Hidden Surfaces

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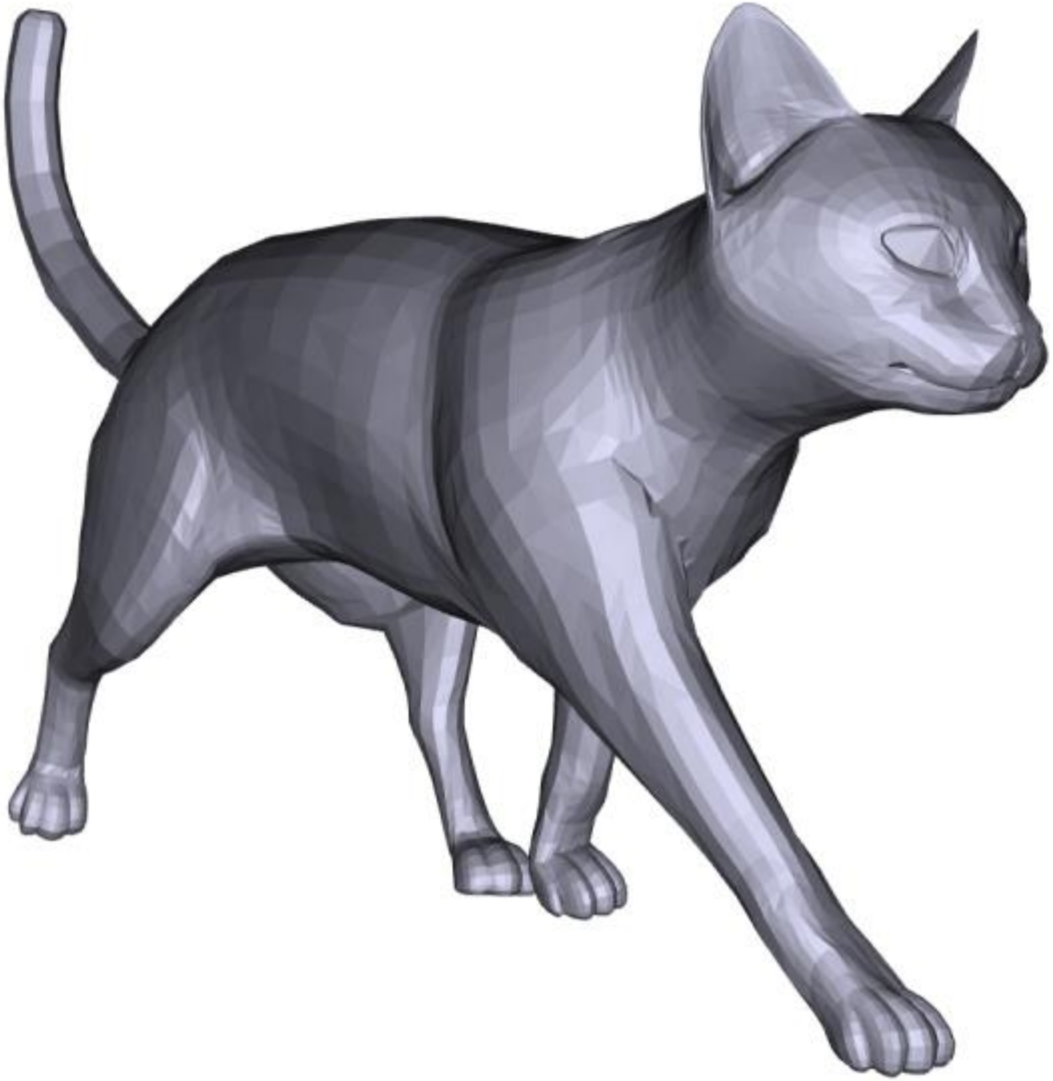
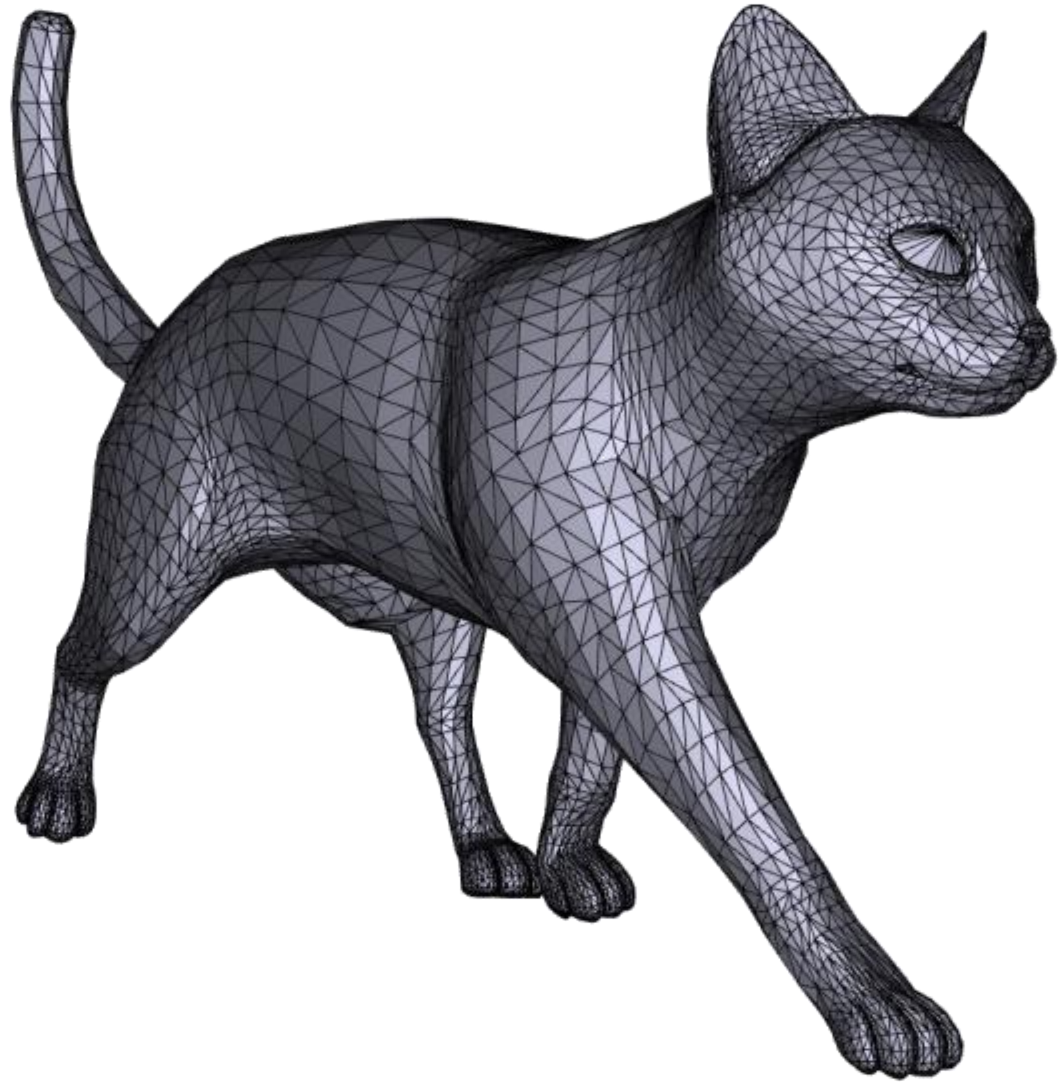
TAMU
Computer
Science

Hidden Surfaces



Hidden Surfaces



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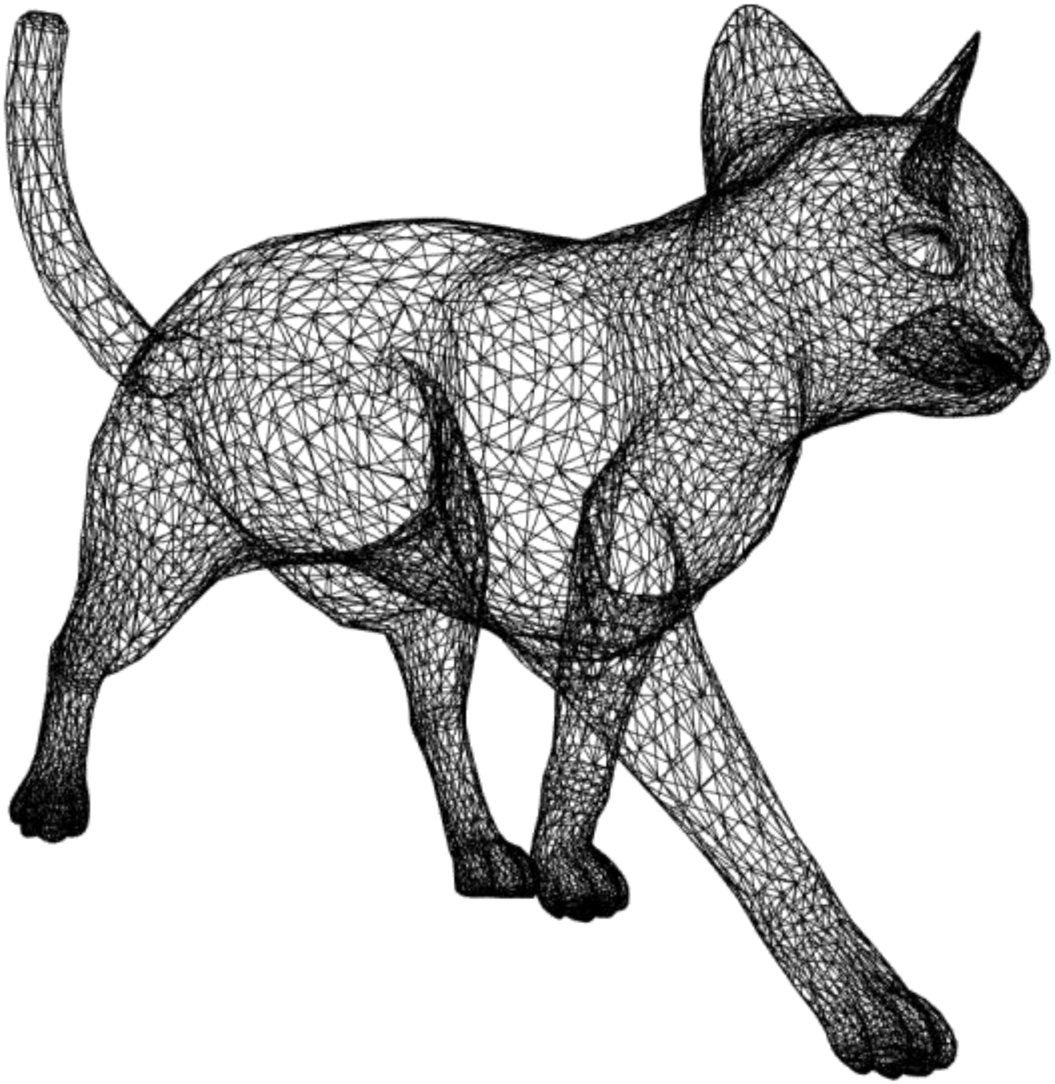
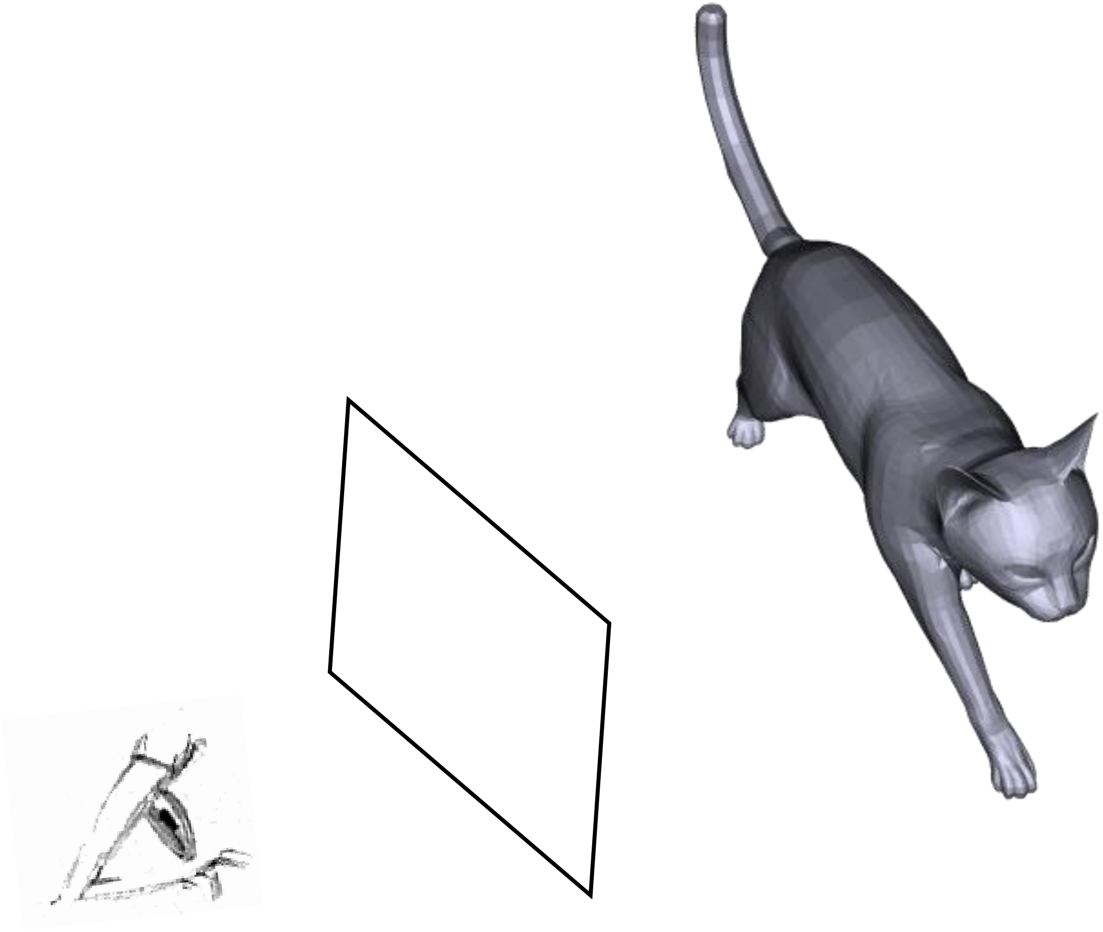


Backface Culling



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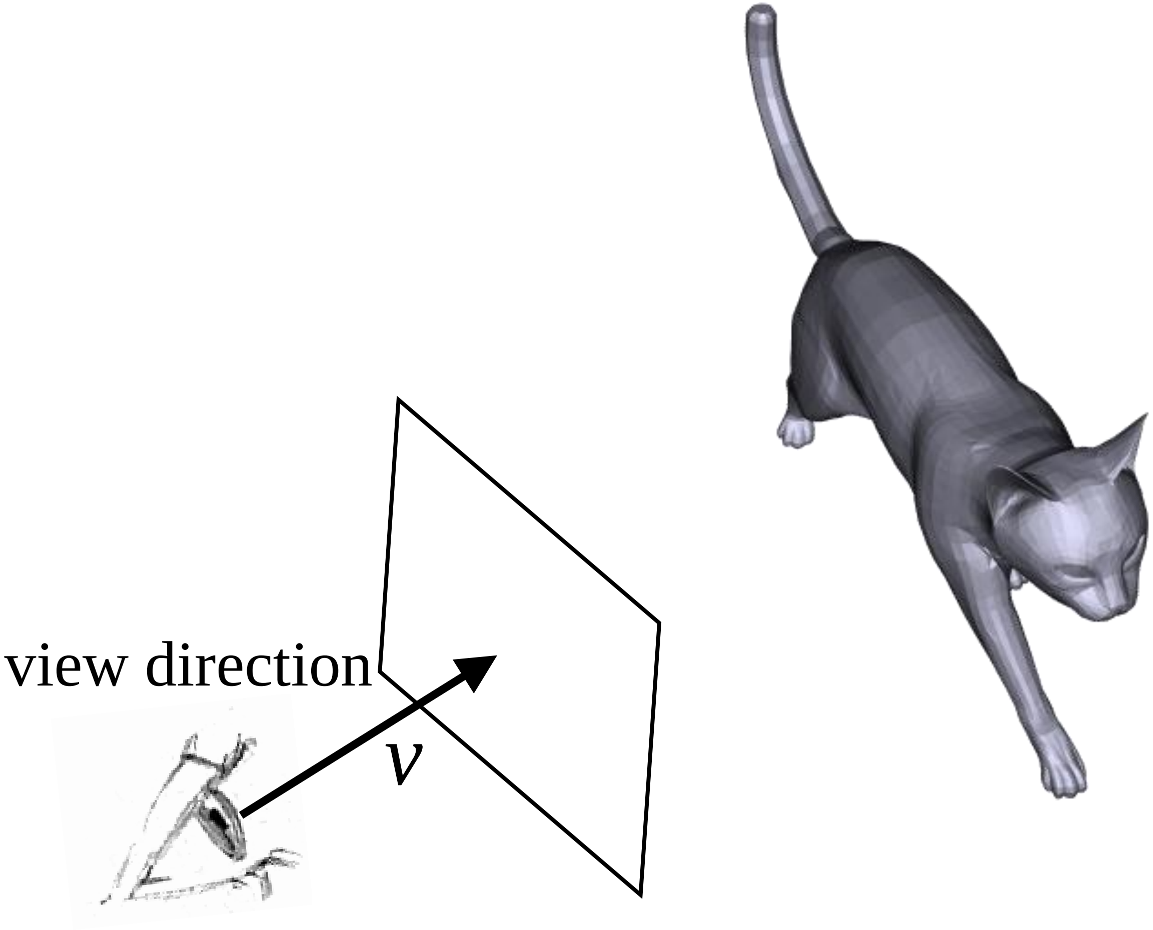

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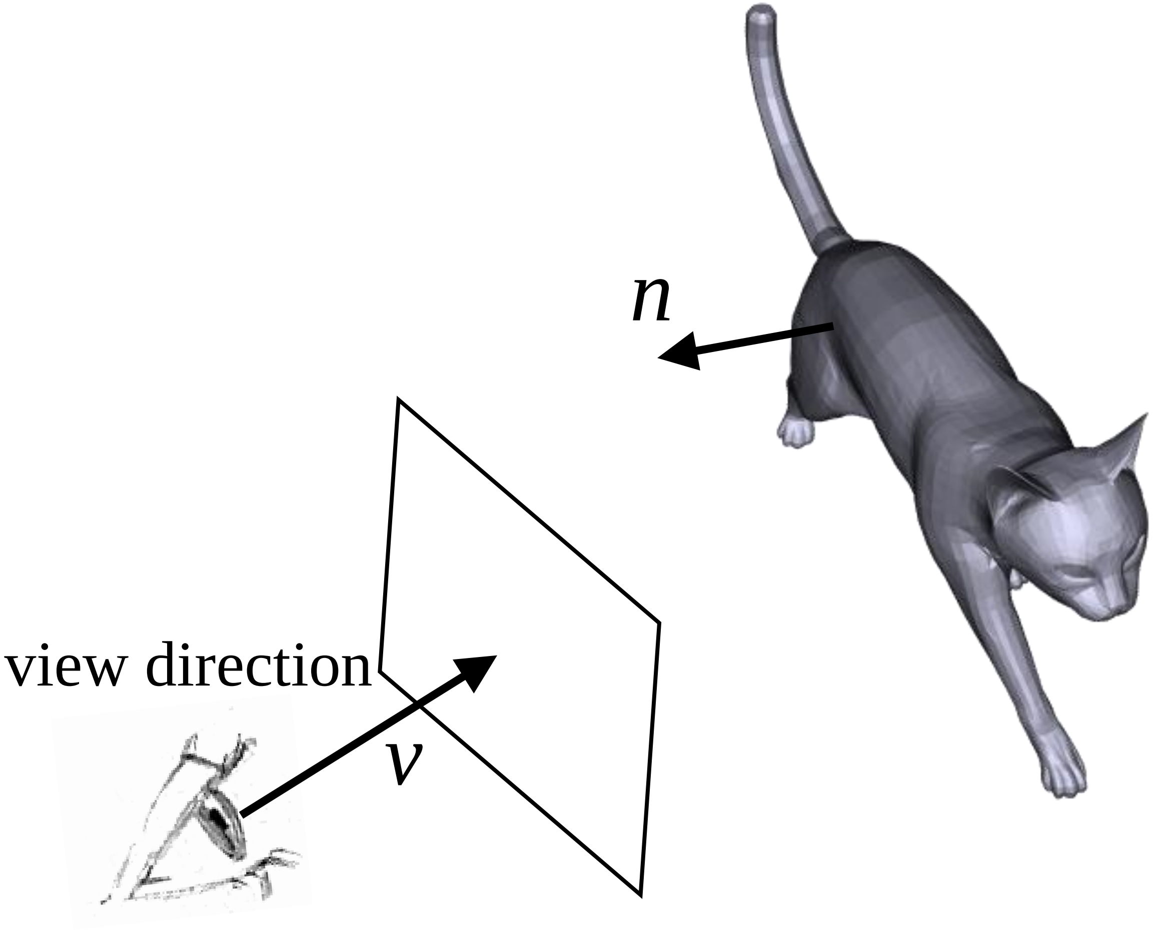
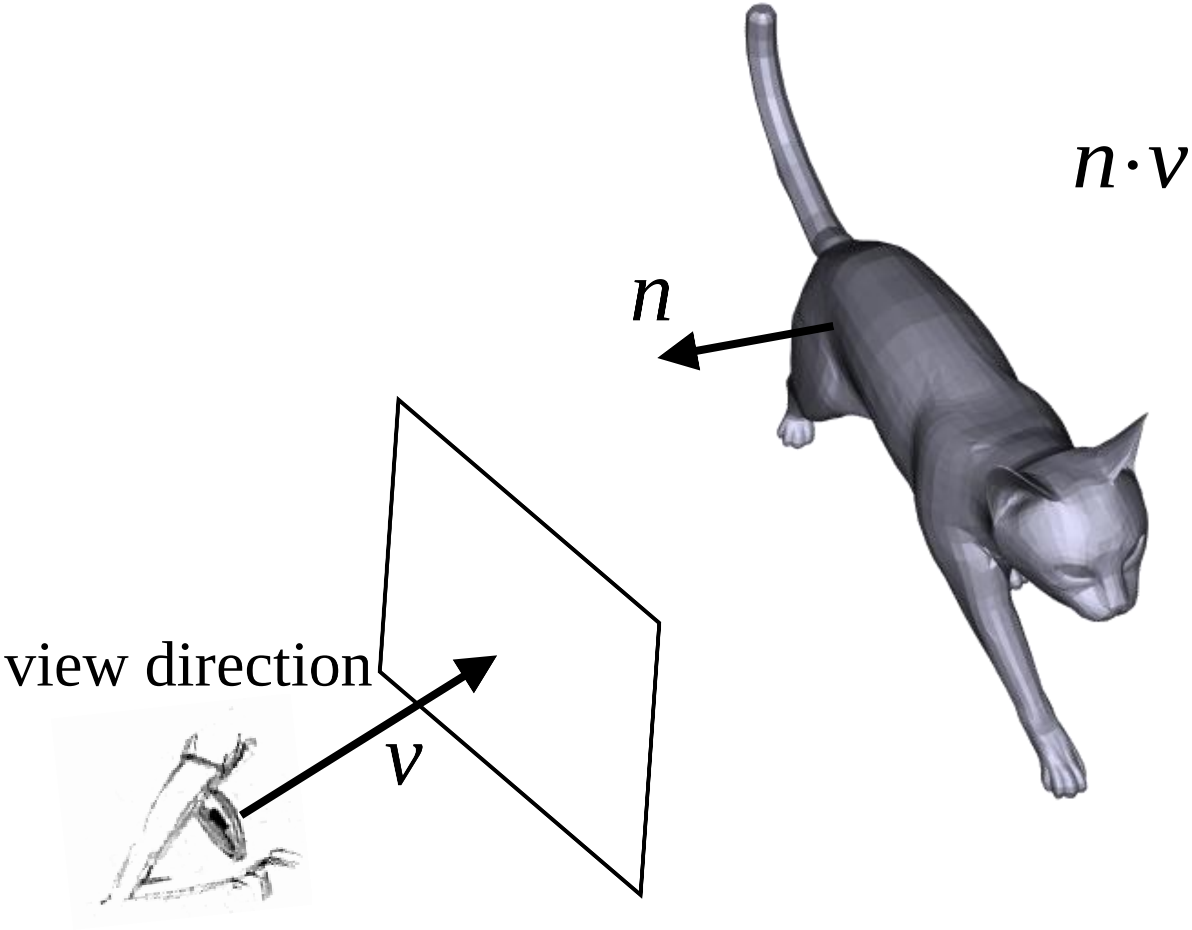


Backface Culling

$n \cdot v < 0$, draw polygon

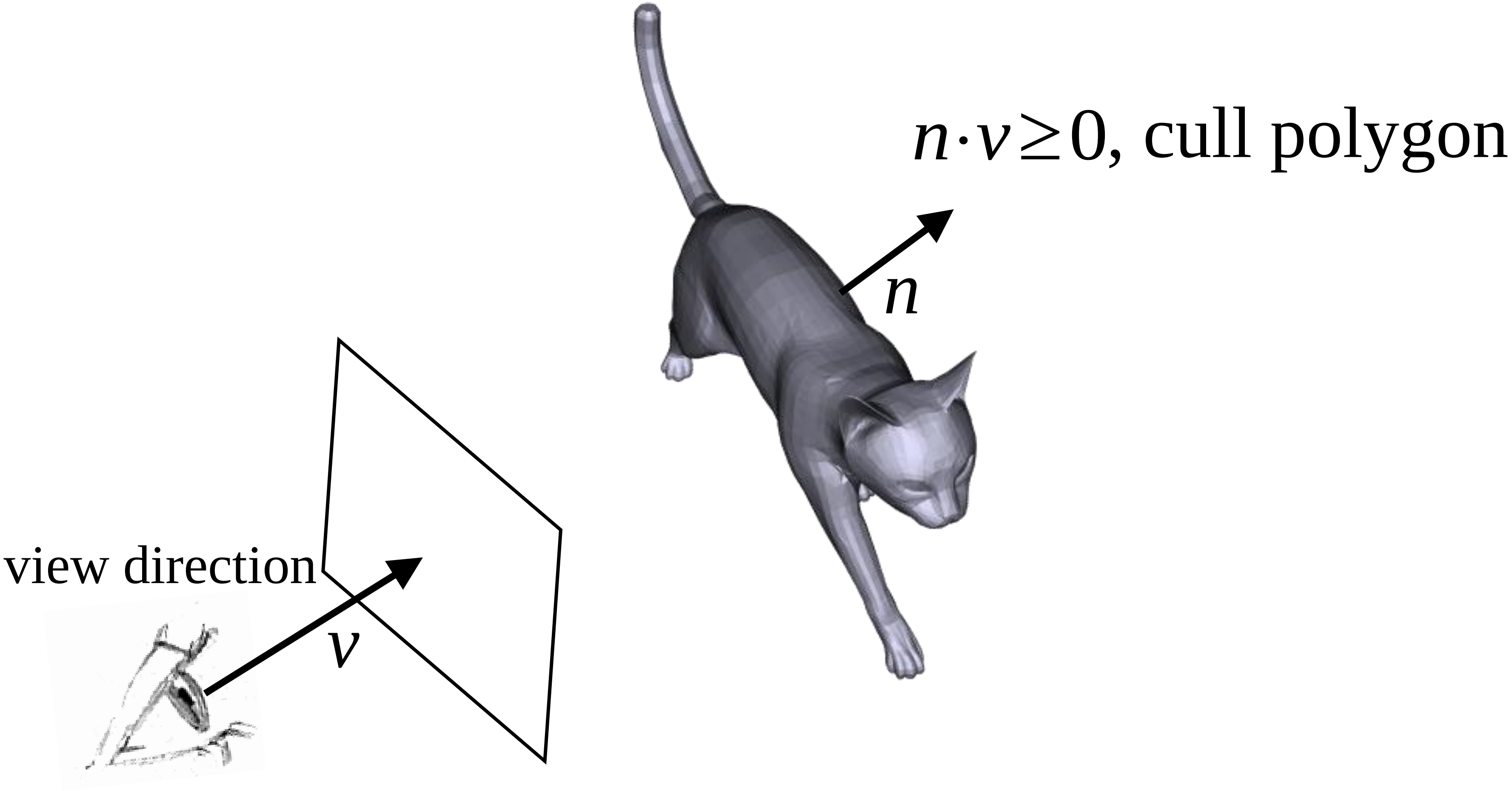


n

view direction

v

Backface Culling



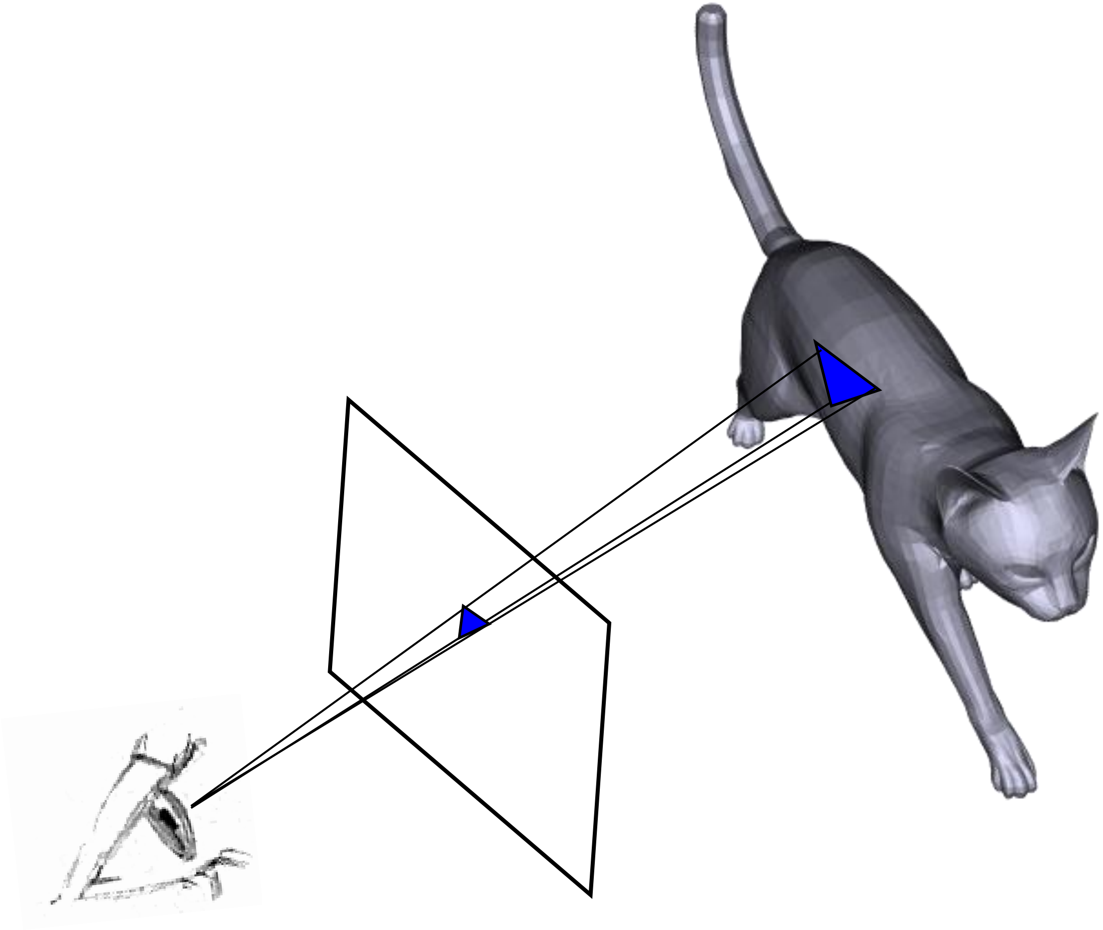
$n \cdot v \geq 0$, cull polygon

n

view direction

v

Backface Culling



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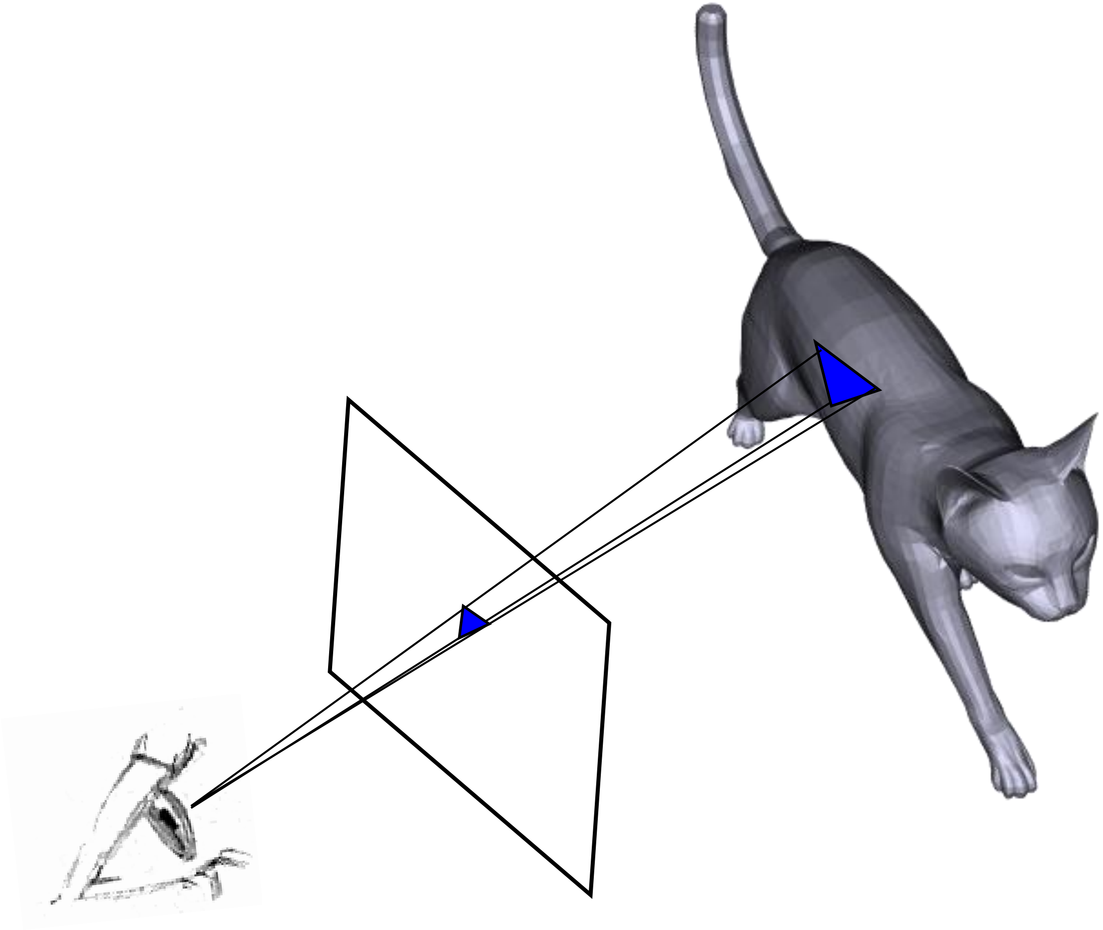
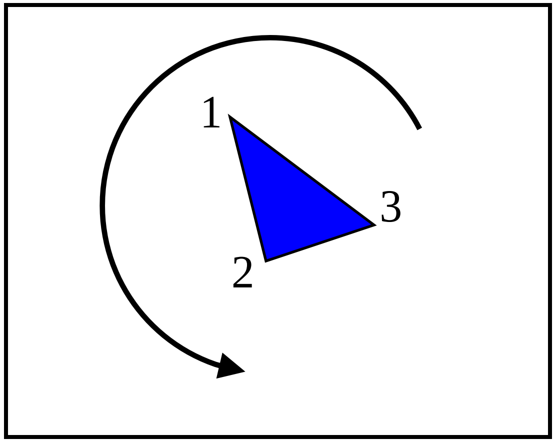
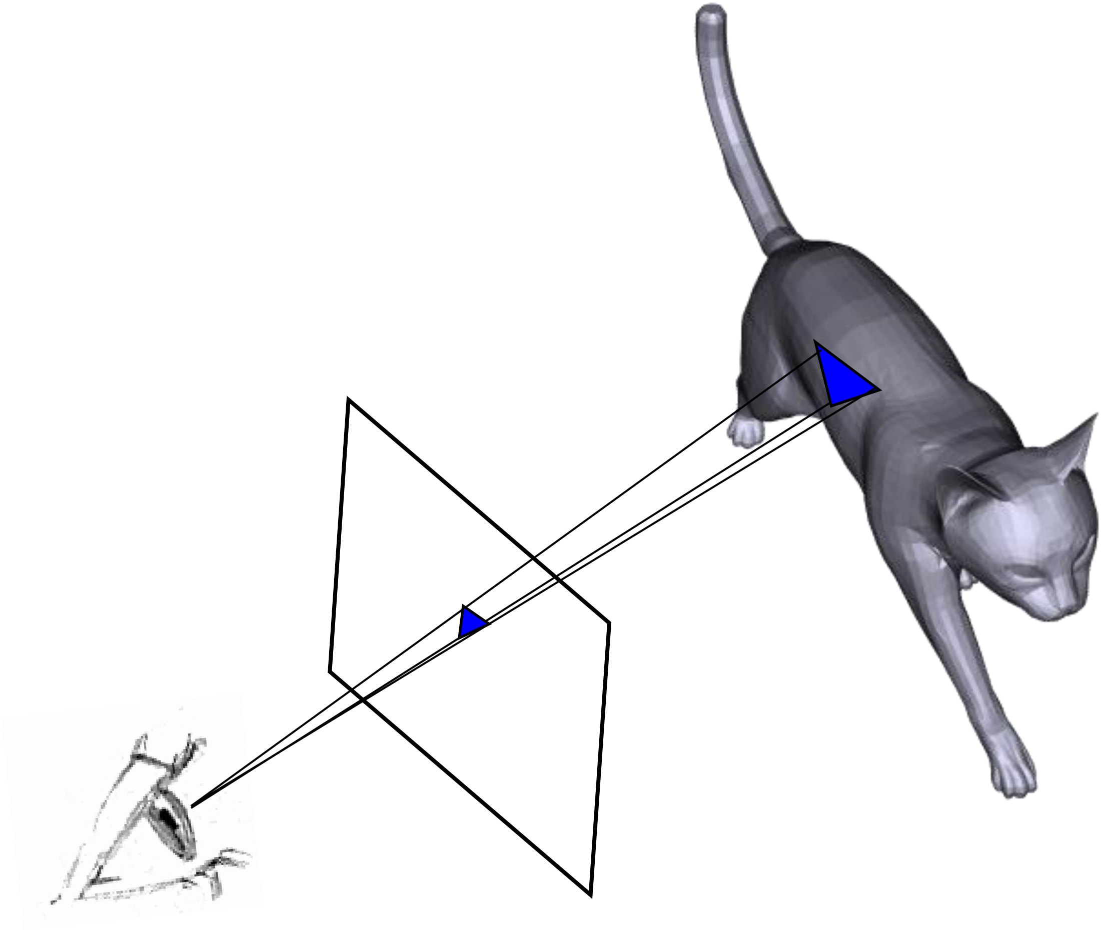
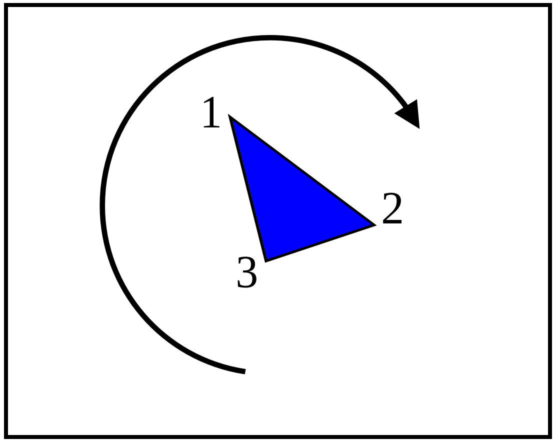




counter clock-wise orientation, draw polygon

Backface Culling





clock-wise orientation,
cull polygon

Backface Culling

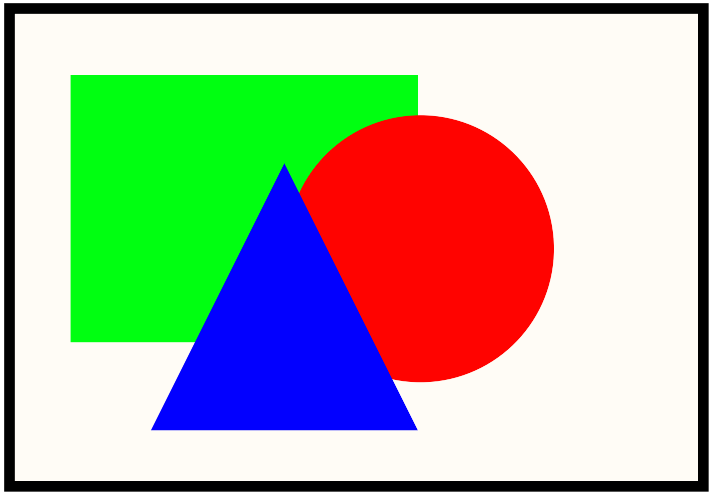
- Advantages
  - Improves rendering speed by removing roughly half of polygons from scan conversion
- Disadvantages
  - Assumes closed surface with consistently oriented polygons
  - NOT a true hidden surface algorithm!!!

Backface Culling

- Is this all we have to do?

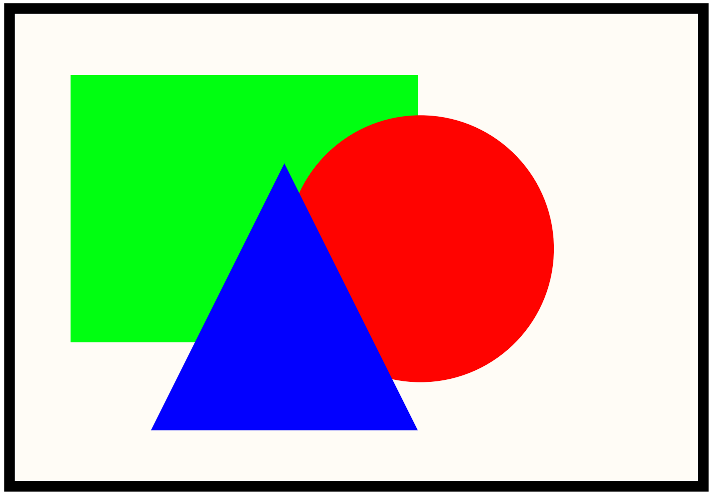
Backface Culling

- Is this all we have to do? No!
  - Can still have 2 (or more) front faces that map to the same screen pixel



Backface Culling

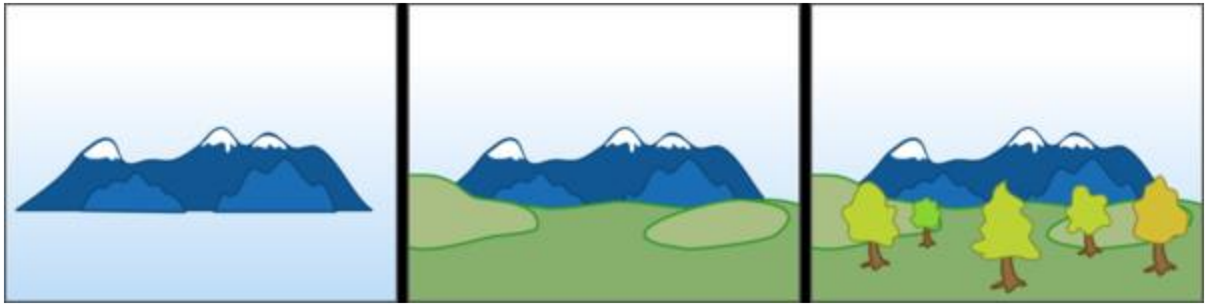
- Is this all we have to do? No!
  - Can still have 2 (or more) front faces that map to the same screen pixel
  - Which actually gets drawn?



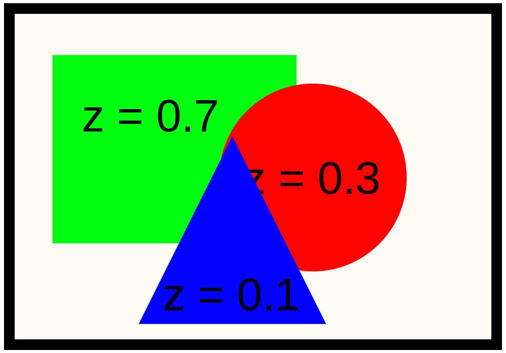
Painter’s Algorithm

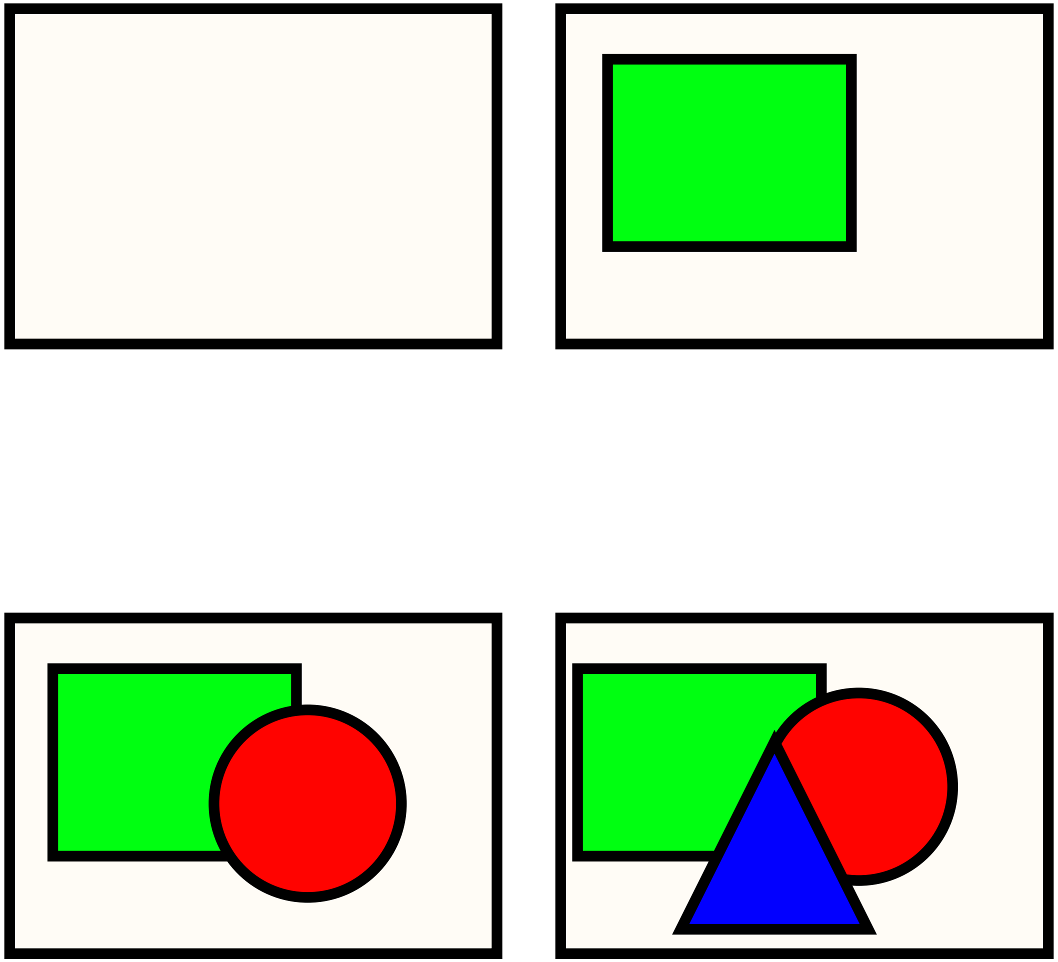
- Sort polygons according to distance from viewer
- Draw from back to front

- How do we sort polygons?



Painter's Example





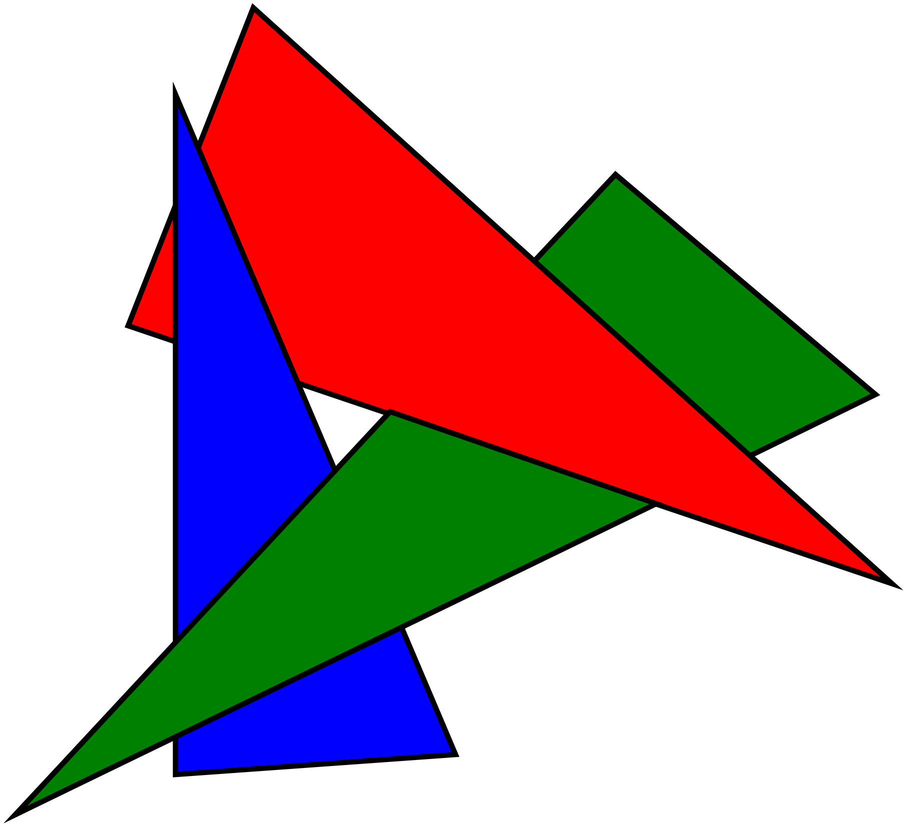
Sort by depth:

Green rect

Red circle

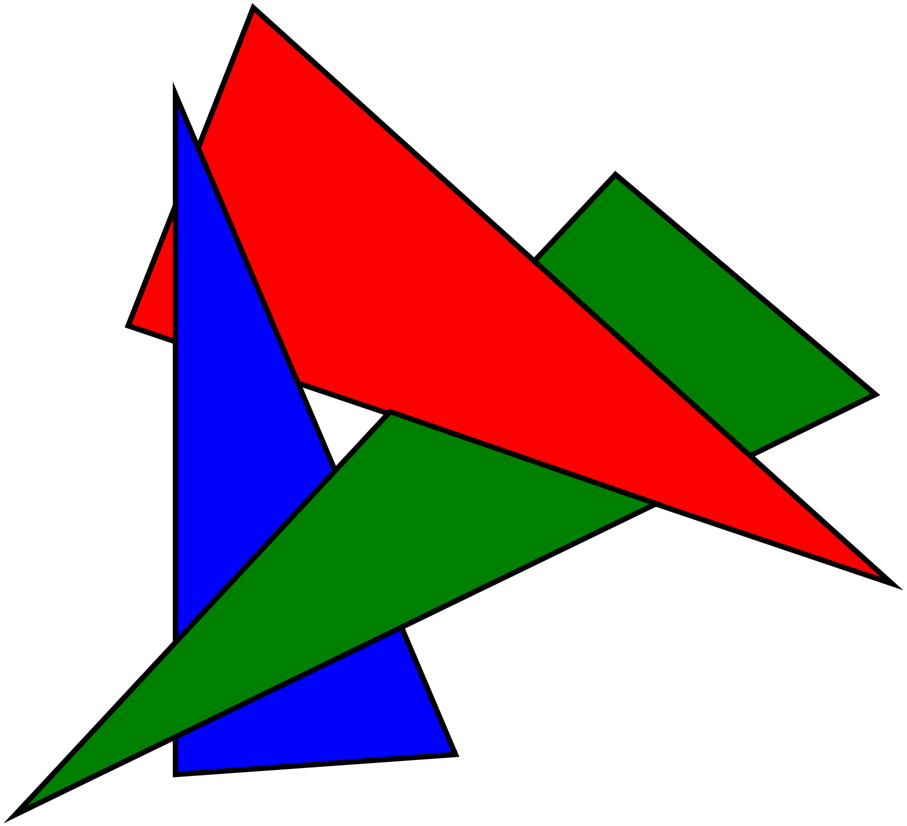
Blue tri

Painter’s Algorithm



Painter's Algorithm

- Sometimes there is NO ordering that produces correct results!!!



Painter's Algorithm

1. Sort all objects' z_{min} and z_{max}

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Painter’s Algorithm

1. Sort all objects’ z_{min} and z_{max}
2. If an object is uninterrupted (its z_{min} and z_{max} are adjacent in the sorted list), it is fine
3. If 2 objects DO overlap

    3.1 Check if they overlap in x

    - If not, they are fine

    3.2 Check if they overlap in y

    - If not, they are fine
    - If yes, need to split one

Painter’s Algorithm

- The splitting step is the tough one
  - Need to find a plane to split one polygon by so that each new polygon is entirely in front of or entirely behind the other
  - Polygons may actually intersect, so then need to split each polygon by the other

Painter’s Algorithm

- The splitting step is the tough one
  - Need to find a plane to split one polygon by so that each new polygon is entirely in front of or entirely behind the other
  - Polygons may actually intersect, so then need to split each polygon by the other
- After splitting, you can resort the list and should be fine

Painter’s Algorithm-Summary

- Advantages
  - Simple algorithm for ordering polygons
- Disadvantages
  - Sorting criteria difficult to produce
  - Redraws same pixel many times
  - Sorting can also be expensive

Depth (“Z”) Buffer

- Simple modification to scan-conversion
- Maintain a separate buffer storing the closest “z” value for each pixel
- Only draw pixel if depth value is closer than stored “z” value
    - Update buffer with closest depth value

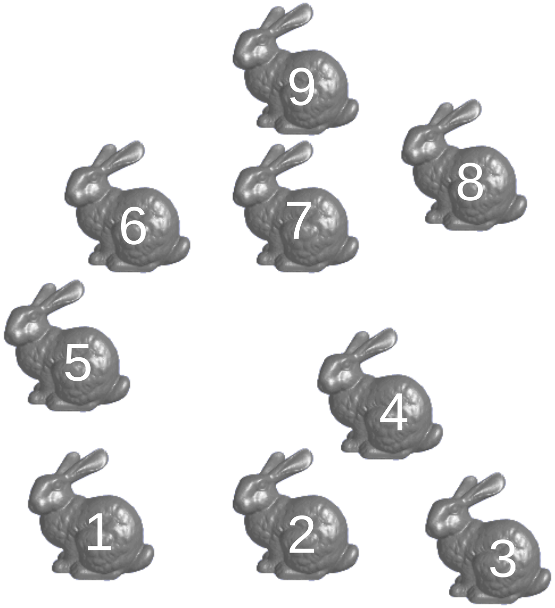
Depth (“Z”) Buffer

- Advantages
  - Simple to implement
  - Allows for a streaming approach to polygon drawing
- Disadvantages
  - Requires extra storage space
  - Still lots of overdraw

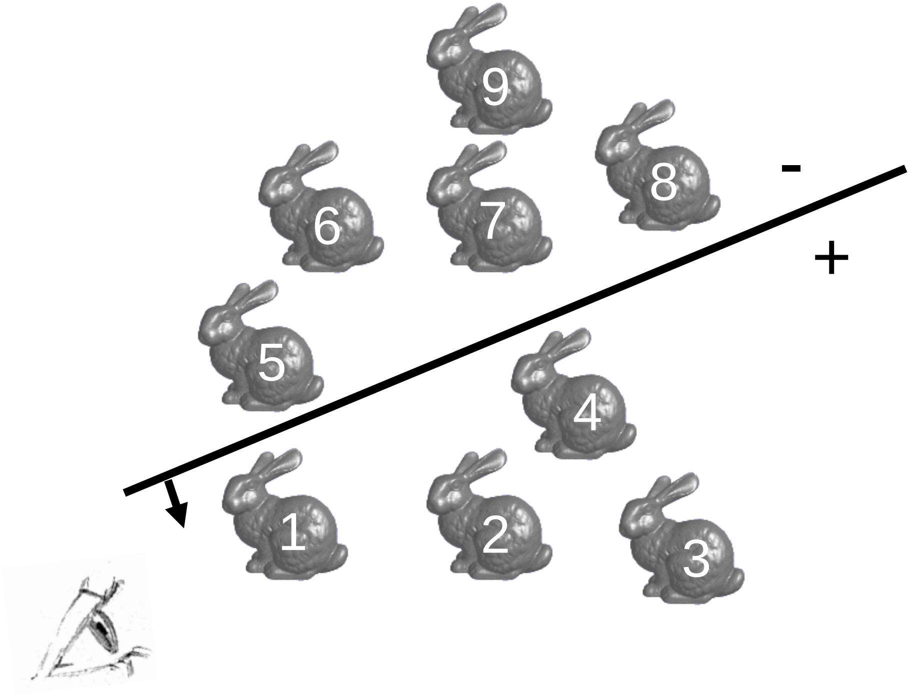
Binary Space Partitioning Trees

- BSP tree: organize all of space (hence *partition*) into a binary tree
  - *Preprocess*: overlay a binary tree on objects in the scene
  - *Runtime*: correctly traversing this tree enumerates objects from back to front
  - Idea: divide space recursively into half-spaces by choosing *splitting planes*
    - Splitting planes can be arbitrarily oriented

BSP Trees: Objects

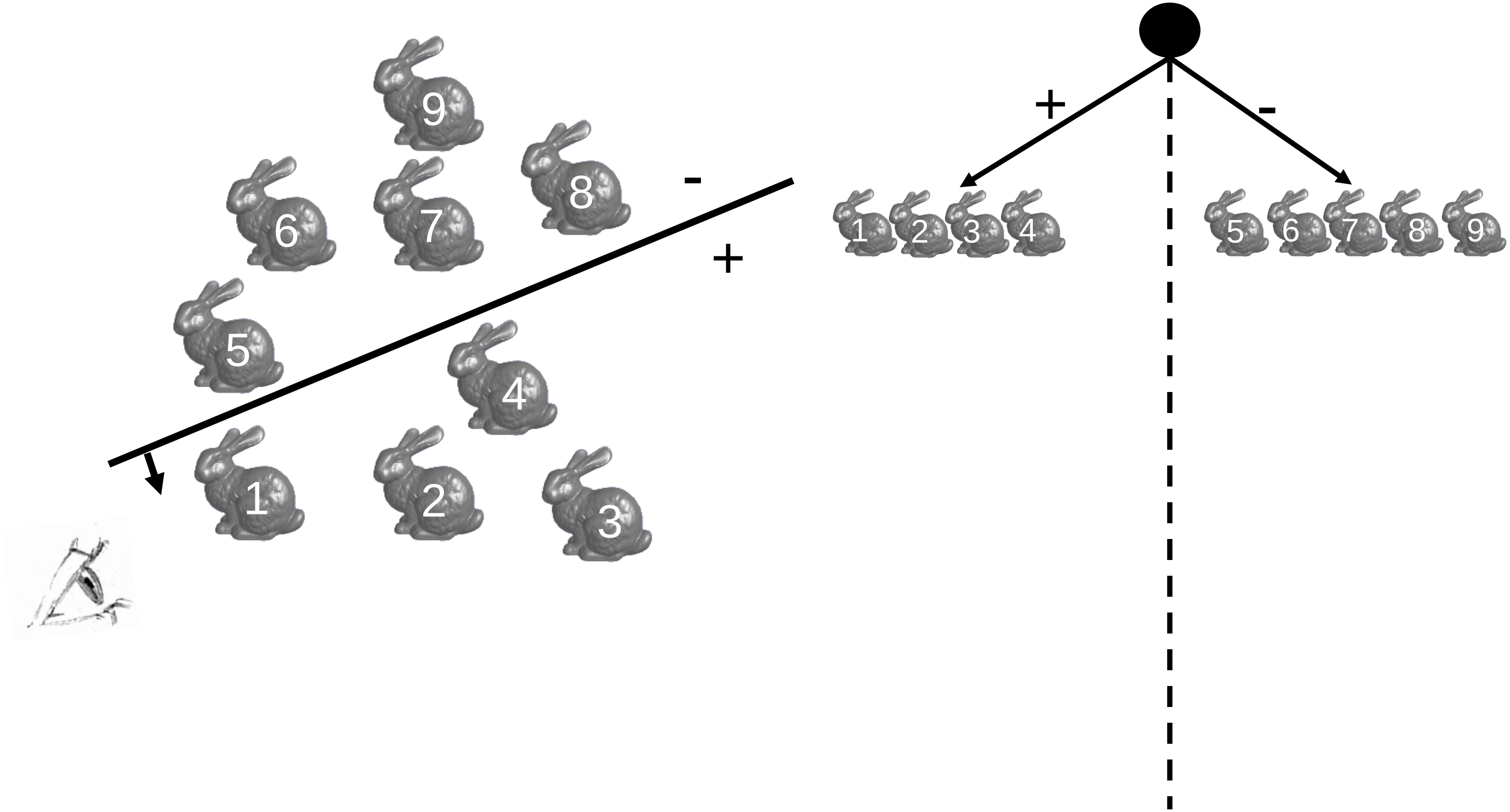


BSP Trees: Objects



BSP Trees: Objects

Put front objects in the left branch



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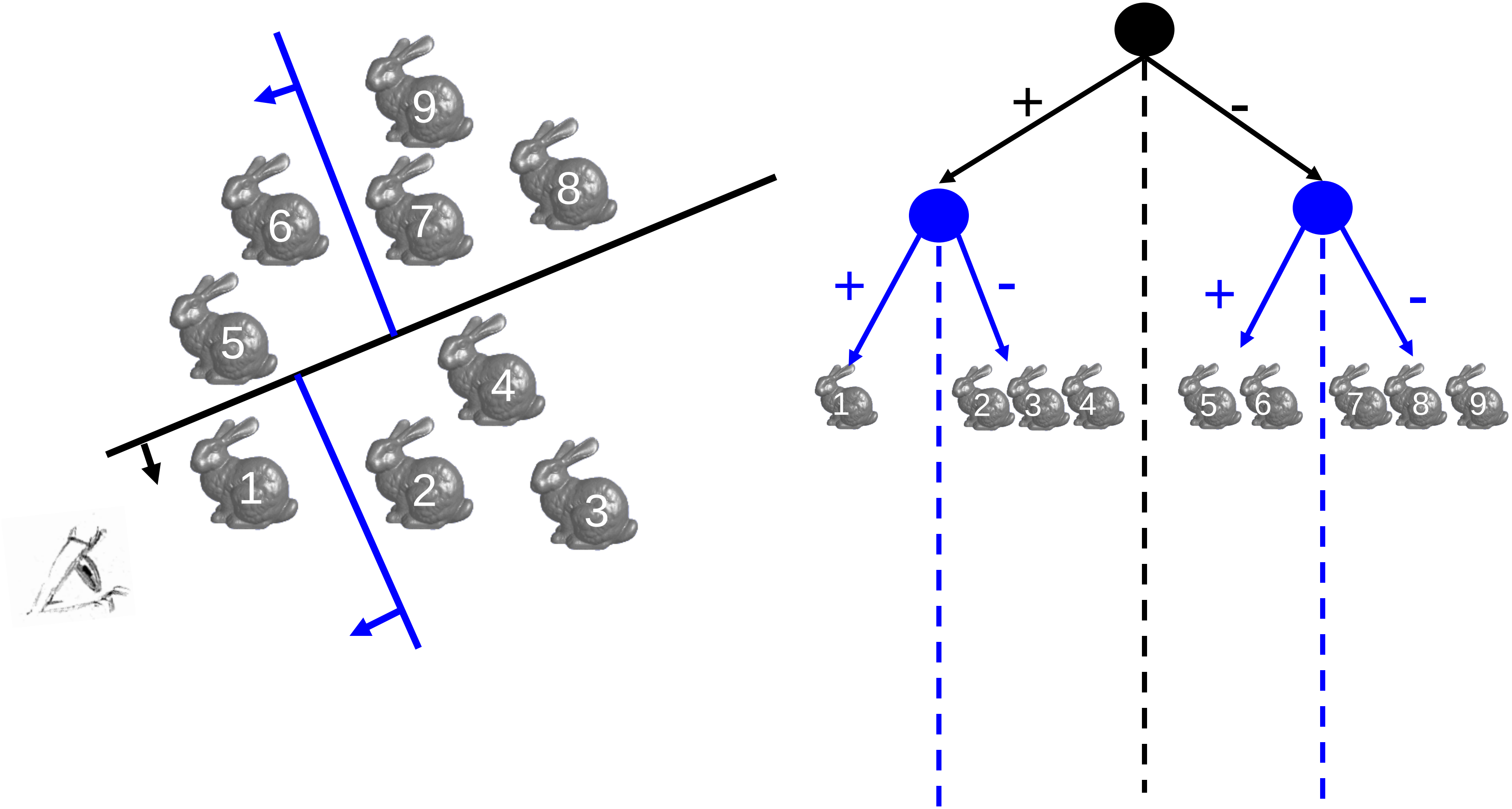

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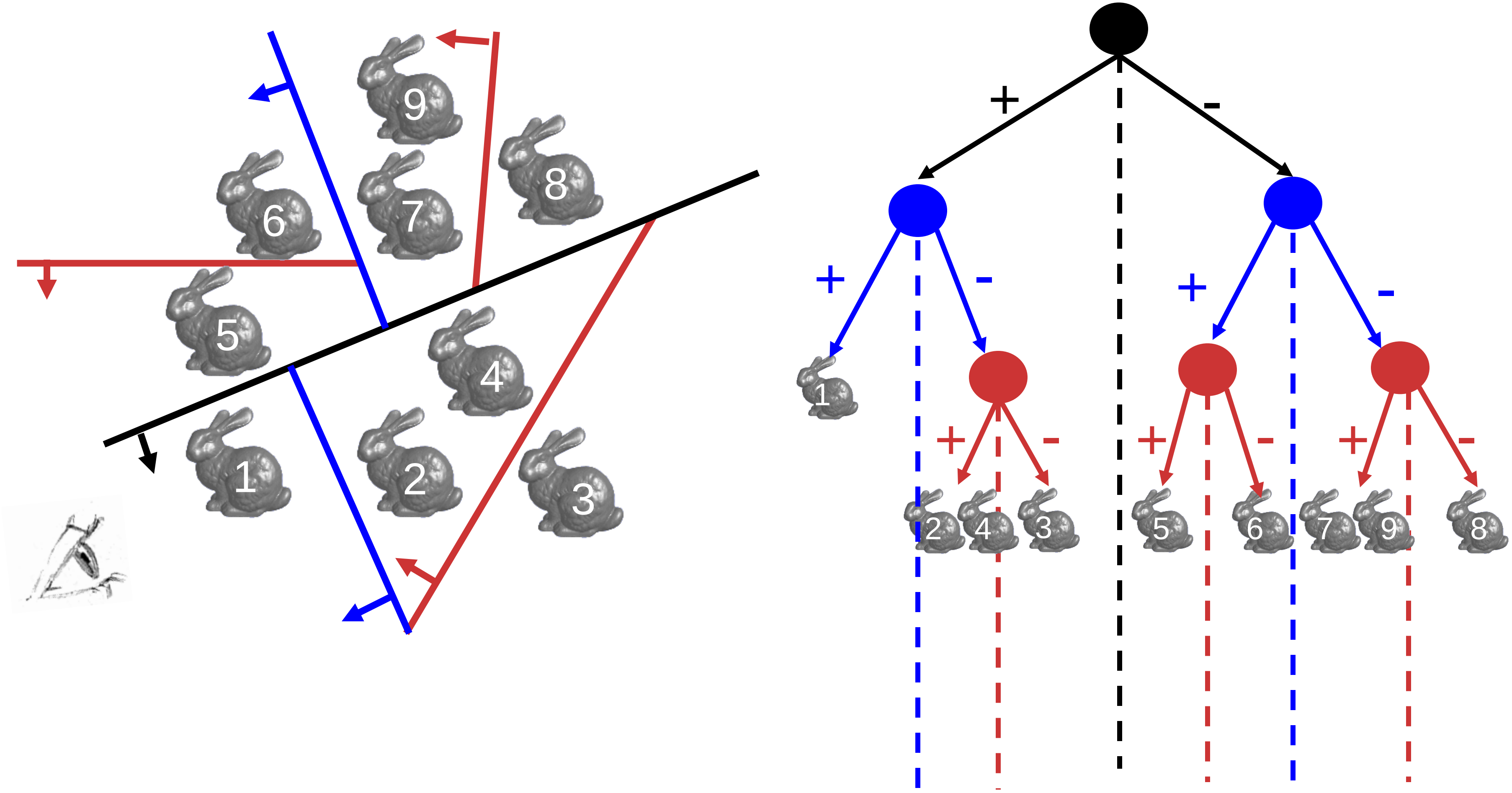

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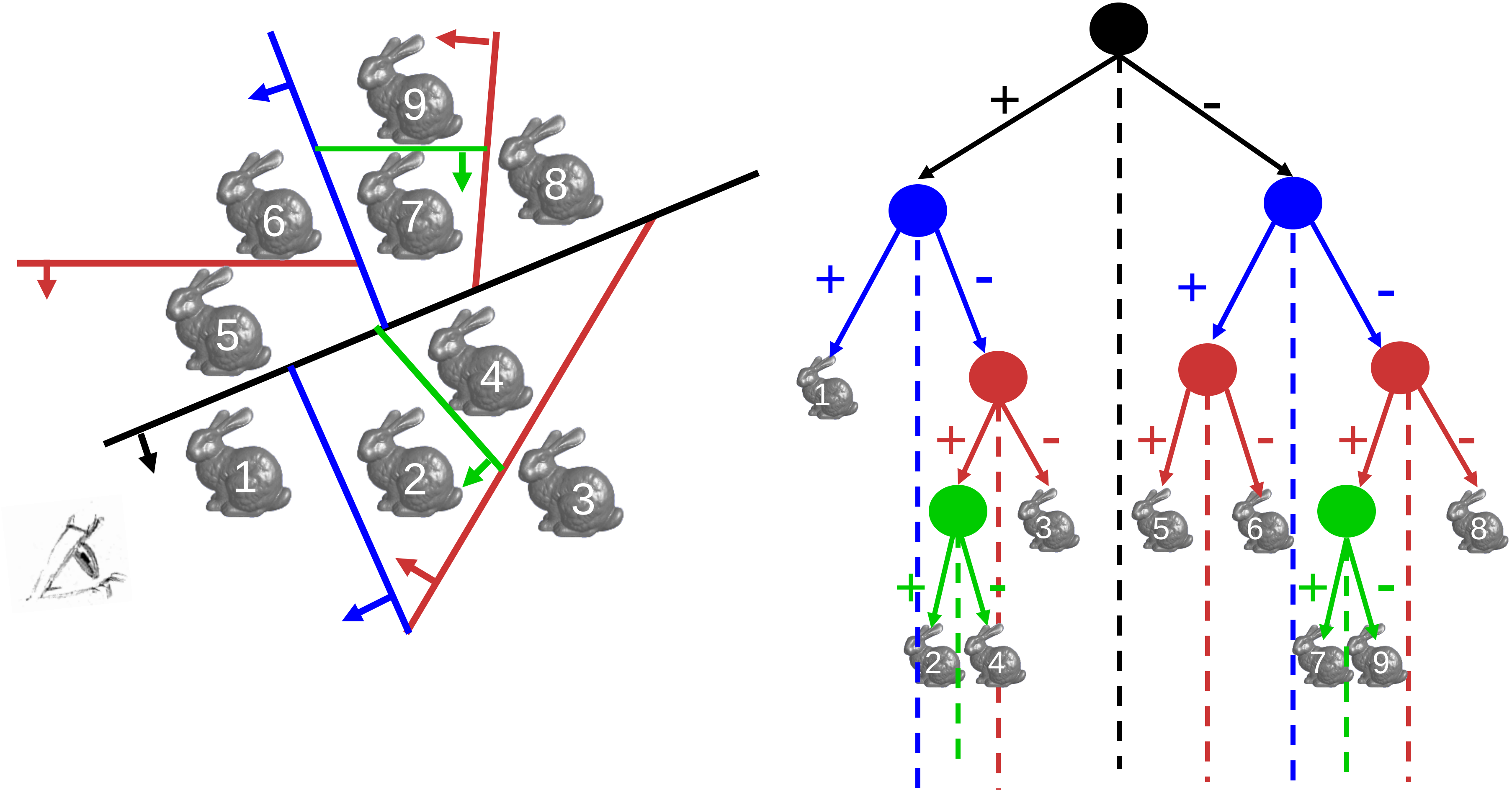

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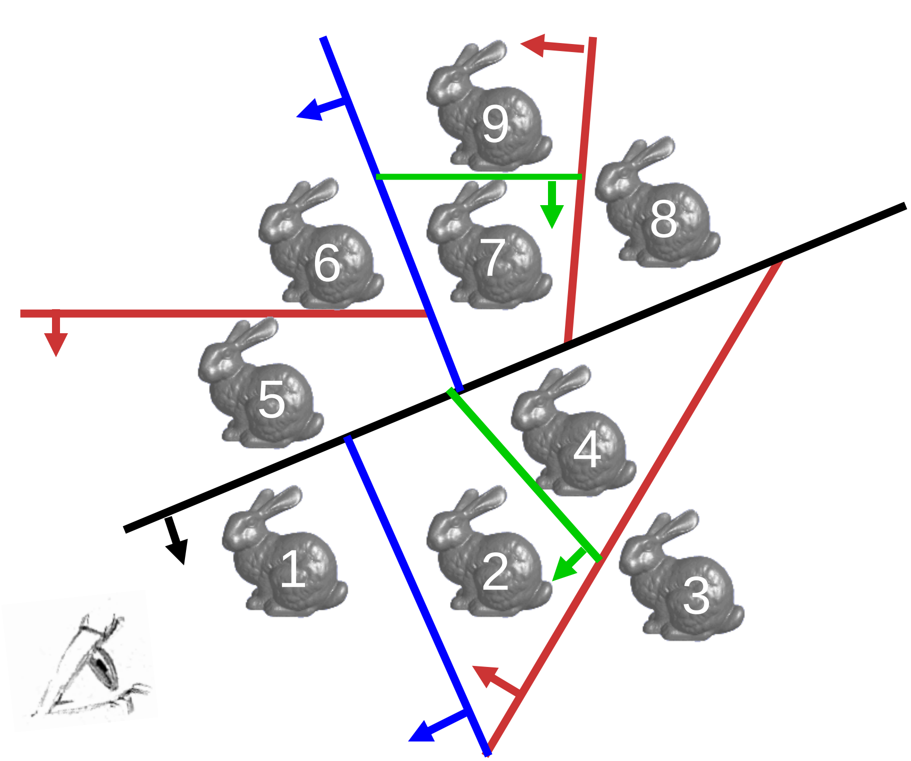
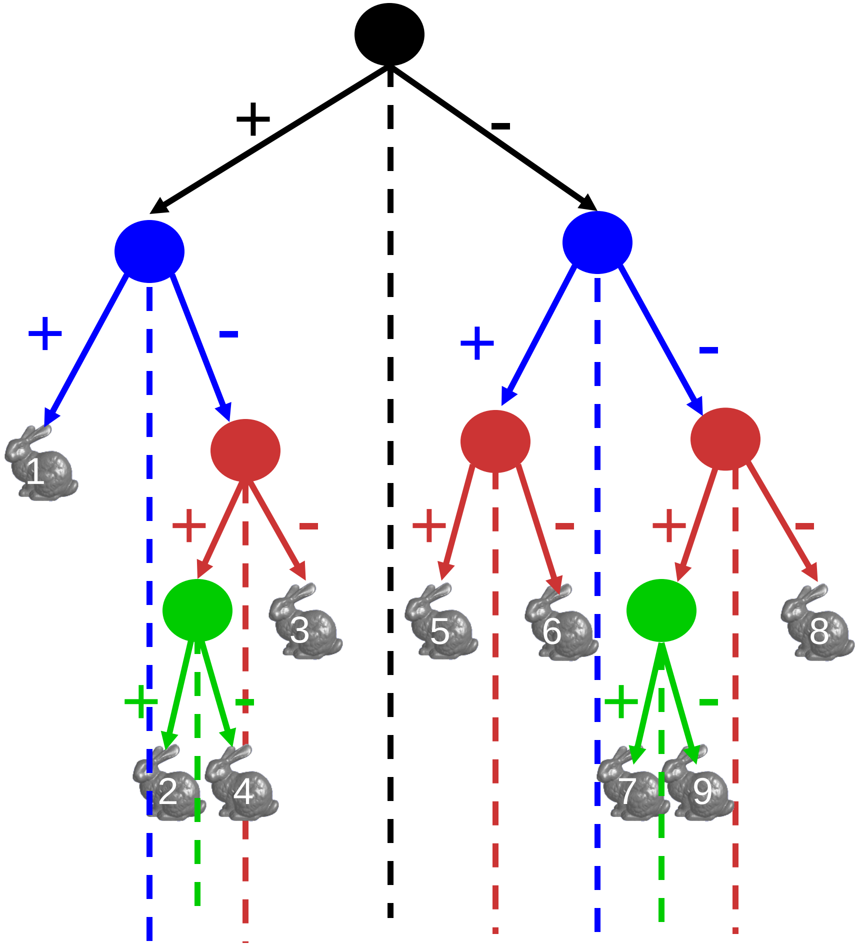
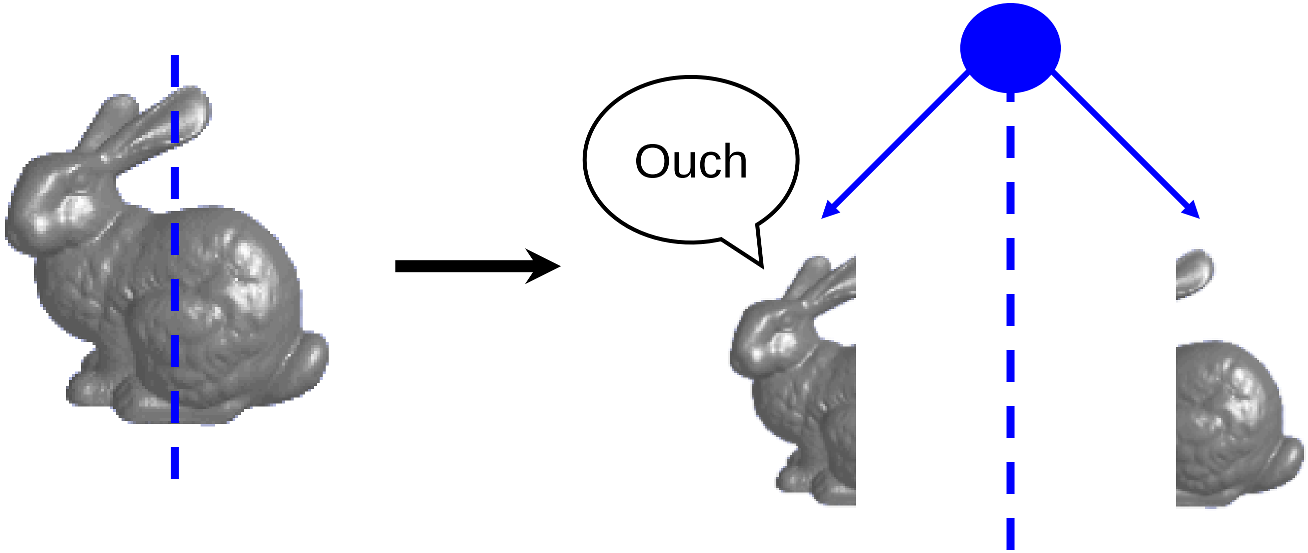




When to stop the recursion?

Object Splitting

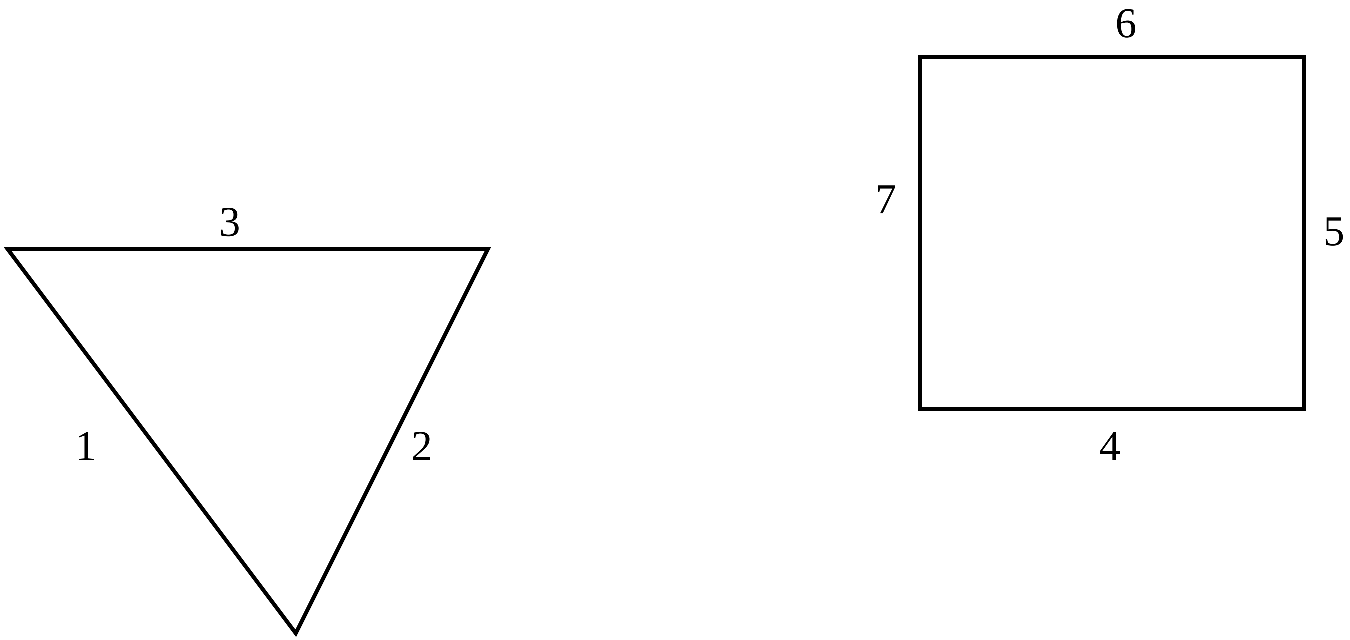
- No bunnies were harmed in my example
- But what if a splitting plane passes through an object?
  - Split the object; give half to each node:
  - Worst case: can create up to O(n^3) objects!



Building a BSP Tree

- Choose a splitting polygon
- Sort all other polygons as
  - Front
  - Behind
  - Crossing
  - On
- Add “front” polygons to front child, “behind” to back child
- Split “crossing” polygons with infinite plane
- Add “on” polygons to root
- Recur

Building a BSP Tree



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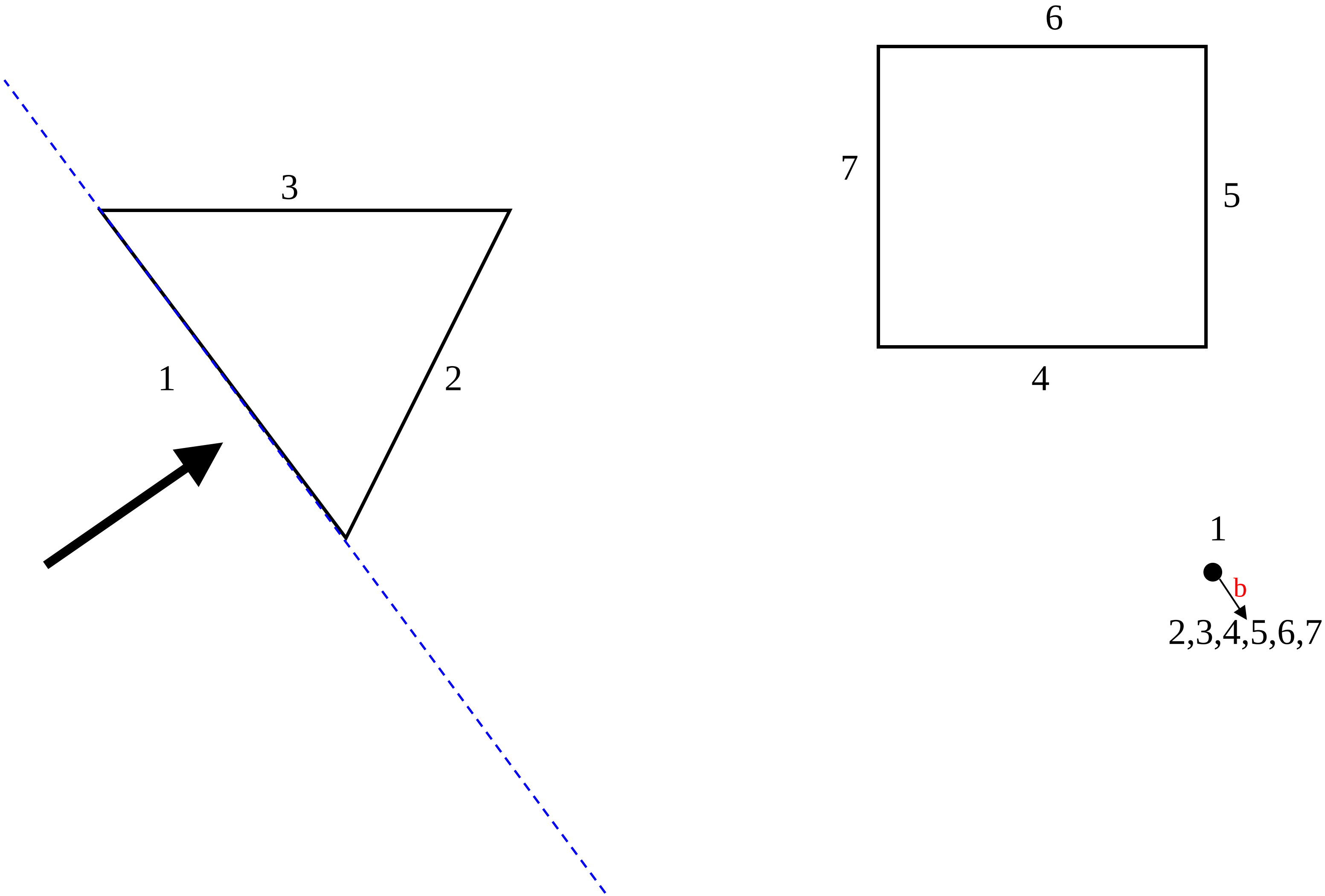

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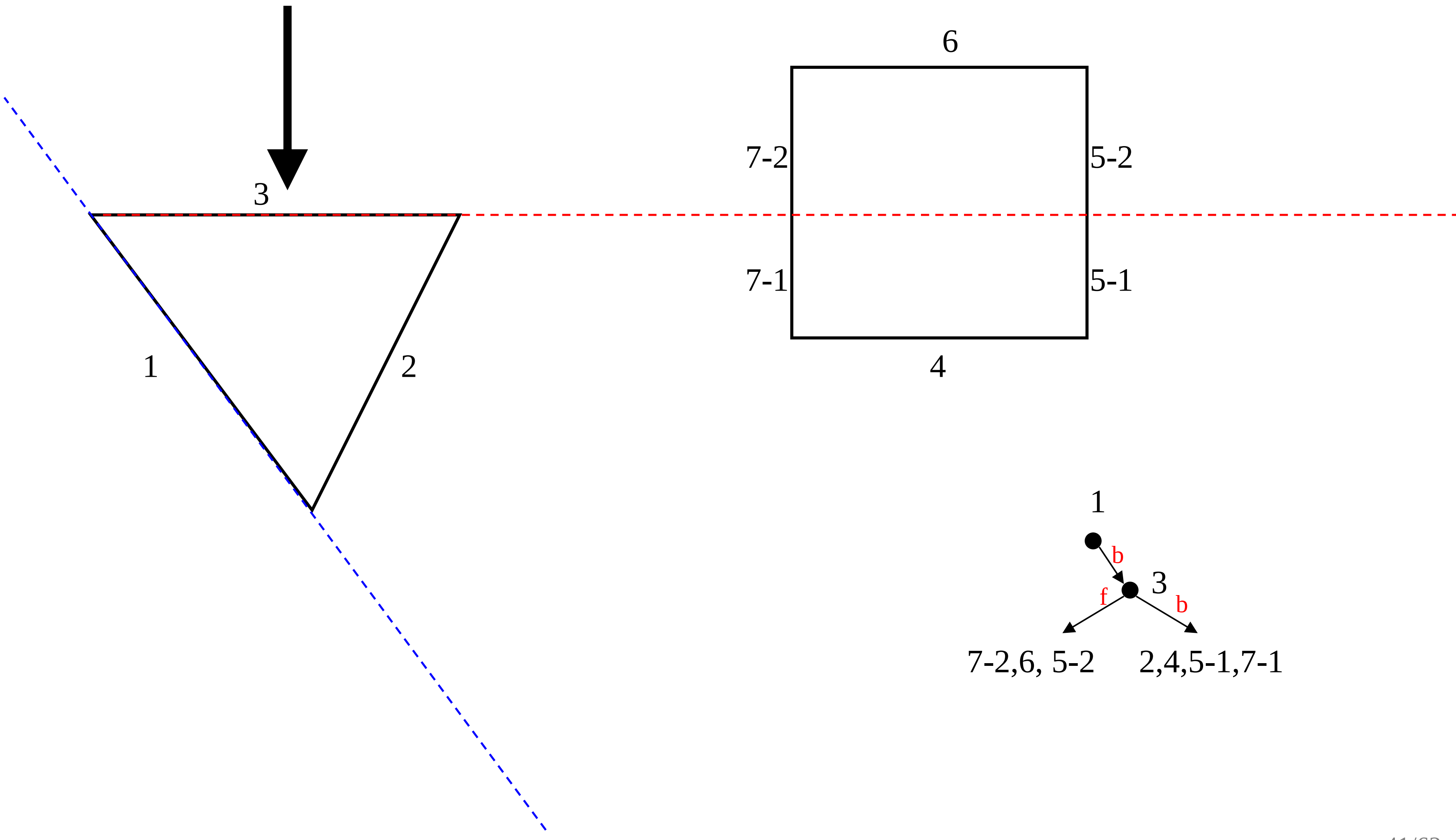

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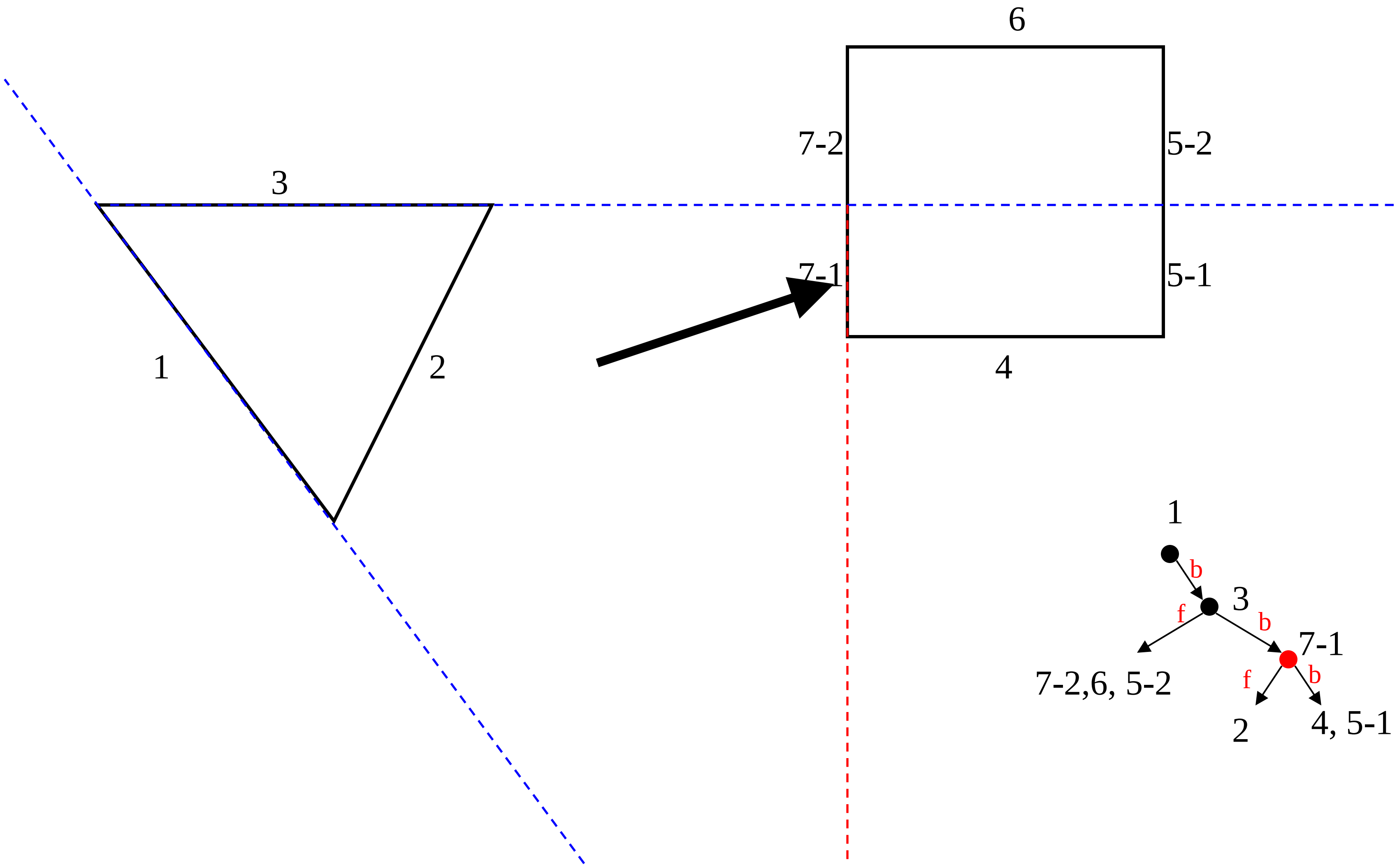

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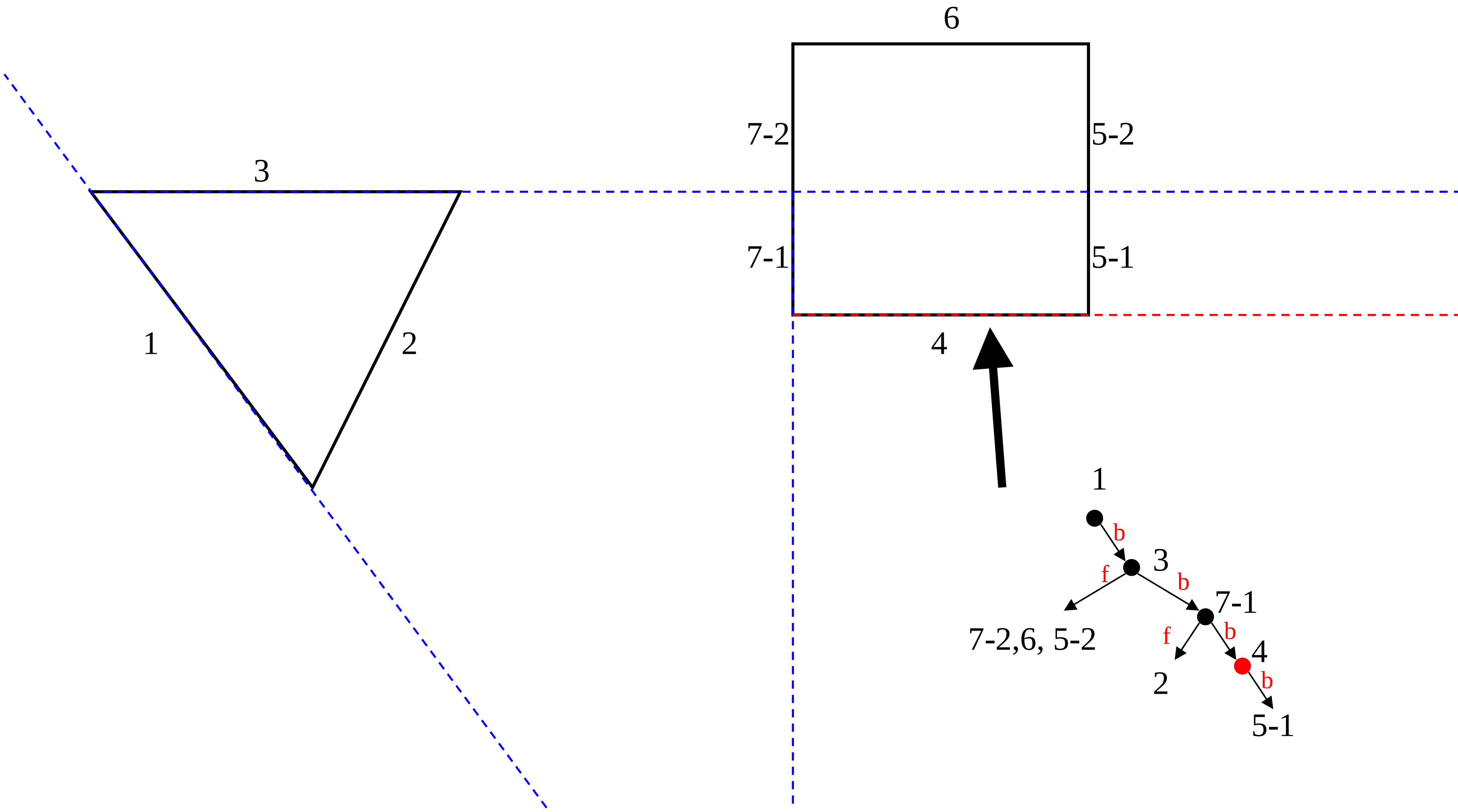

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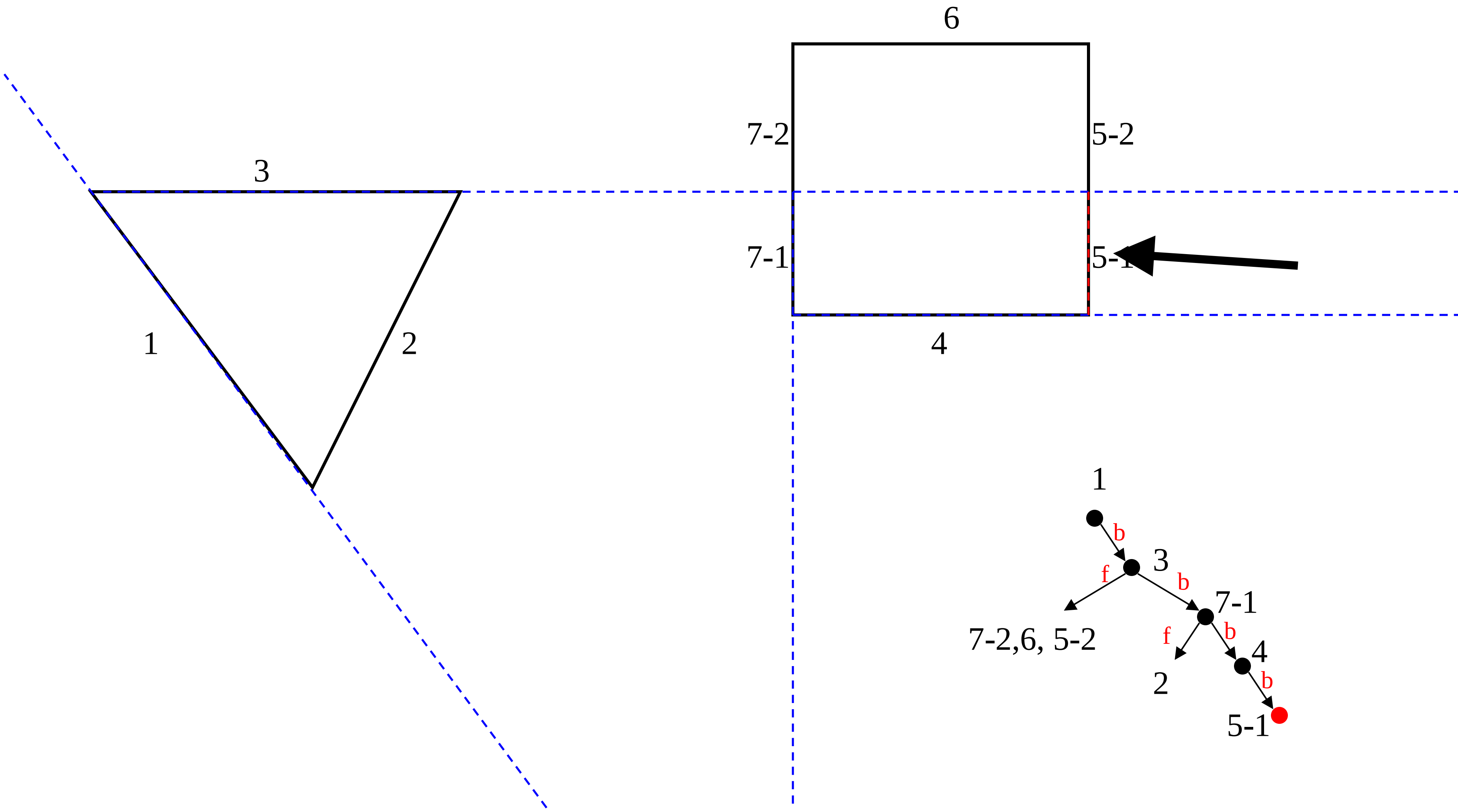

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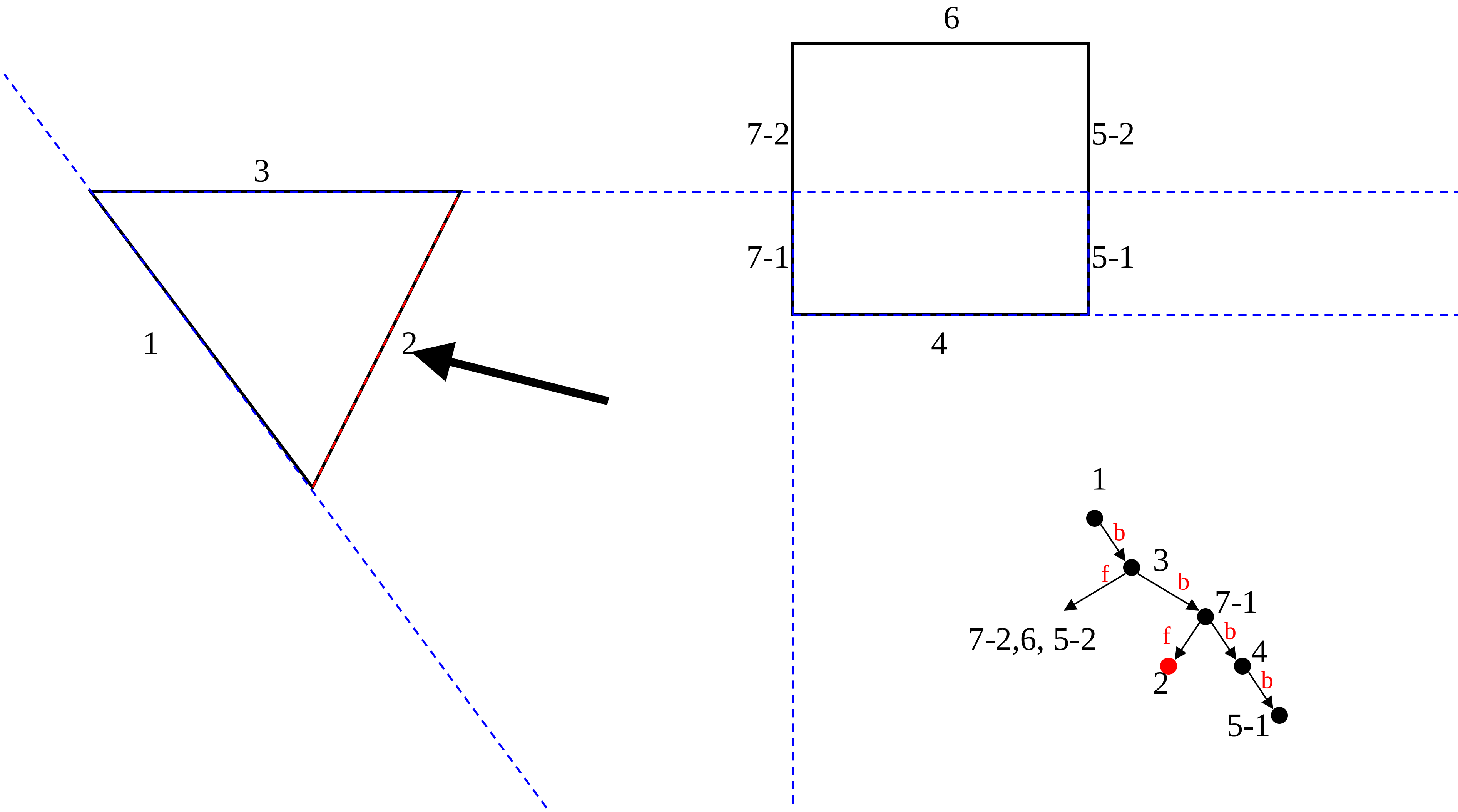

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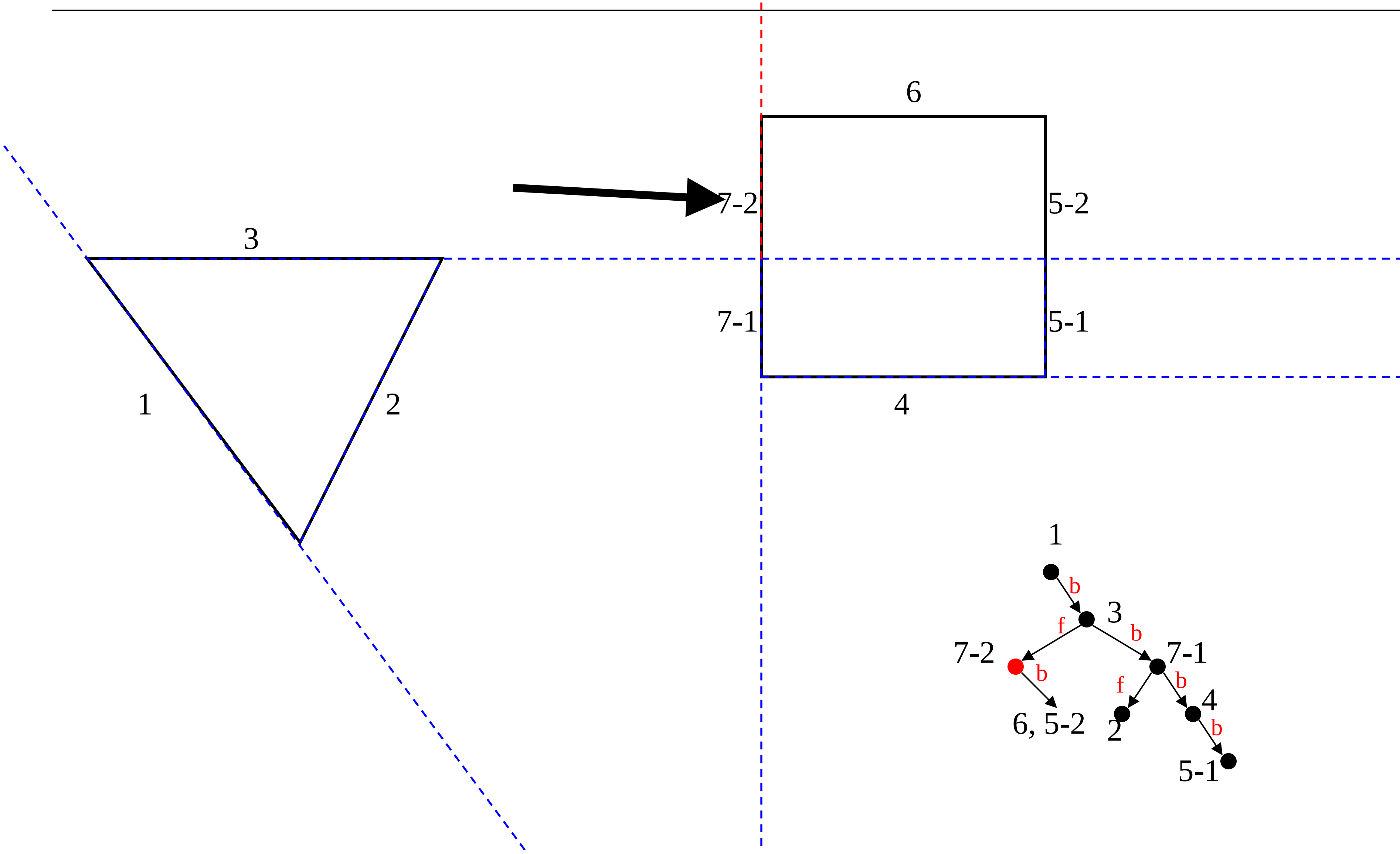

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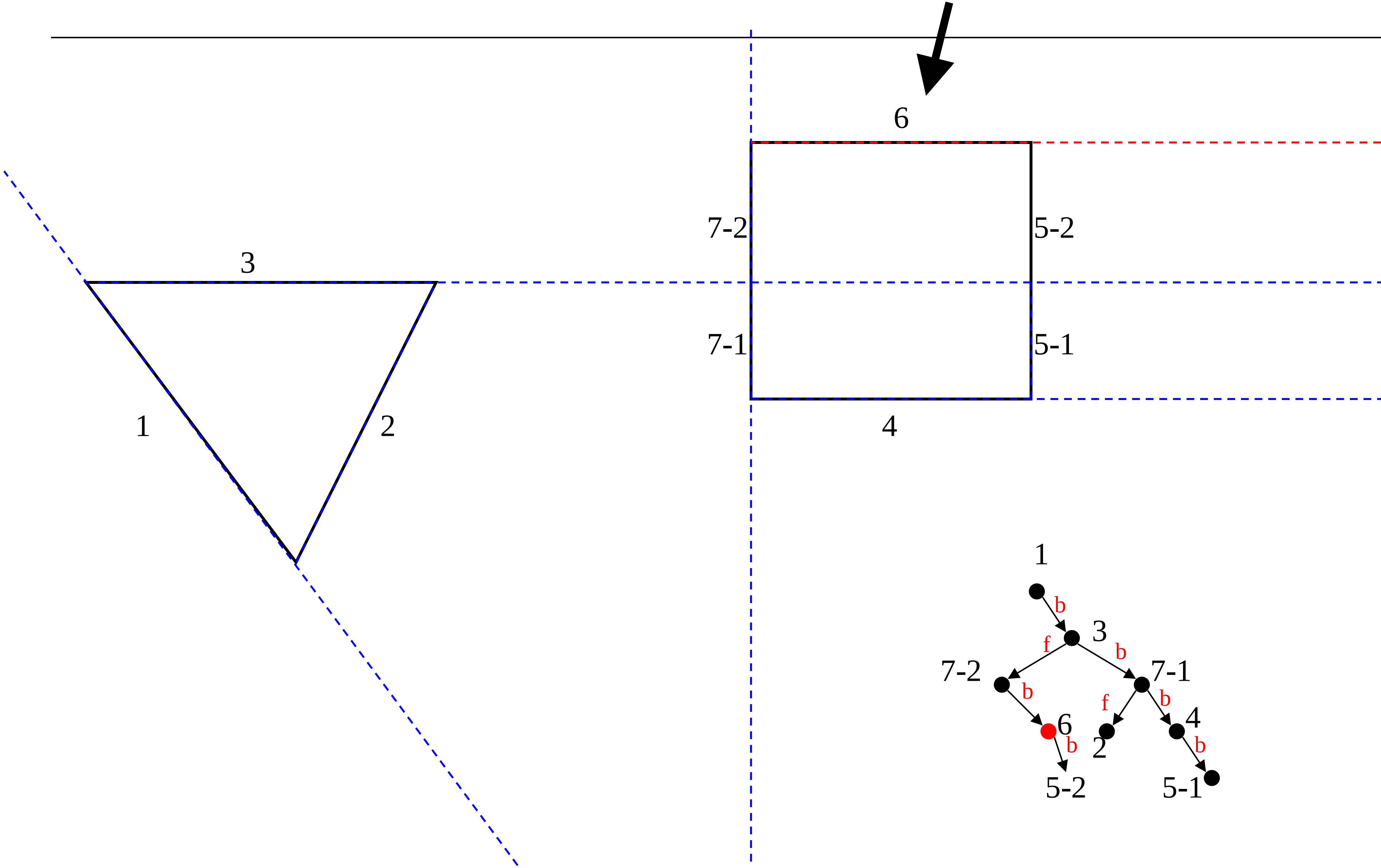

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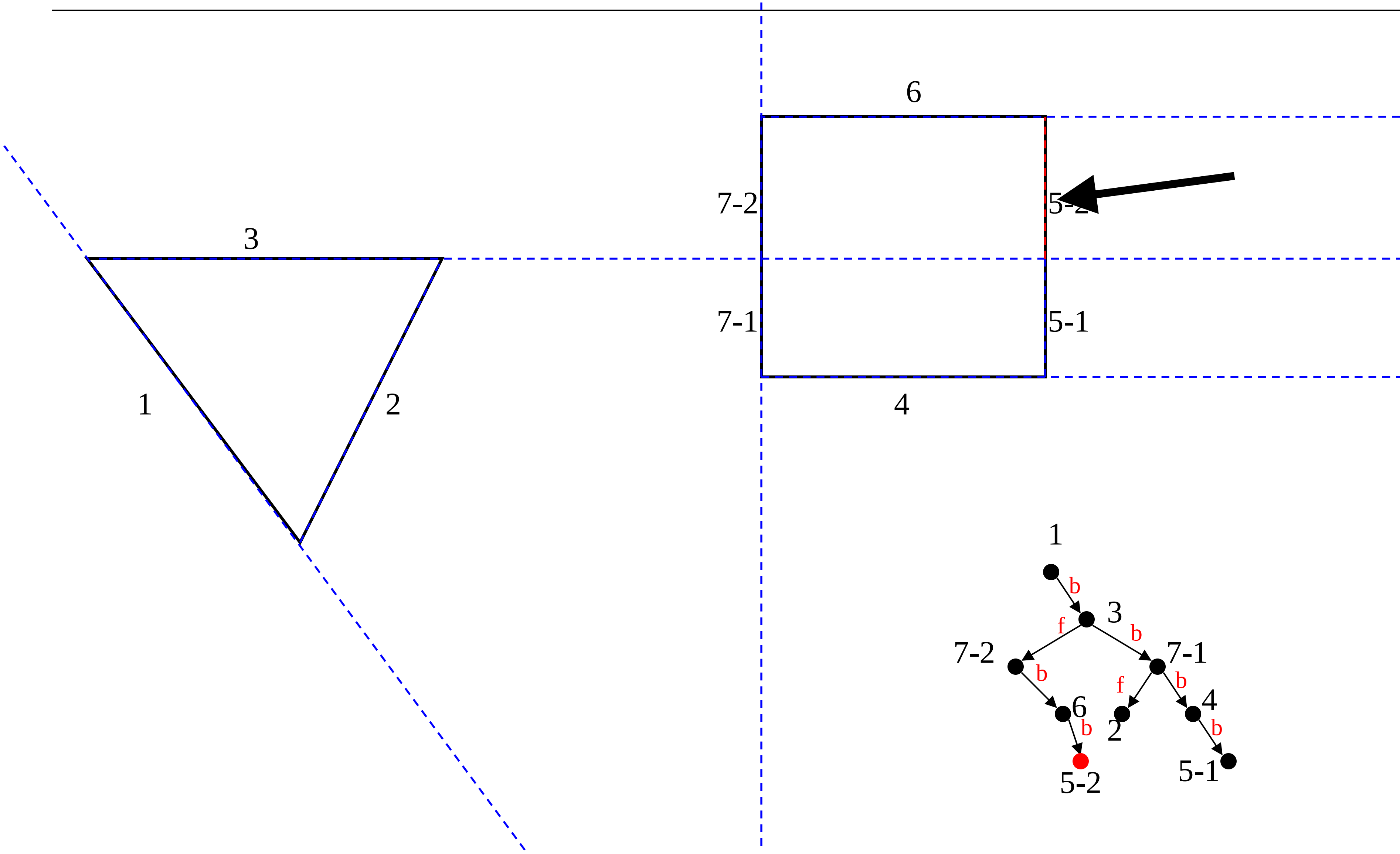

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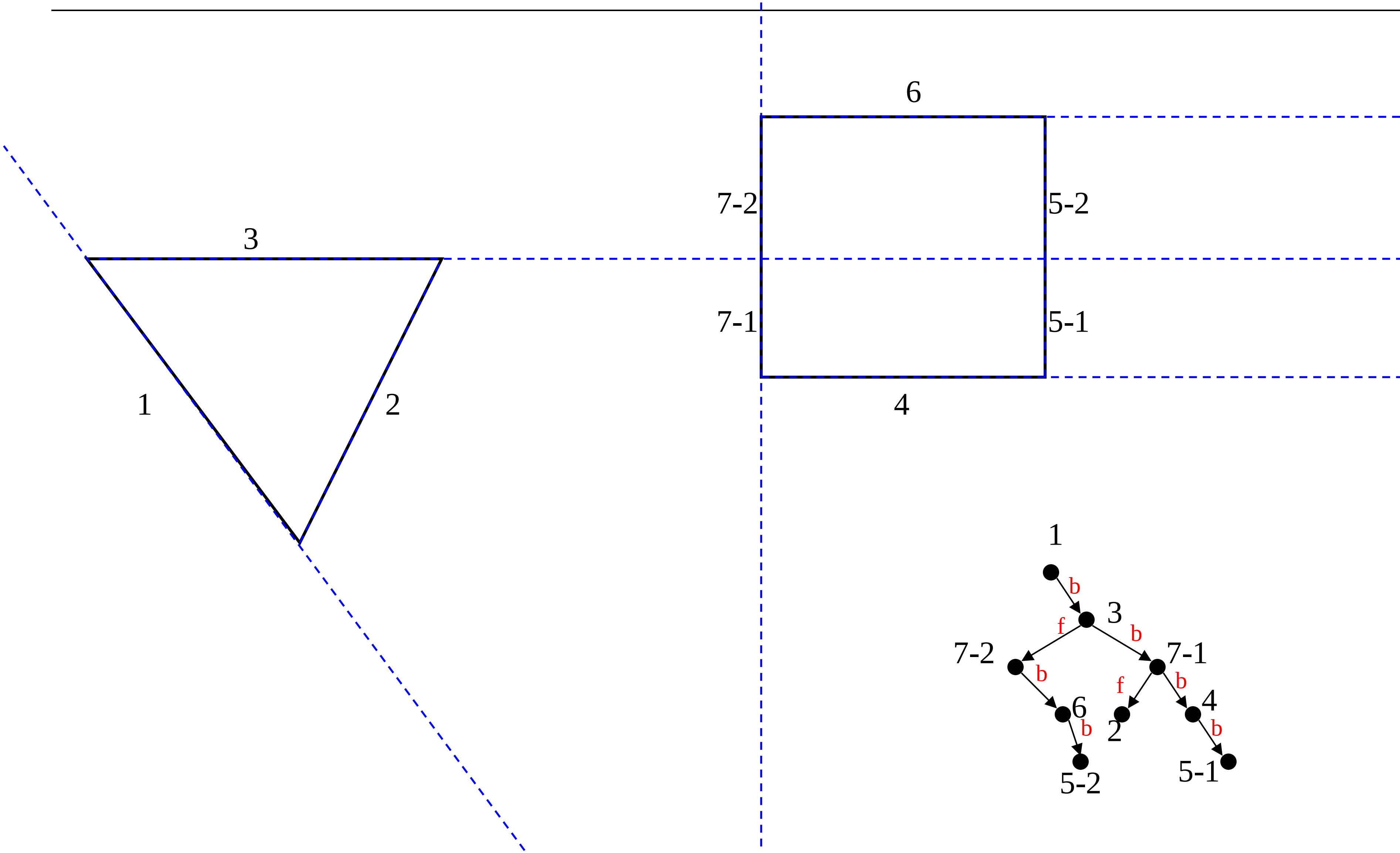
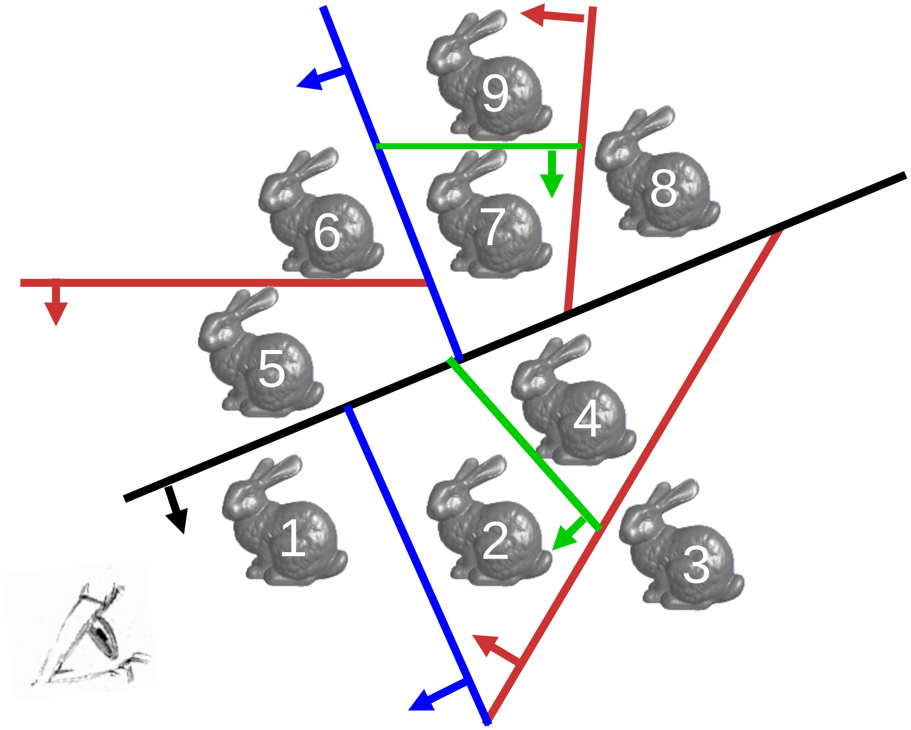


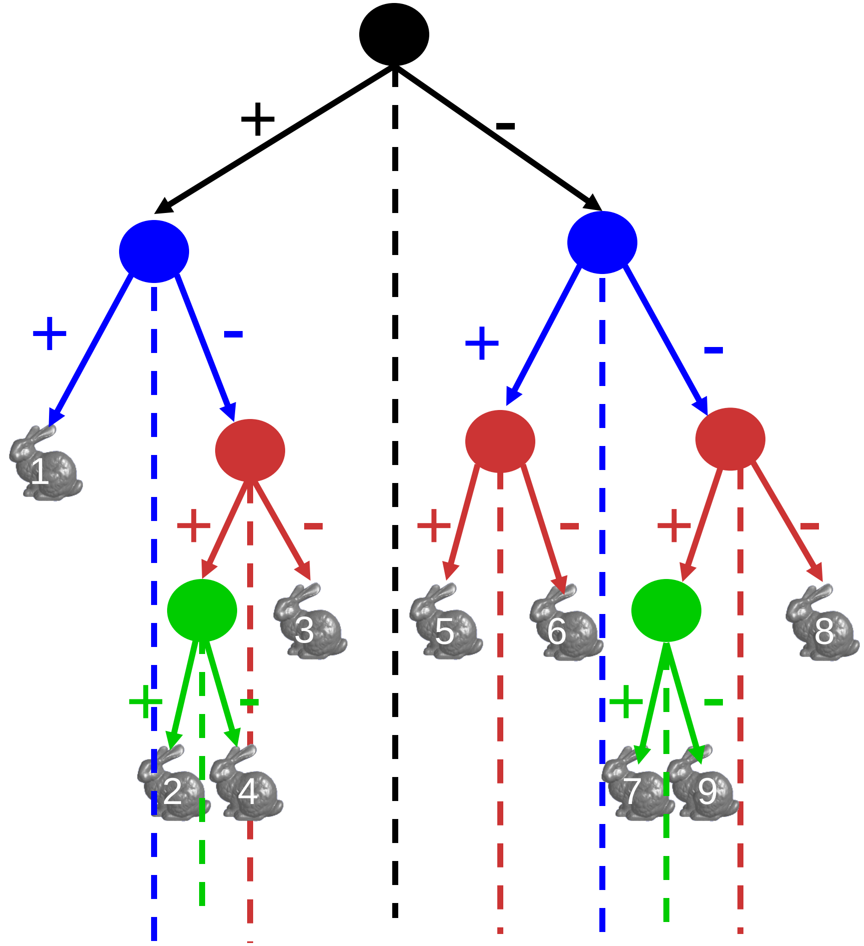
Rendering with a BSP Tree

- If eye is in front of plane
  - Draw “back” polygons
  - Draw “on” polygons
  - Draw “front” polygons
- If eye is behind plane
  - Draw “front” polygons
  - Draw “on” polygons
  - Draw “back” polygons
- Else eye is on plane
  - Draw “front” polygons
  - Draw “back” polygons

BSP Trees: Objects

Correctly traversing this tree enumerates objects from back to front

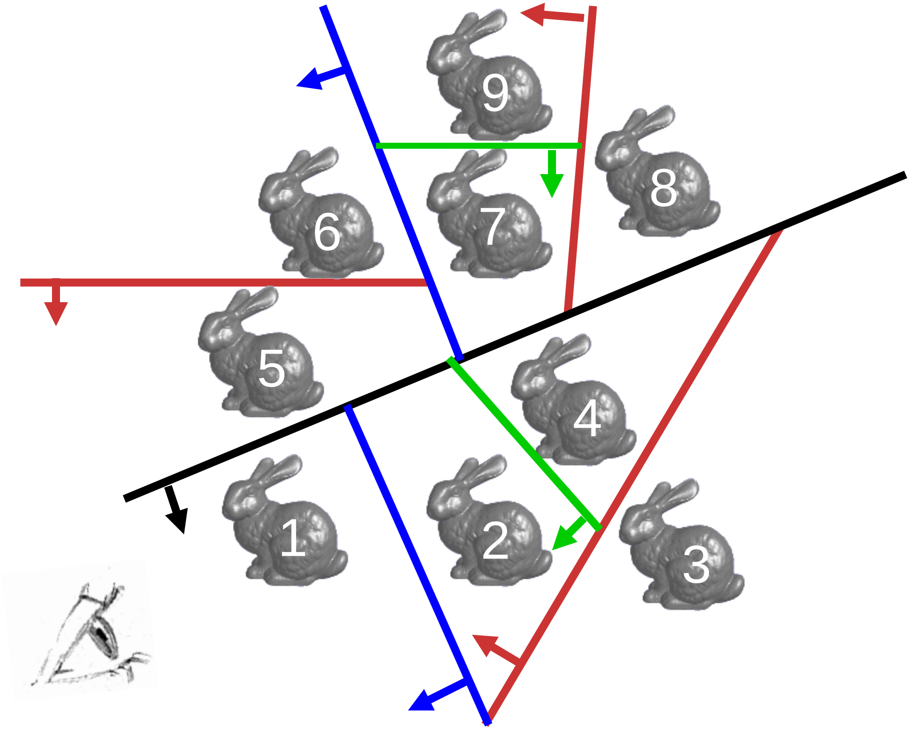


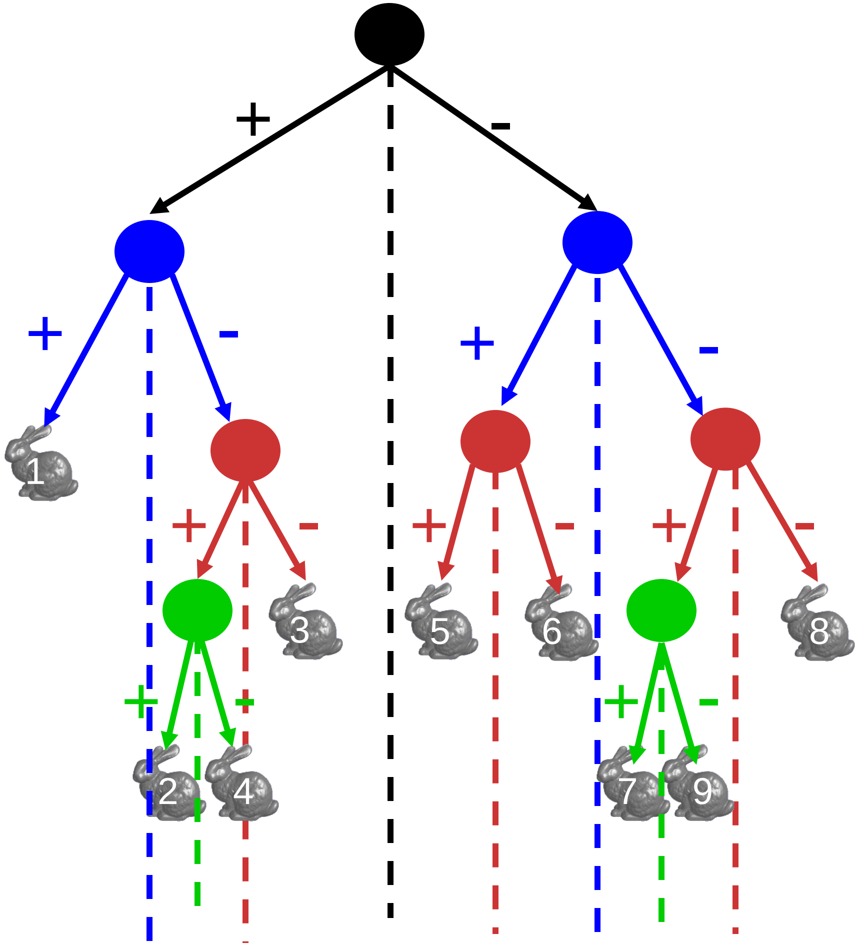


Traversal order?

BSP Trees: Objects

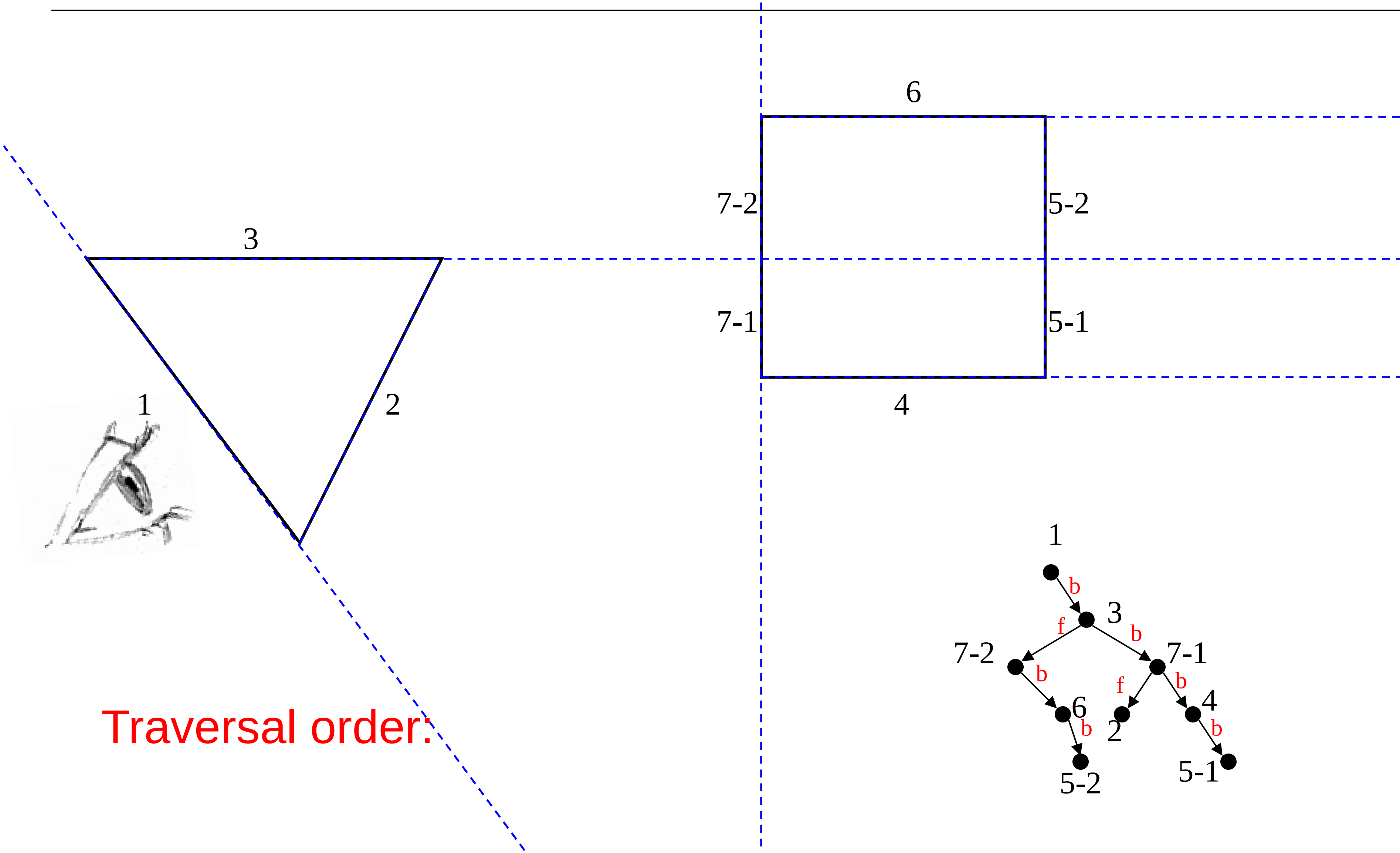
Correctly traversing this tree enumerates objects from back to front





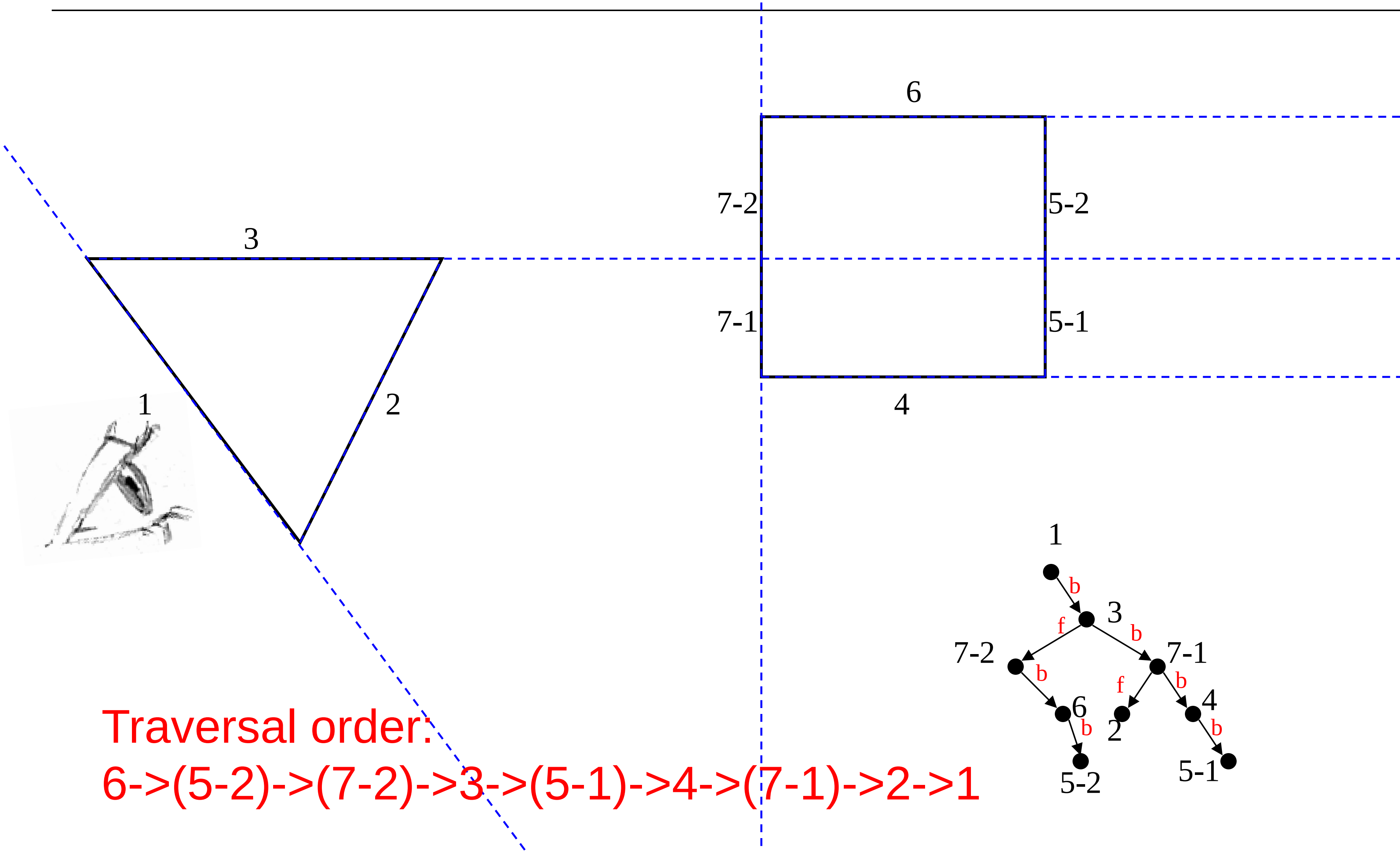
Traversal order:
8->9->7->6->5->3->4->2->1

Building a BSP Tree



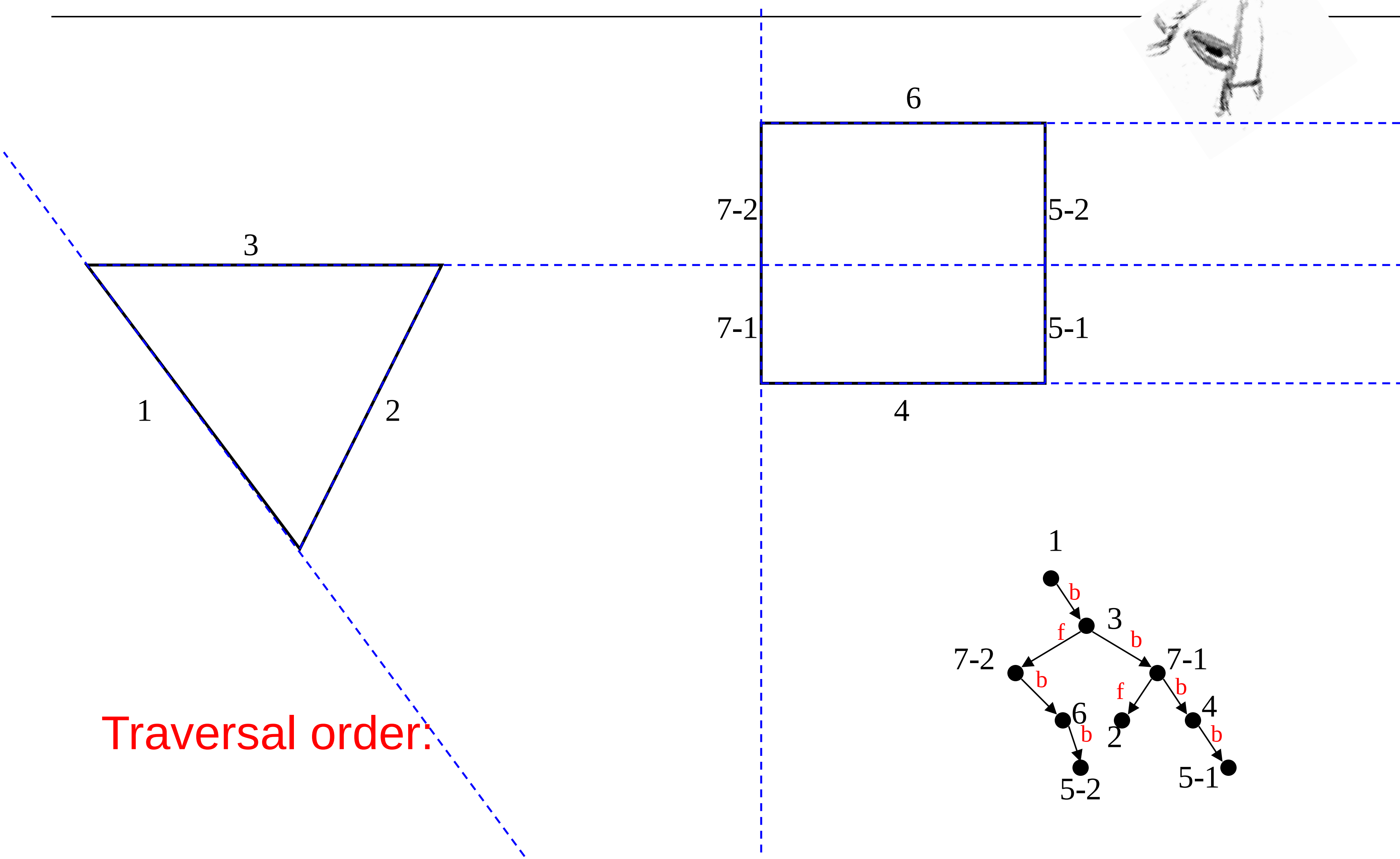
Traversal order:

Building a BSP Tree



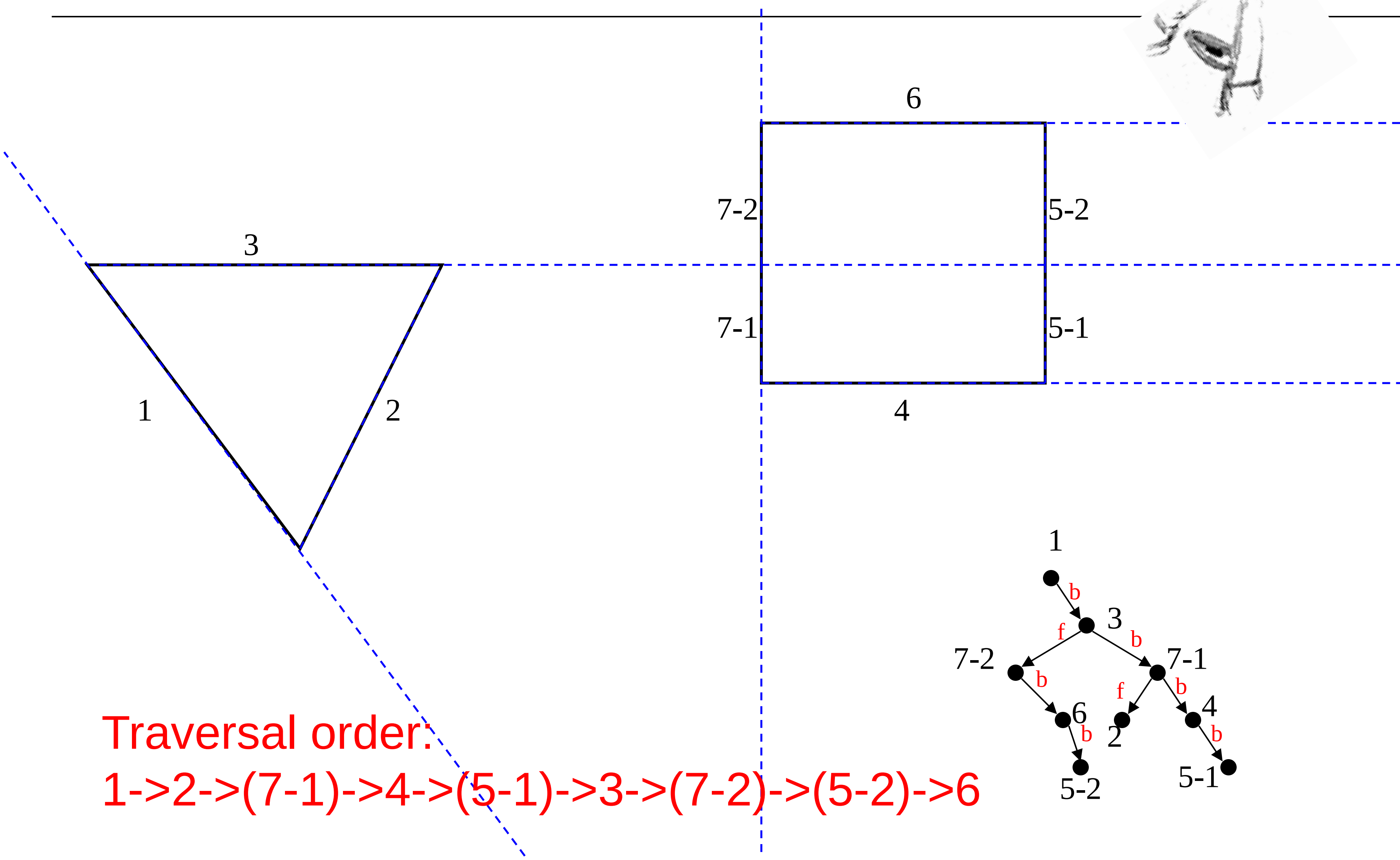
Traversal order:
6->(5-2)->(7-2)->3->(5-1)->4->(7-1)->2->1

Building a BSP Tree



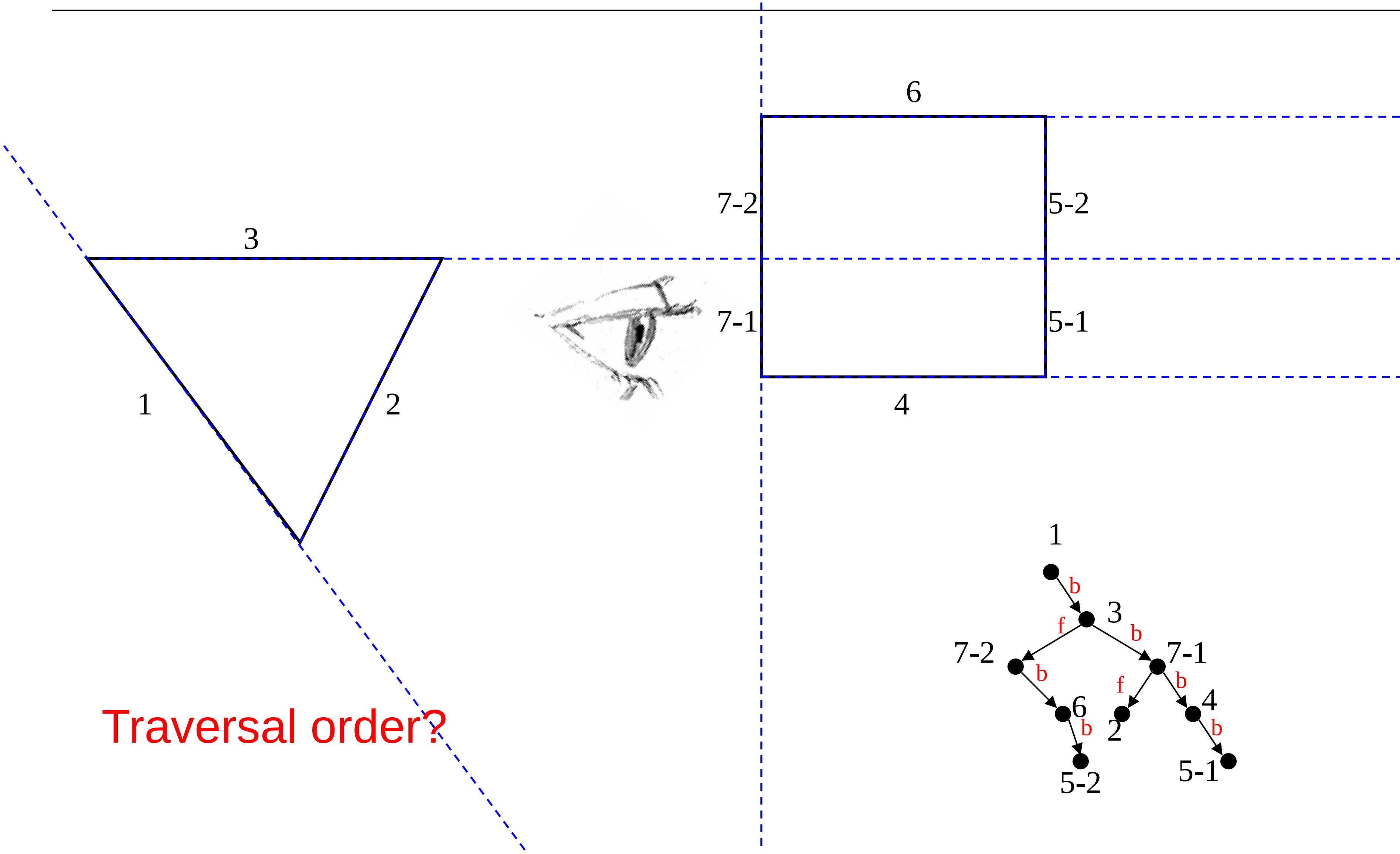
Traversal order:

Building a BSP Tree



Traversal order:
1->2->(7-1)->4->(5-1)->3->(7-2)->(5-2)->6

Building a BSP Tree



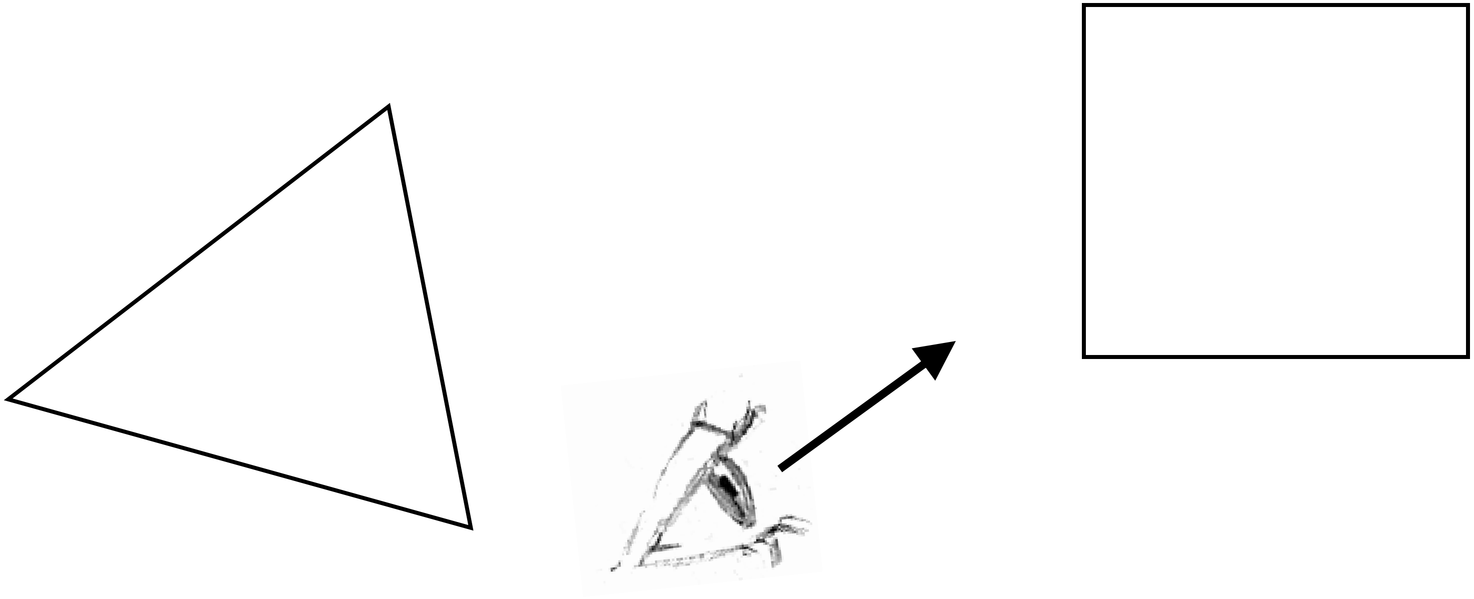
Traversal order?

Rendering with a BSP Tree

- Advantages
  - No depth comparisons needed
  - Polygons split and ordered automatically
- Disadvantages
  - Computationally intense preprocess stage restricts algorithm to static scenes
  - Splitting increases polygon count
  - Redraws same pixel many times
  - Choosing splitting plane not an exact science

Improved BSP Rendering

- Take advantage of view direction to cull away polygons behind viewer



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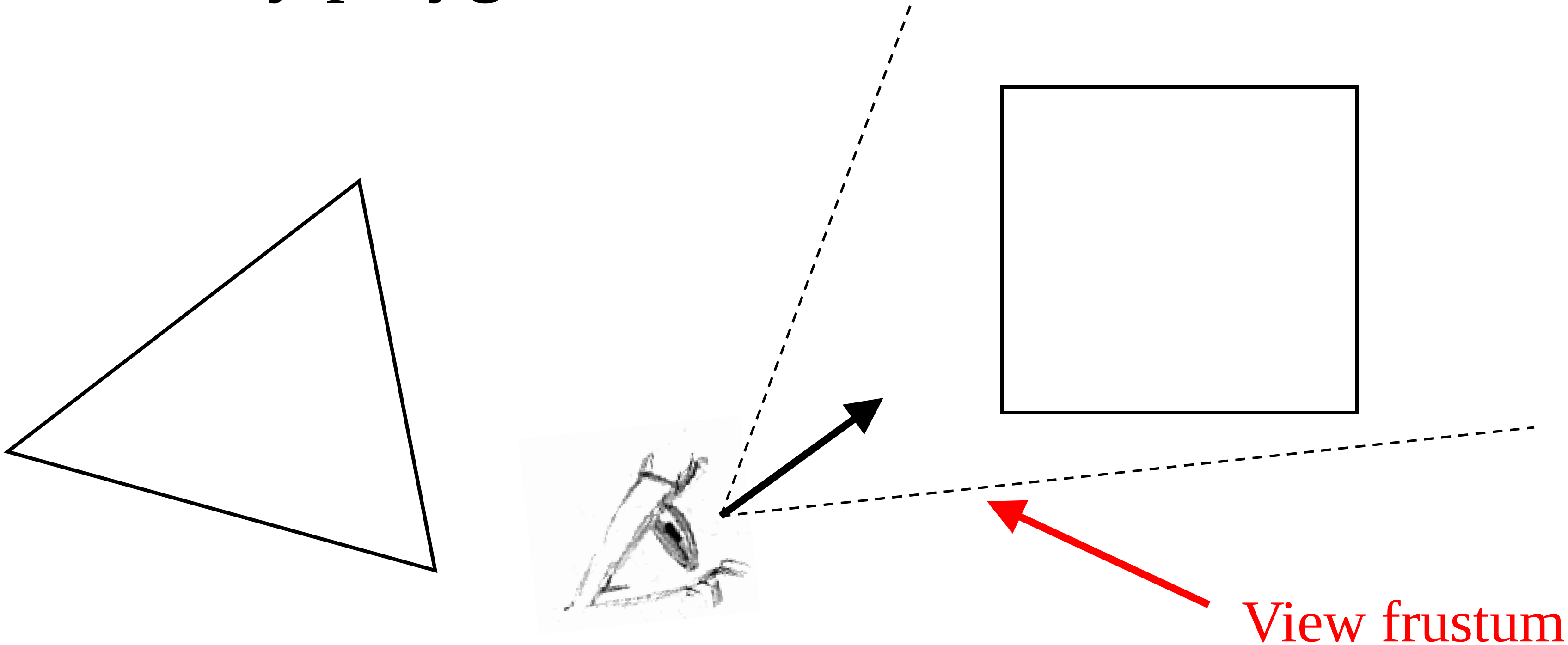

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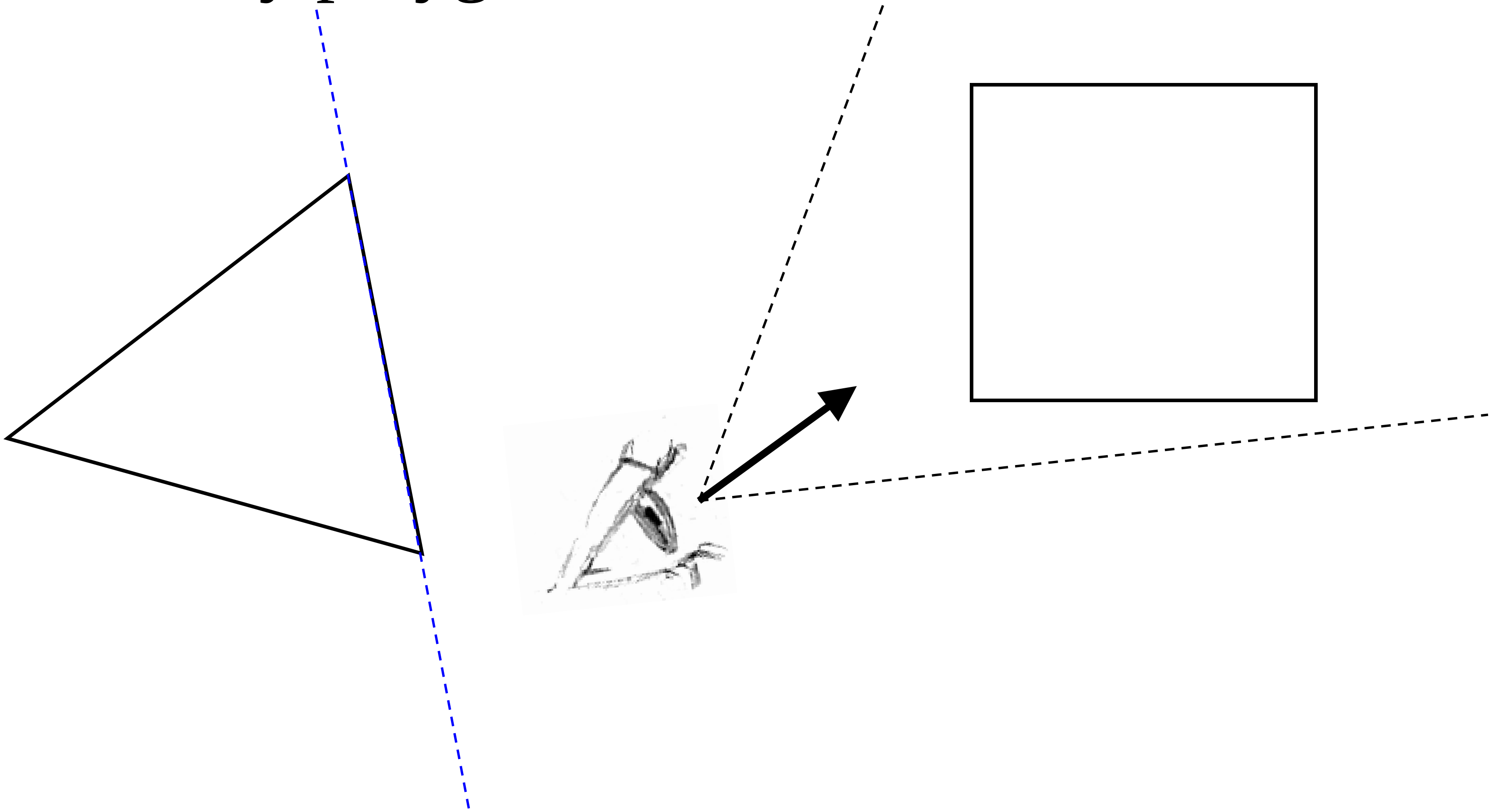


OpenGL and Hidden Surfaces

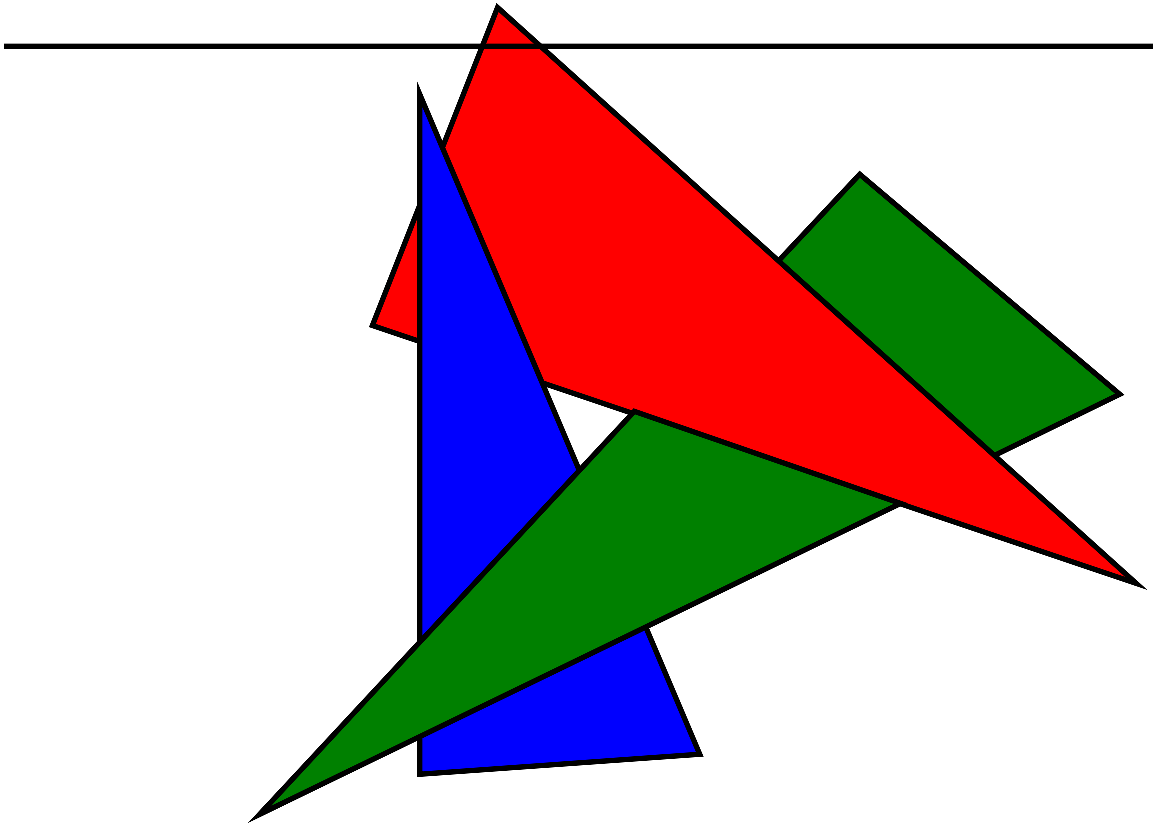
```
glEnable(GL_DEPTH_TEST);
glEnable(GL_CULL_FACE);

glClear(GL_COLOR_BUFFER_BIT |
   GL_DEPTH_BUFFER_BIT );
glCullFace ( GL_BACK );
```

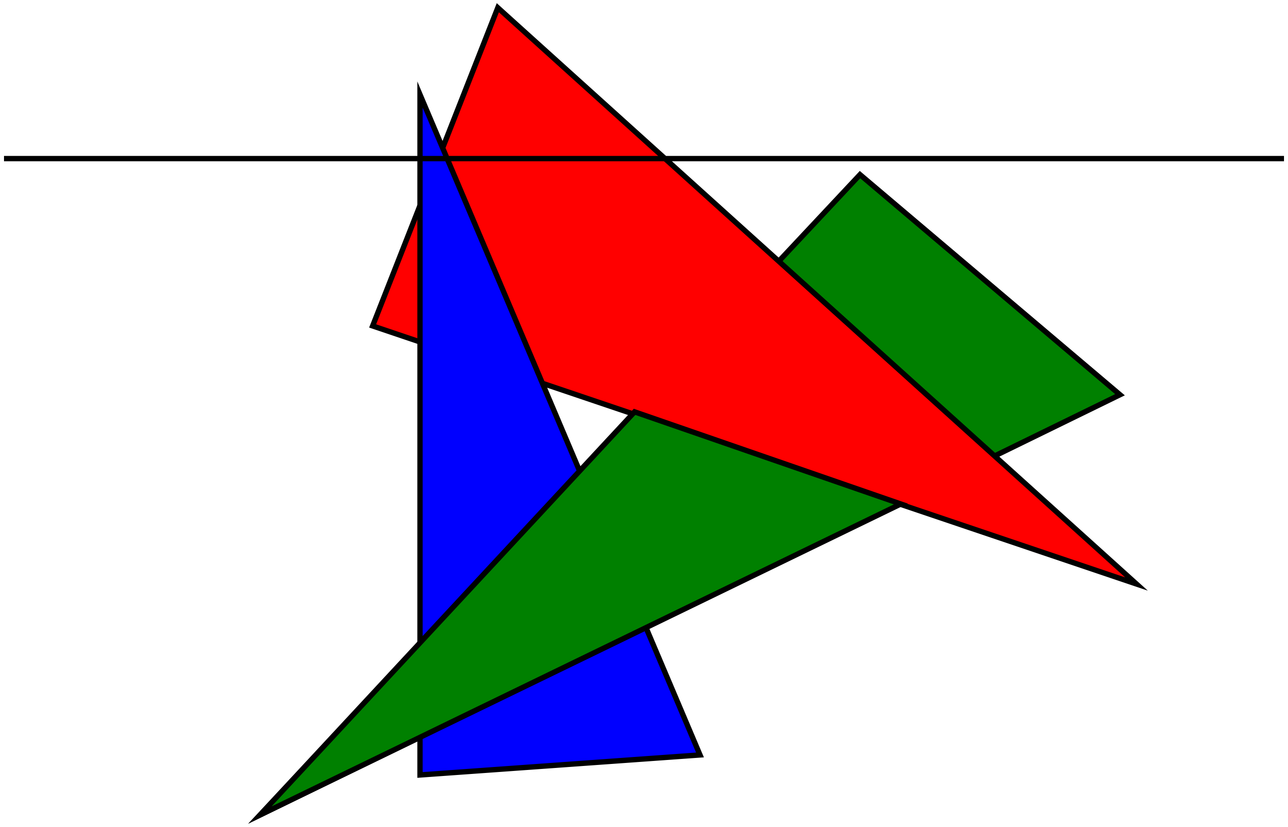
Scan Line Algorithm

- Assume for each line of screen, we have scan-lines for all polygons intersecting that line
- For each polygon, keep track of extents of scan line
- Whenever the x-extents of two scan lines overlap, determine ordering of two polygons

Scan Line Algorithm



Scan Line Algorithm



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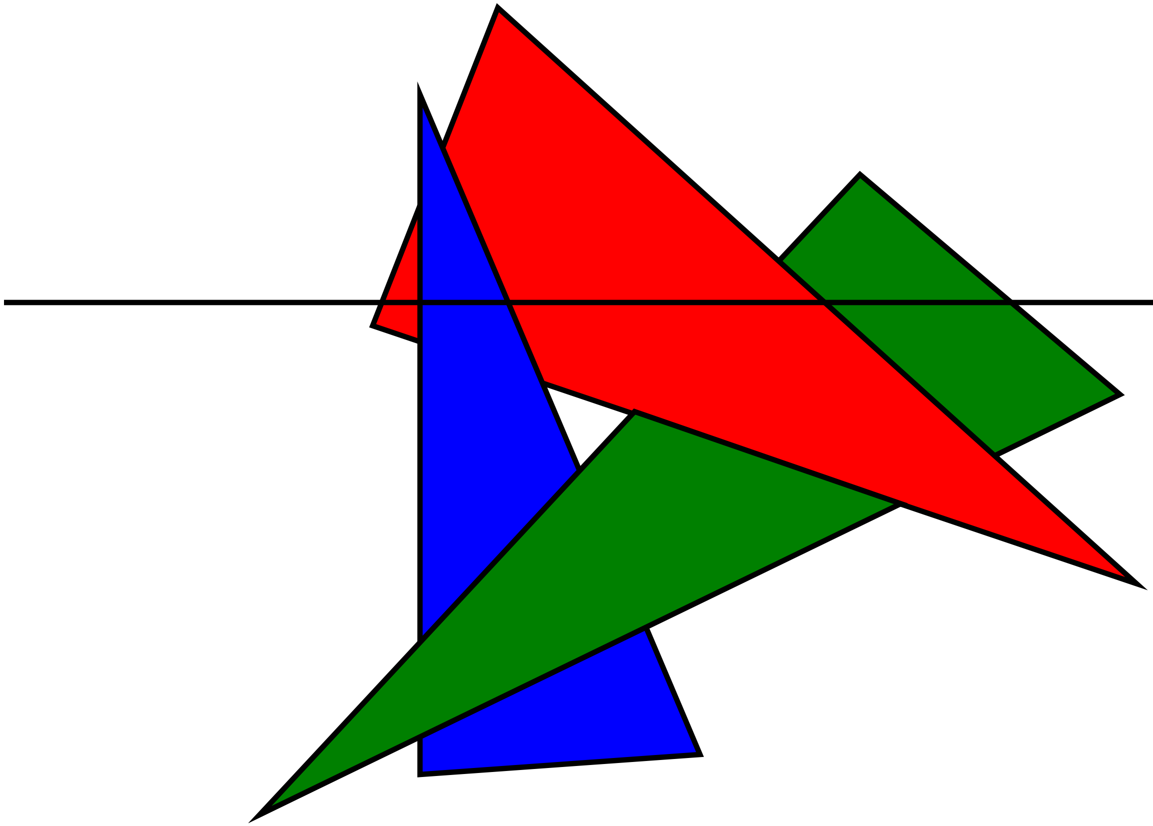

Scan Line Algorithm

- Advantages
  - Takes advantage of coherence resulting in fast algorithm
  - Does not require as much storage as depth buffer
- Disadvantages
  - More complex algorithm
  - Requires all polygons sent to GPU before drawing