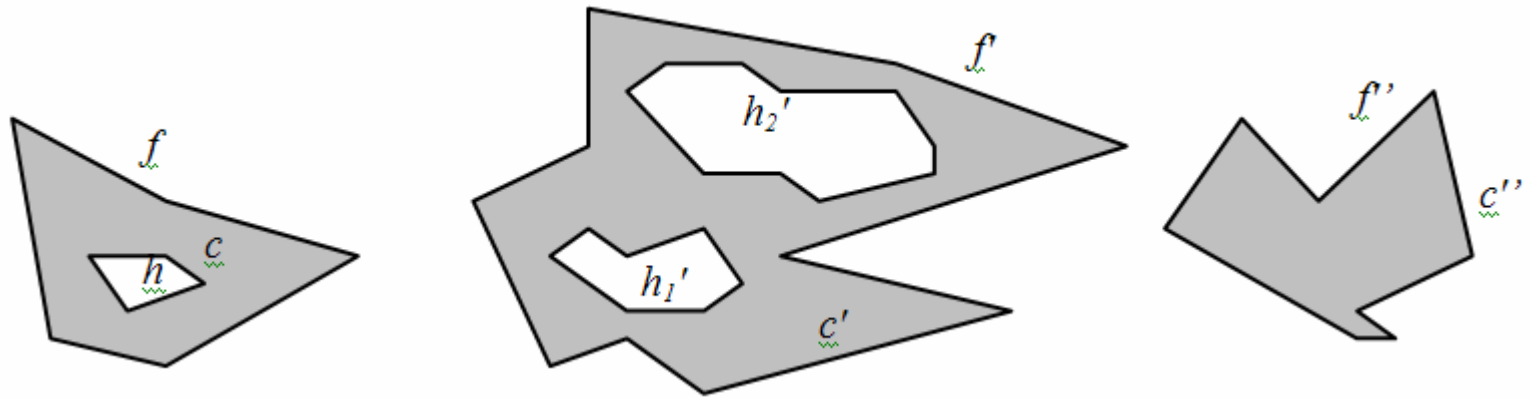
# Halfsegment

- A halfsegment is just a segment for which the left or the right end point is considered as significant.
- A halfsegment *h* = (*s*, *d*) consists of an segment s and a flag *d* emphasizing one of the segment's end points which is called the dominating point of h.
- If *d* = *left* then the left (smaller) end point of *s* is the dominating point of h, and h is called *left halfsegment*. Otherwise, the *right* end point of *s* is the dominating point of *h*, and *h* is called *right halfsegment*.
- In SECONDO, each segment *s* is mapped to two halfsegments (*s*, *left*) and (*s*, *right*).



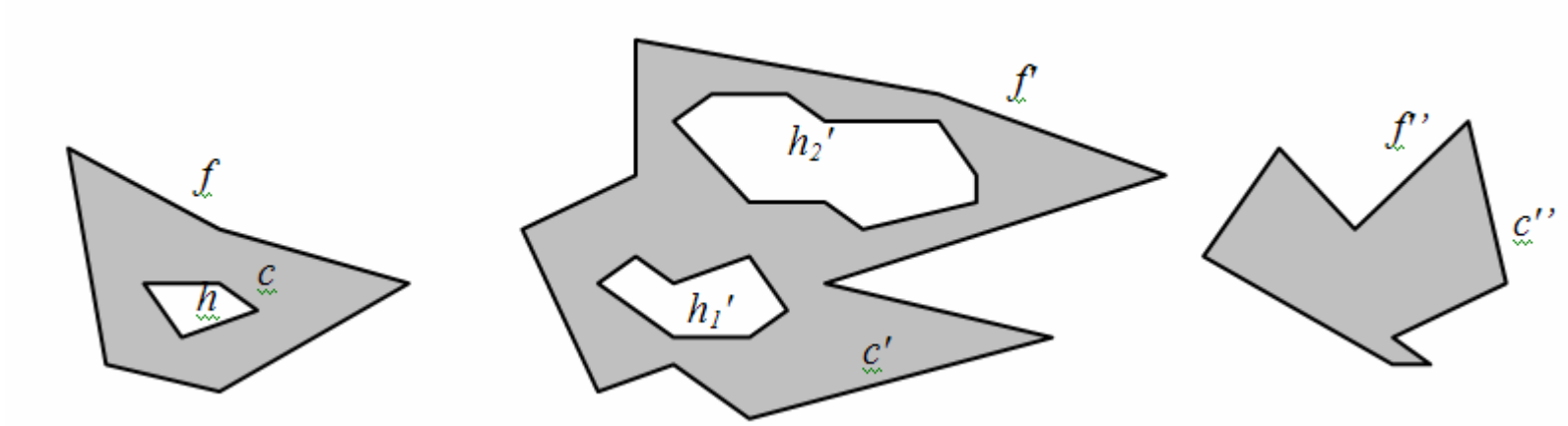
# Polygon

- The polygon structure employed in this work was proposed by Güting et al. (1995) and Güting and Schneider (1995) and used in SECONDO.
- Polygon are composed by faces. A face have a cycle and may have one or more holes.
- Example: Polygon composed by three faces (f , f', and f'').
  - Face f is composed by the cycle c and the hole h.
  - Face f' is composed by the cycle c' and the holes $h_1$' and $h_2$'.
  - Face f'' is composed by the cycle c'' and it has no hole.



# Polygon

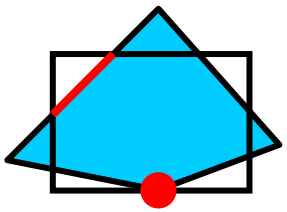
- In practice, a polygon is represented essentially as an ordered list (array) of halfsegments. The order used is the one suitable to support plane-sweep algorithms.
- Each halfsegment has a set of attributes storing the cycle (or hole), the face that it belongs and the position of its halfsegment partner.



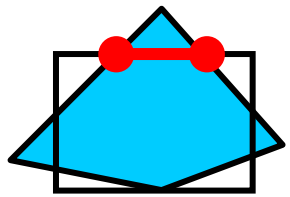
# Polygon Clipping Algorithm

- Sutherland-Cohen line clipping algorithm is used to clipping halfsegments against the window
  - It is probably the most efficient method for trivial acceptance and rejection cases
- Clipping of one halfsegment is completely independent of other halfsegments clipping
  - It is possible to employ a parallel implementation

- Sutherland-Cohen line clipping algorithm may returns a clipped halfsegment or an intersection point



- Intersection points between segments and edges must be handled, new halfsegments may be produced



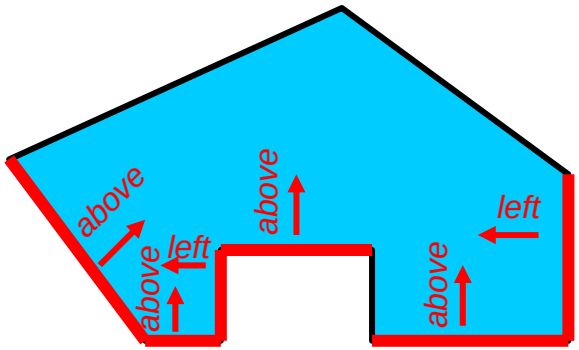
*Turning points*

# Polygon Clipping Algorithm

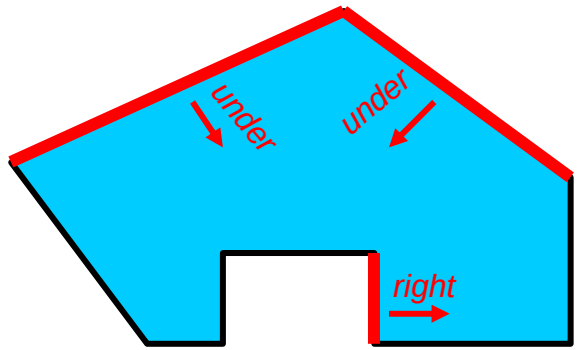
```
FOR each halfsegment s in a set of segments DO
    SutherlandCohenLineClipping(s, window, clippedHS,
                                    intersectionPoint,  isIntersectionPoint));
    IF (isIntersectionPoint)
        evaluateTurningPoint(intersectionPoint);
    ELSE
        add clippedHS to the halfsegment output list;
        evaluateTurningPoint(clippedHS.leftPoint);
        evaluateTurningPoint(clippedHS.rightPoint);

create new halfsegments from turning points;

Reconstructe the polygon;
```

# Evaluate turning point

- InsideAbove *flag*
  - True: the area inside the polygon lies **above** the halfsegment; or, if the halfsegment is a vertical line, it means that the area inside the polygon is on the **left** of the half segment.
  - False: otherwise.



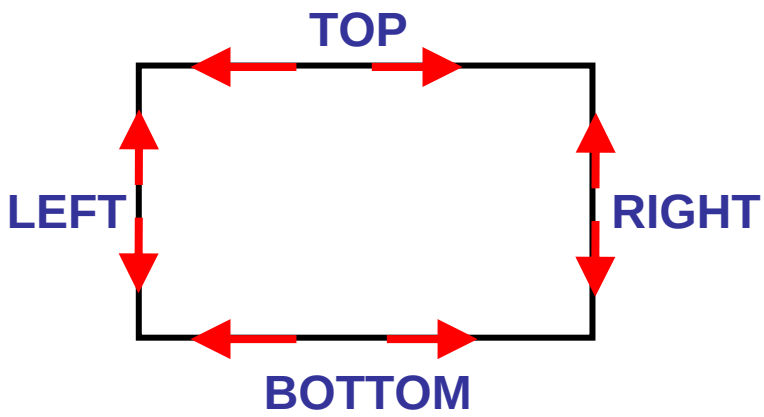

Halfsegments where *InsideAbove* is ***true***




Halfsegments where *InsideAbove* is ***false***

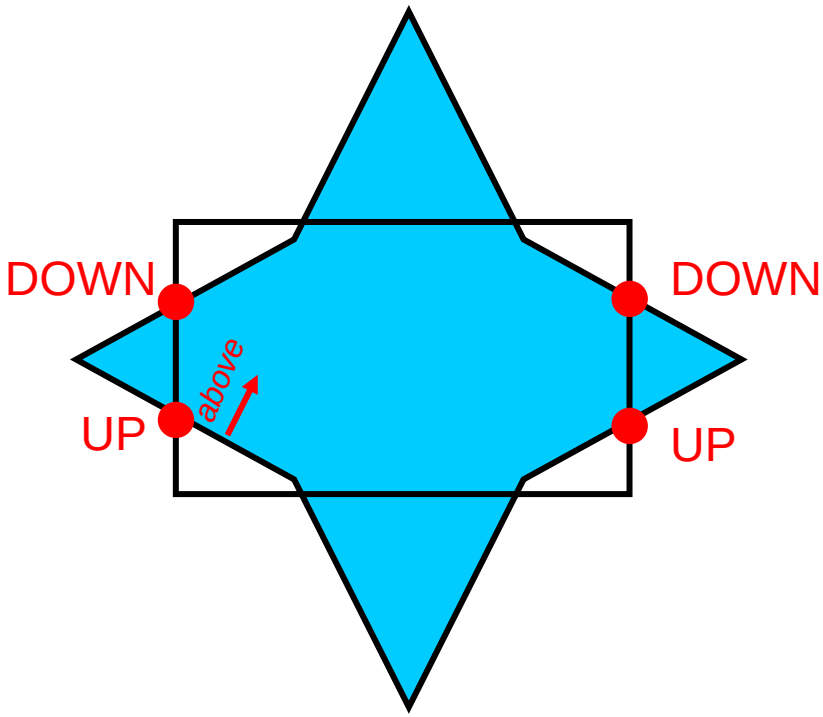
# Evaluate turning point

- For each window edge the inside above flag is evaluated, and a direction for the turning point is set. This flag will be used to create new edges.
  - LEFT and RIGHT edges: up or down directions
  - TOP and BOTTOM edges: left or right directions



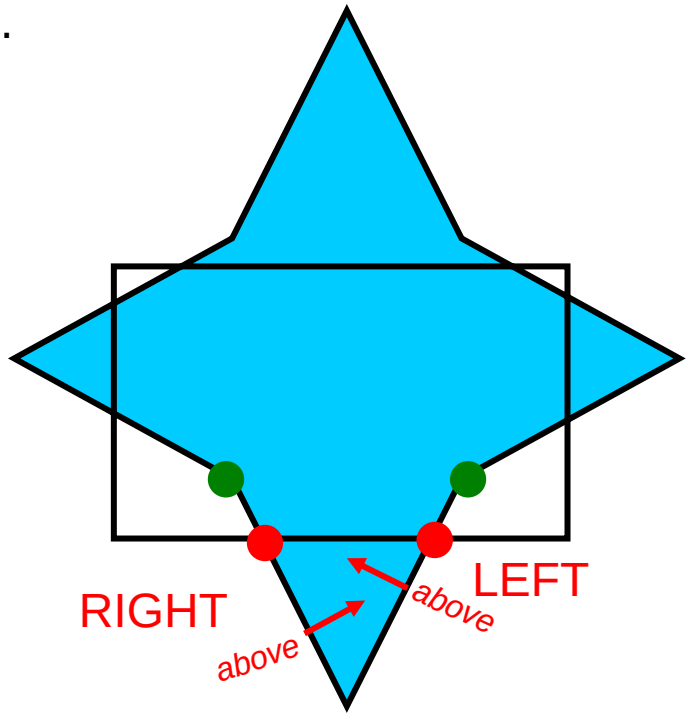
# Evaluate turning point

- For each window edge the inside above flag is evaluated, and a direction for the turning point is set. This flag will be used to create new edges.
  - LEFT and RIGHT edges:
    - UP: IF insideAbove of the half segment the turning point belongs is true
    - DOWN: Otherwise



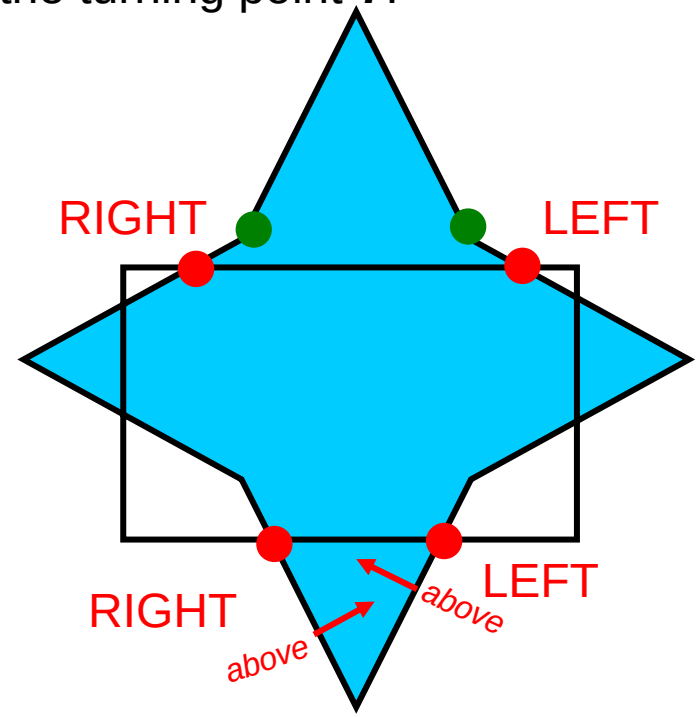
# Evaluate turning point

- For each window edge the inside above flag is evaluated, and a direction for the turning point is set. This flag will be used to create new edges.
  - TOP and BOTTOM edges: the inside above flag is not enough to set a direction
  - We also evaluate the position of halfsegment point that is above the turning point.



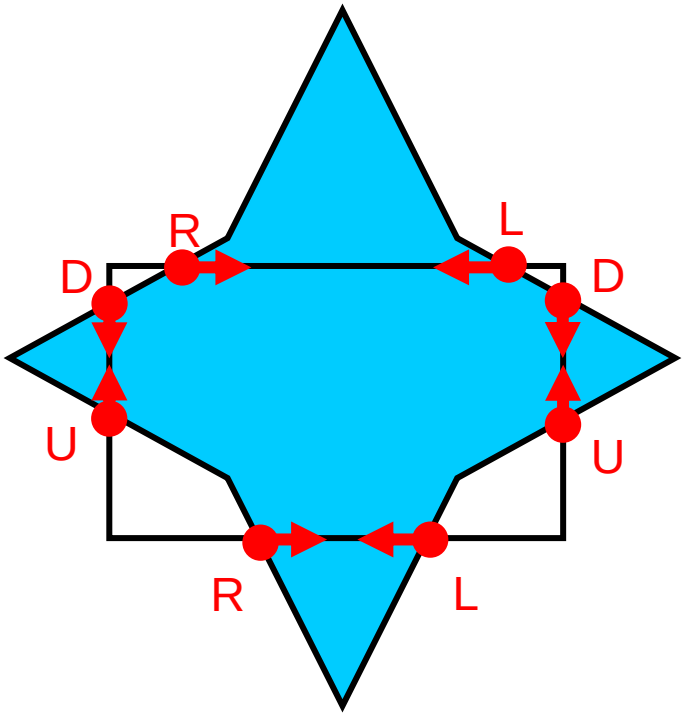
# Evaluate turning point

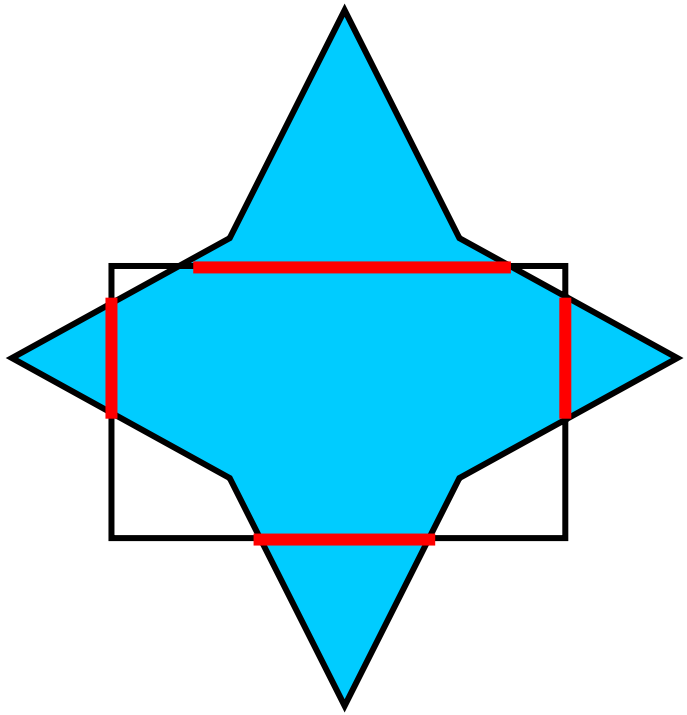
- For each window edge the inside above flag is evaluated, and a direction for the turning point is set. This flag will be used to create new edges.
  - TOP and BOTTOM edges: the inside above flag is not enough to set a direction
  - Since halfsegment's point ***P*** is above the turning point ***T***.
    - IF halfsegment.insideAbove is TRUE
      - IF T.x > P.x ➔RIGHT
      - ELSE ➔ LEFT
    - ELSE
      - IF T.x > P.x ➔LEFT
      - ELSE ➔ RIGHT



# Create new Halfsegments from Turning Points

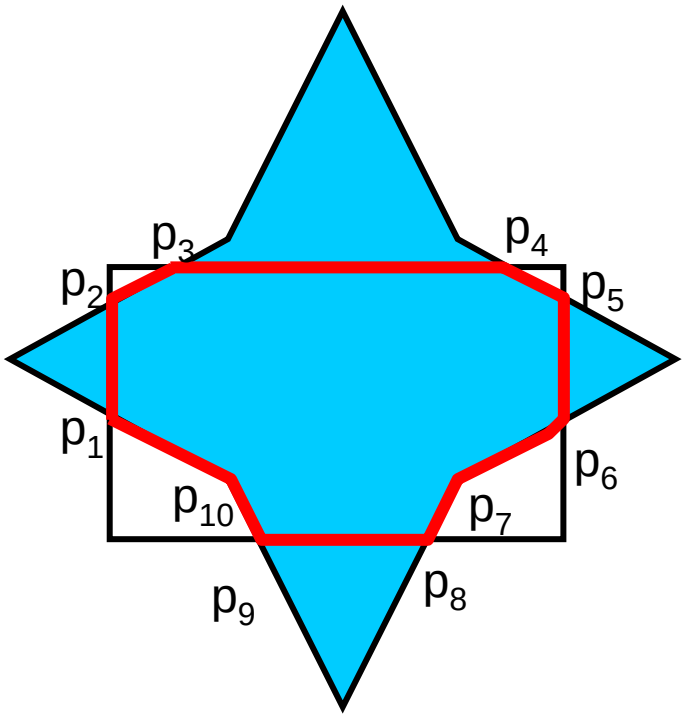
- At the end of turning point evaluation we will have:
  - a set of turning points for each edge
  - each turning point has its direction set
- So, we can create new halfsegments from those turning points

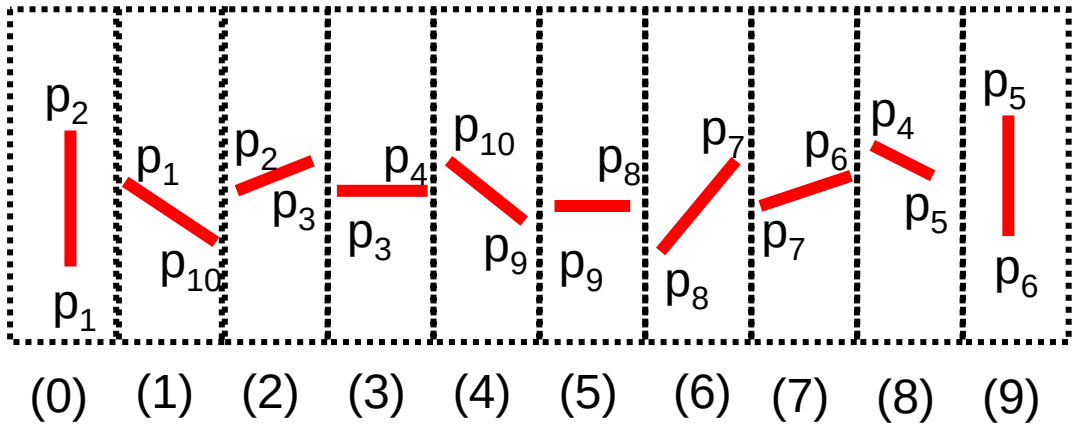


# Polygon Reconstruction Algorithm

- At the end of the clipping we have a set of halfsegments which do not have any information about which polygon's part they belong to (face, cycle and cycle's edge).
- Polygon reconstruction algorithm sort polygon halfsegments in plane sweep order, and cross them adjusting properly the face number, cycle number, and edge number (polygon's halfsegements attributes).

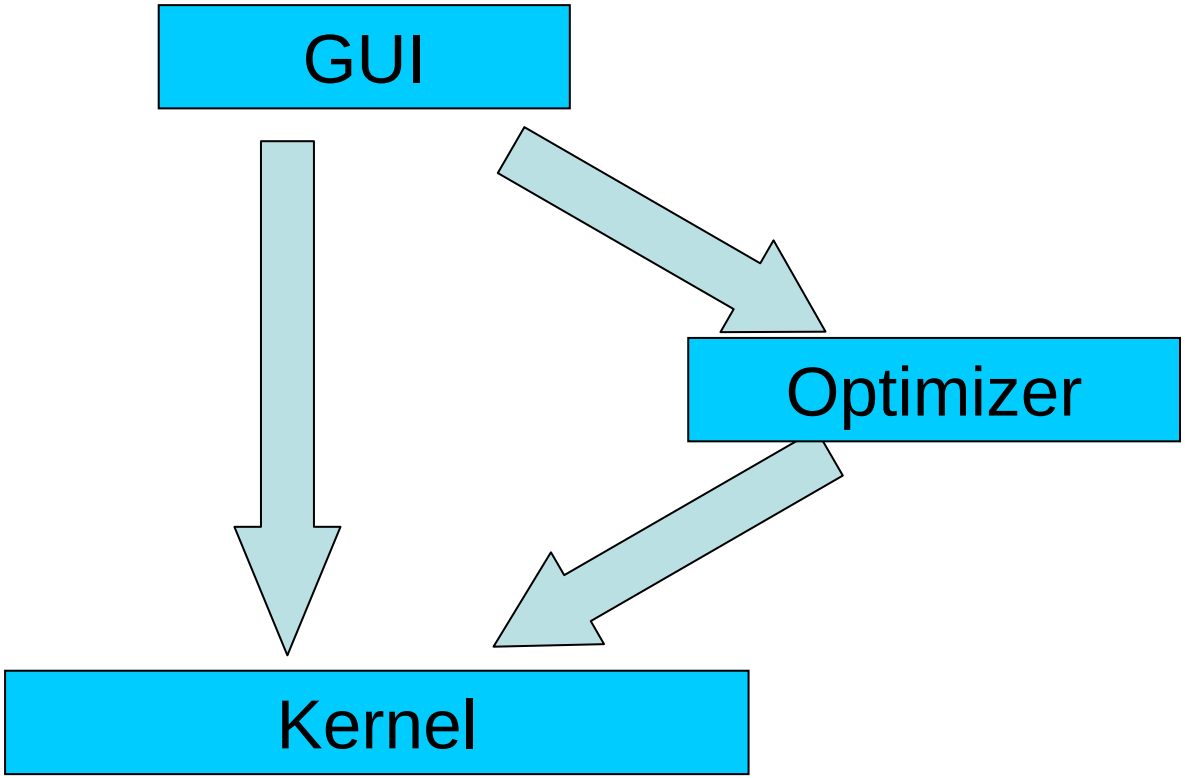


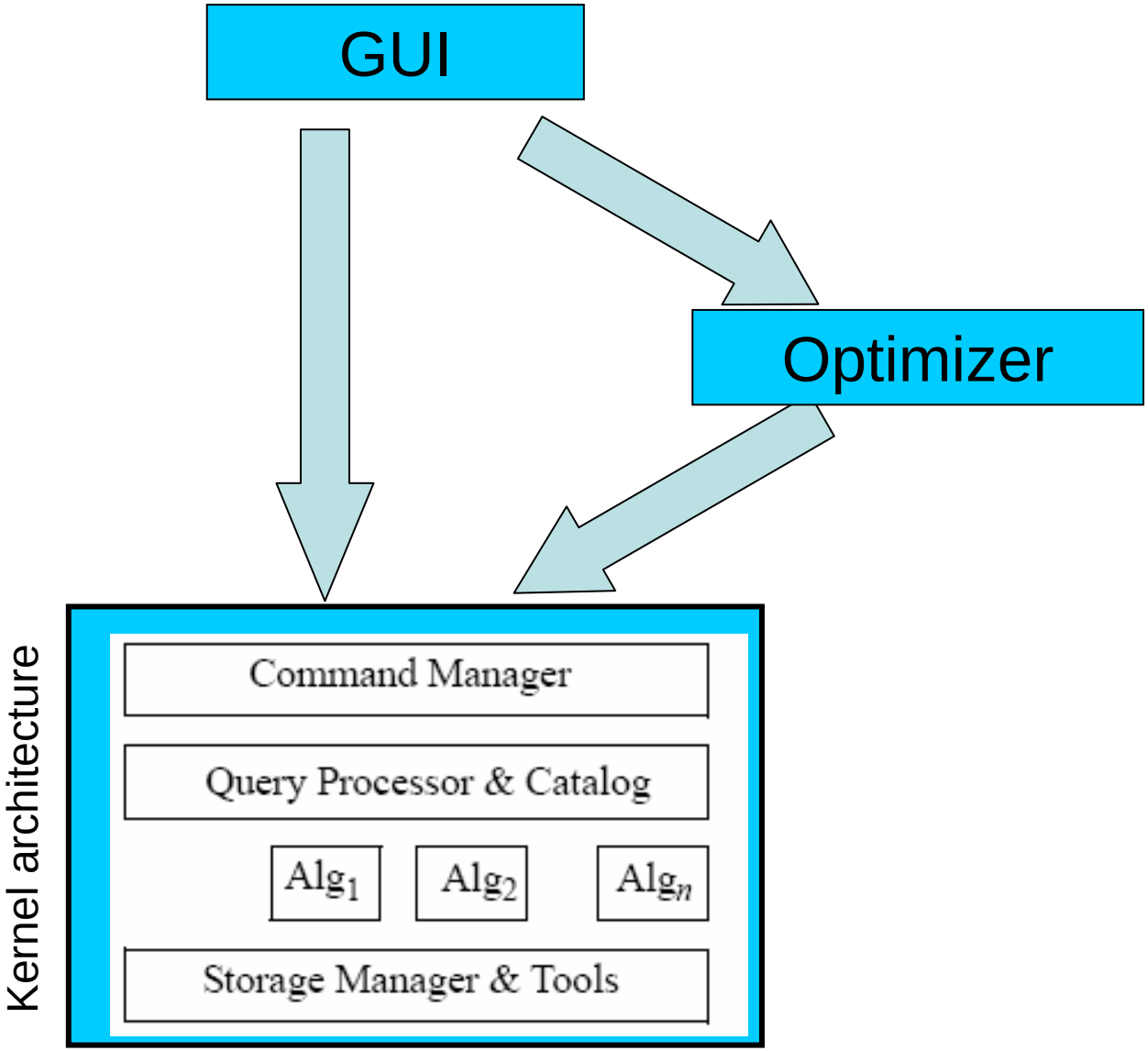
# SECONDO: a platform for prototyping and teaching

- SECONDO is generic environment supporting the implementation of database systems for a wide range of data models and query languages
- It is extensible by algebra modules, using a well defined interface.
  - Algebras groups data types and operations.
- It supports new data models and data structures
- It may be used by groups at universities to pursue and prototype their research ideas for database systems
- Some examples of Algebras:
  - Standard Algebra
  - Relational Algebra
  - Spatial Algebra
  - Temporal Algebra
  - RTree Algebra
  - Midi Algebra
  - etc

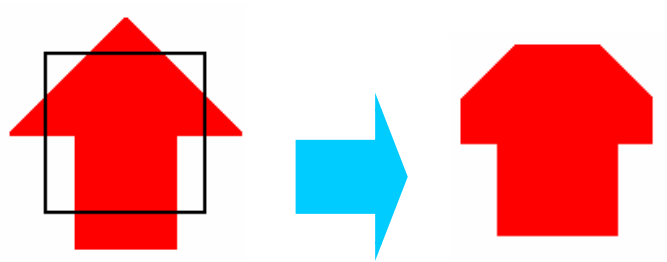
# Cooperation of SECONDO components



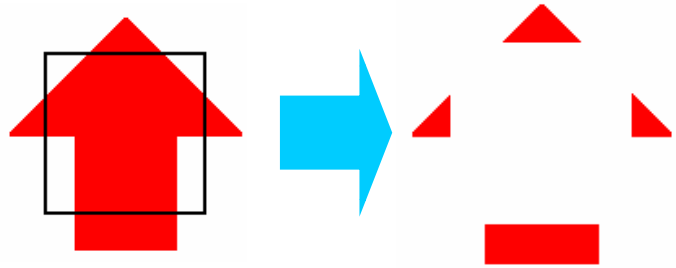
# SECONDO Kernel architecture



# Polygon clipping algorithms in SECONDO



Name: **windowclippingin**
Signature: (line x rect) ➔line
(region x rect) ➔ region
Syntax: windowclipping**in**( _, _ )
Meaning: computes the part of the object that is **inside** the window.
Example: query windowclippingin(trajectory(train7), bbox(thecenter))



Name: **windowclippingout**
Signature: (line x rect) ➔line
(region x rect) ➔ region
Syntax: windowclipping**out**( _, _ )
Meaning: computes the part of the object that is **outside** the window.
Example: query windowclippingout(trajectory(train7), bbox(thecenter))

**Polygon reconstrucion** algorithm
- It was implemented as a method of class Region in Spatial Algebra
- It is used by the clipping algorithms to compute the clipped polygons.

# Conclusions

- In this work, we proposed two new algorithms:
  - polygon clipping by a rectangle window; and,
  - polygon reconstruction
- The polygon reconstruction algorithm may be used in any case where it is needed to compute a polygon from an unordered set of segments. An example of application is polygon clipping.
- Related to polygon clipping algorithm, we proposed and implemented two proposals:
  - an algorithm to return the portion of the polygon that is **inside** a rectangle window; and,
  - an algorithm to return the portion of the polygon that is **outside** the window.
- Although our algorithm implementations in SECONDO has a good performance, we do not execute an experimental evaluation against other similar algorithms, which we plan to do as future work.

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# Polygon Clipping and Polygon Reconstruction

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