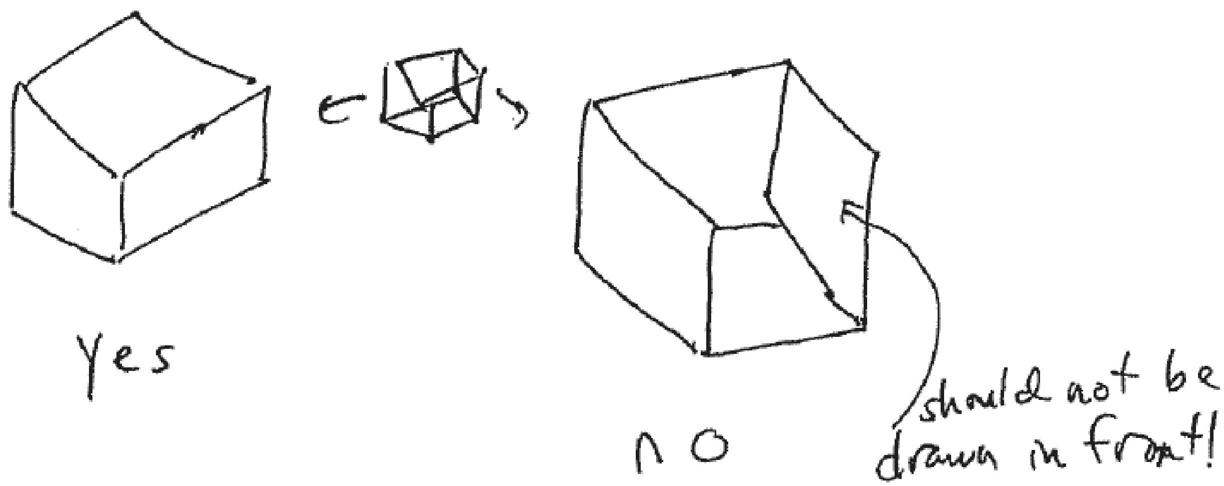
CS 428: Fall 2009

Introduction to Computer Graphics

Visibility

Visibility

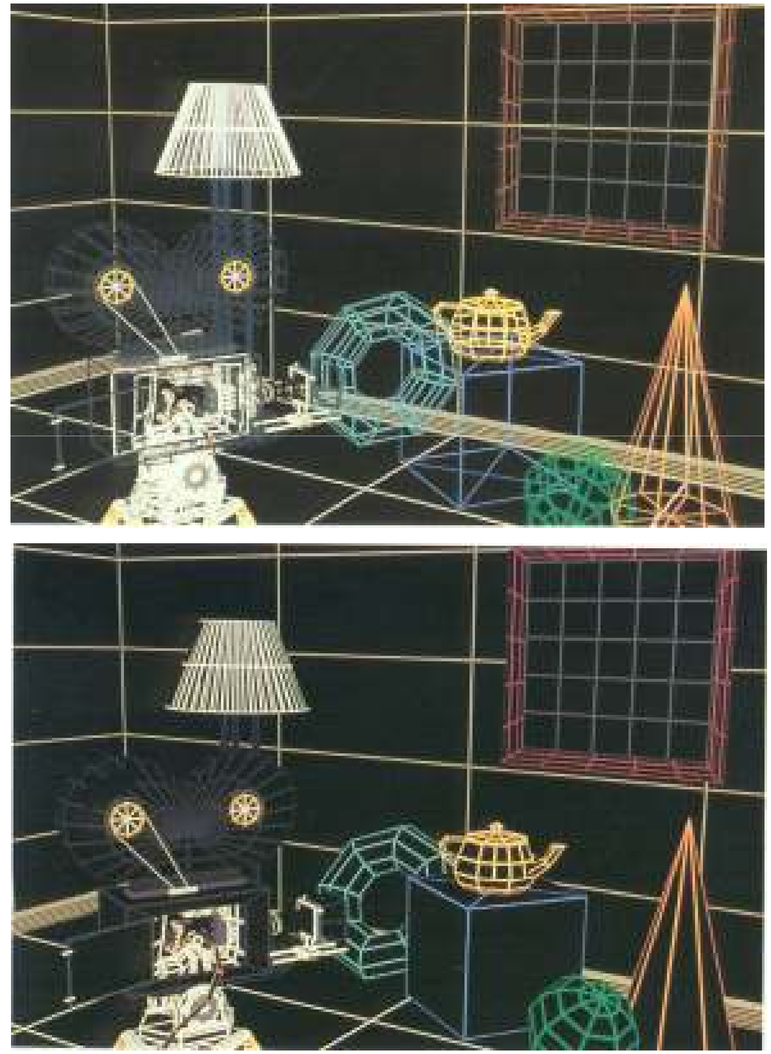
- Also known as **hidden surface removal**
  - Respect the nature of occlusion in visual scenes



  - Algorithms for determining which parts of the object/surfaces are **visible**
    - For now only **opaque** objects

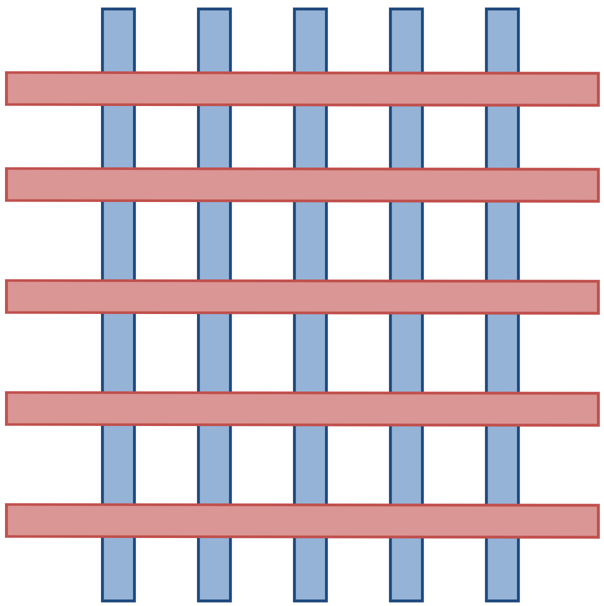
Visibility algorithms

- **Occlusion**
  - More than one point projects to the same point in the image
  - Obviously, the point closest to the observer is visible
  - Unless the closest point is (semi)transparent, in which case objects behind become visible



Visibility algorithms

- **Complexity**
  - Visibility computation is comparable to sorting
  - Worst case complexity is worse
  - Given a scene with **n** polygons, there might exist ~$\mathbf{n^2}$ visible parts
  - Worst case complexity is $\mathbf{O(n^2)}$



Visibility

- A variety of algorithms
  - Each work better (more efficiently) in different situations

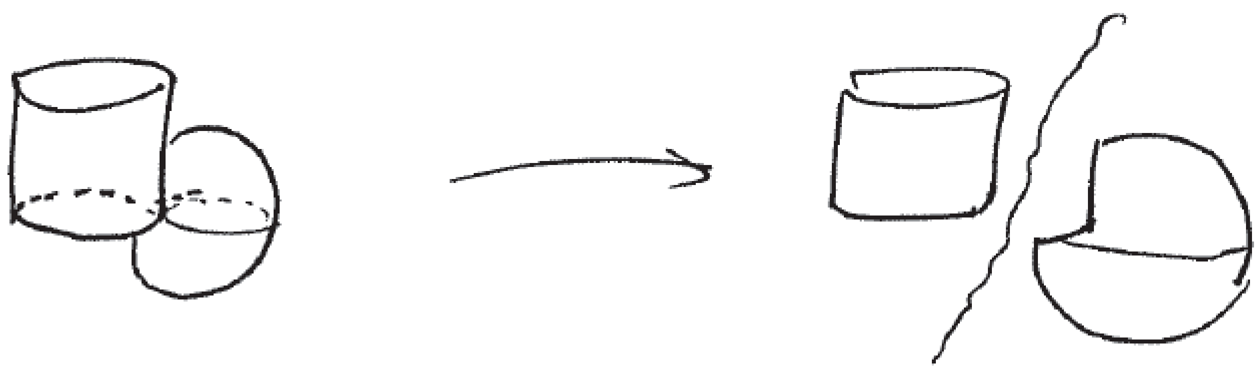
- Two main categories
  - Object precision algorithms
  - Image precision algorithms

Object precision

- Operate on geometric primitives
  - For every object in the scene
    - Compute visible part (not occluded by **any** other object in the scene) → needs **high** precision
    - Draw visible part
- Results are independent of display resolution
- Brute force algorithm is $\mathbf{O(n^2)}$
  - n = number of objects on screen
  - Can be improved (pre-computation) to **O(n log n)**

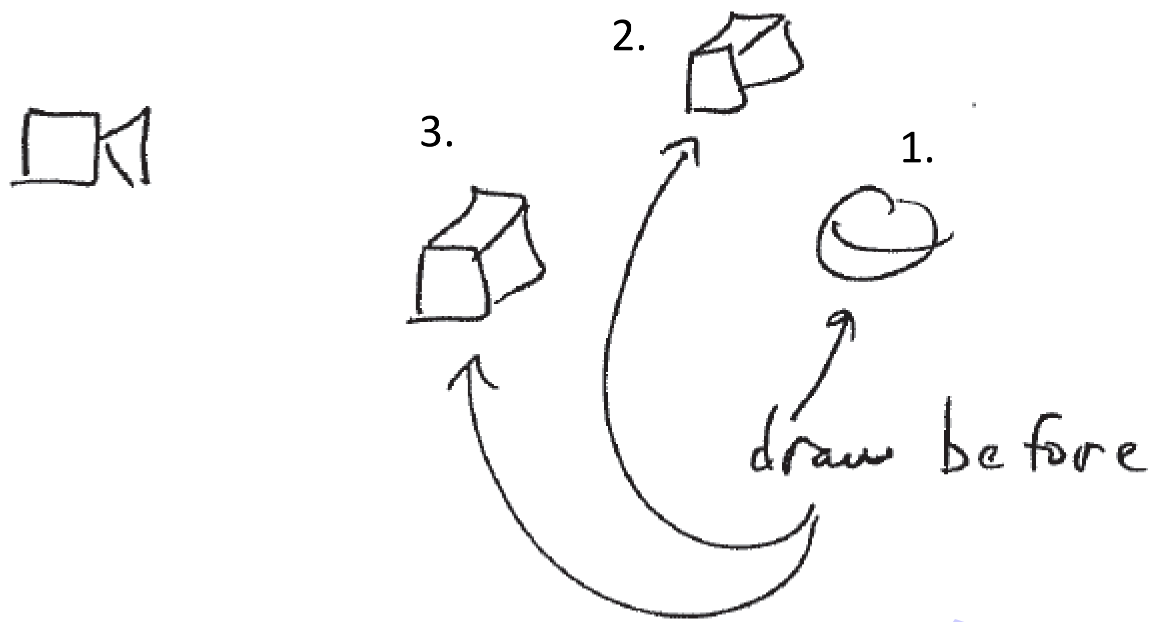
Object precision

- Hard(er) to implement
  - Due to numerical error
  - Due to tricky geometric computations (intersections, Boolean operations, etc.)

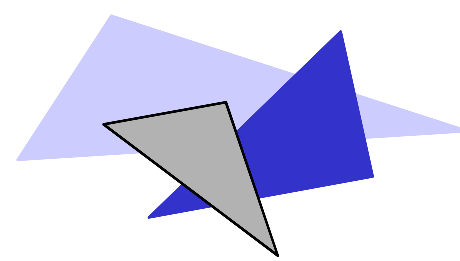


List priority methods

- Draw surfaces in **back-to-front** order

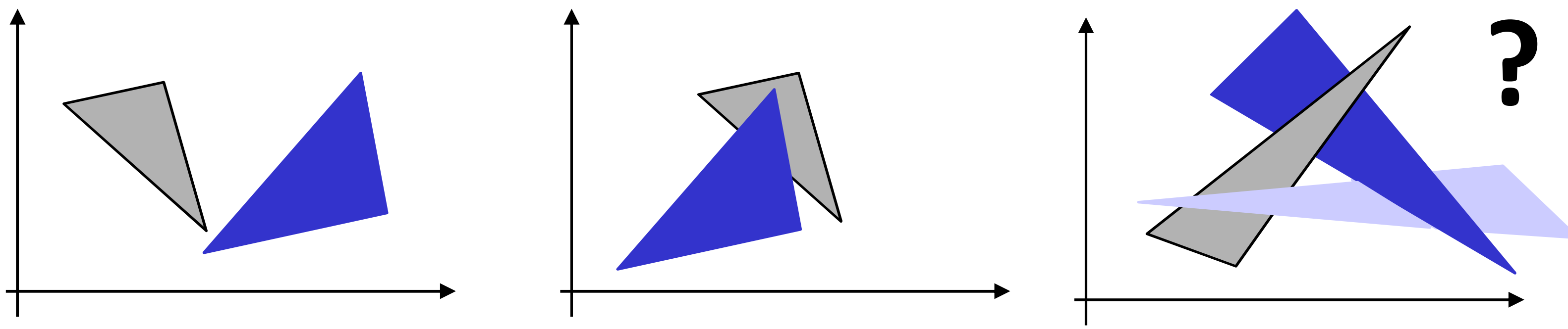


  - **Painters algorithm**



List priority methods

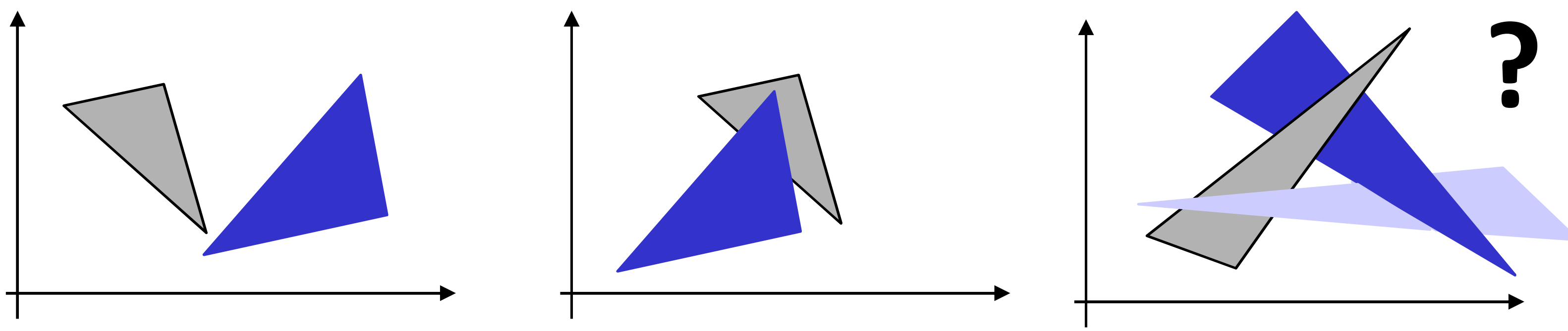
- **Problem:**
  such an ordering does not always exist



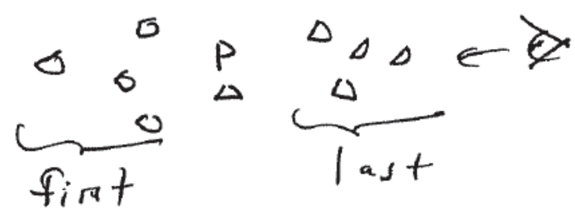
  - In such cases, polygons must be **split**
  - This can result in many split polygons (see worst case complexity)

List priority methods

- **Observation:**
  polygons are drawn in the correct order if



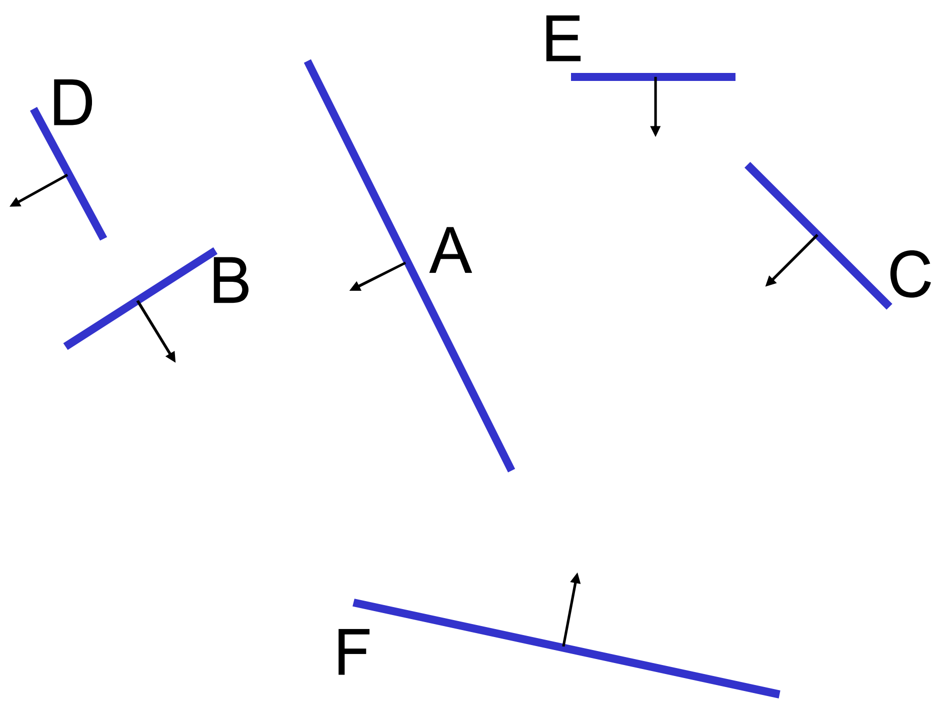
  - For every polygon part **P**
    - Draw everything behind **P**
    - Draw **P**
    - Draw everything in front of **P**



Binary space partion (BSP)

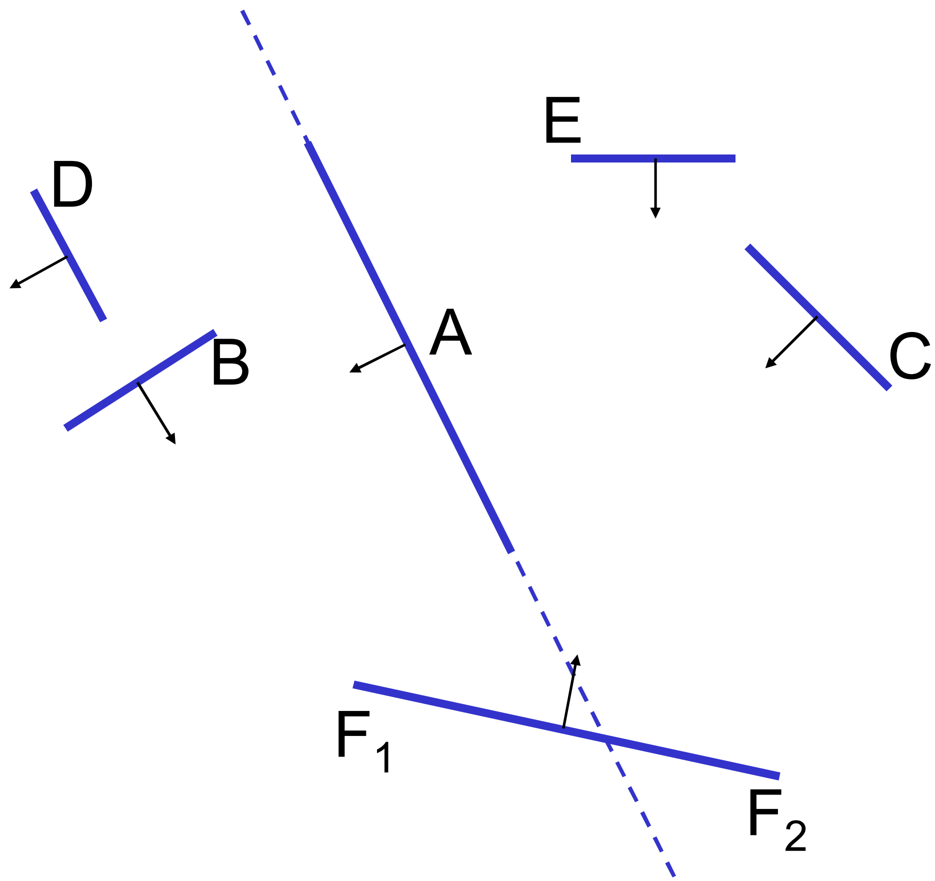
- BSP tree: binary spatial subdivision
- A tree that encodes **viewpoint-independent** and **relative** position/depth information
  - Every node is a splitting plane, which cuts space into two parts (two **half-spaces**)
  - Leads to an ordering with respect to every line in 2D (plane in 3D, etc.)
  - For visibility, the splitting (hyper)planes are defined by the scene geometry

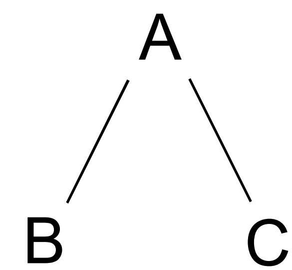
Binary space partion (BSP)



A

Binary space partion (BSP)





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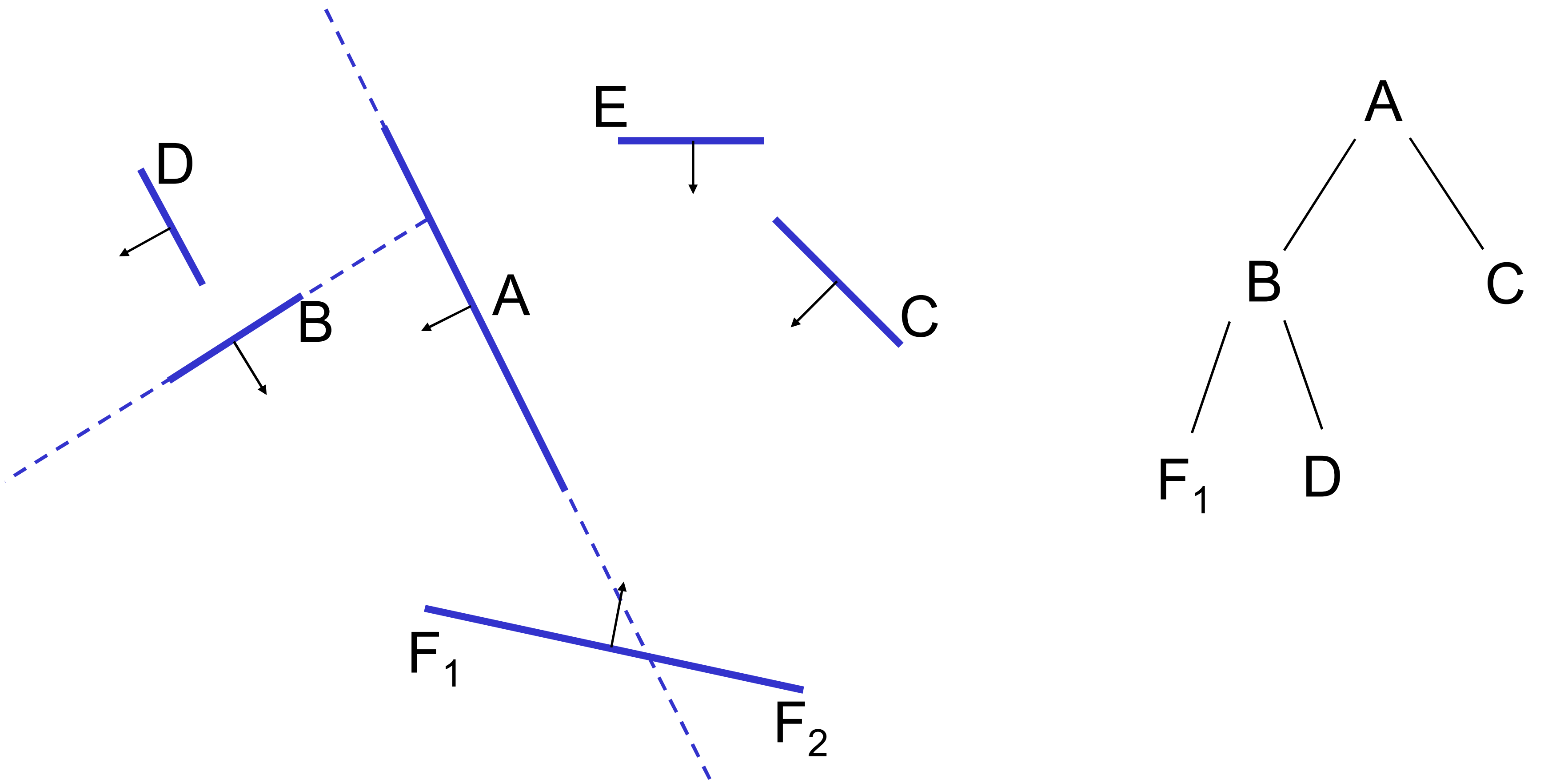

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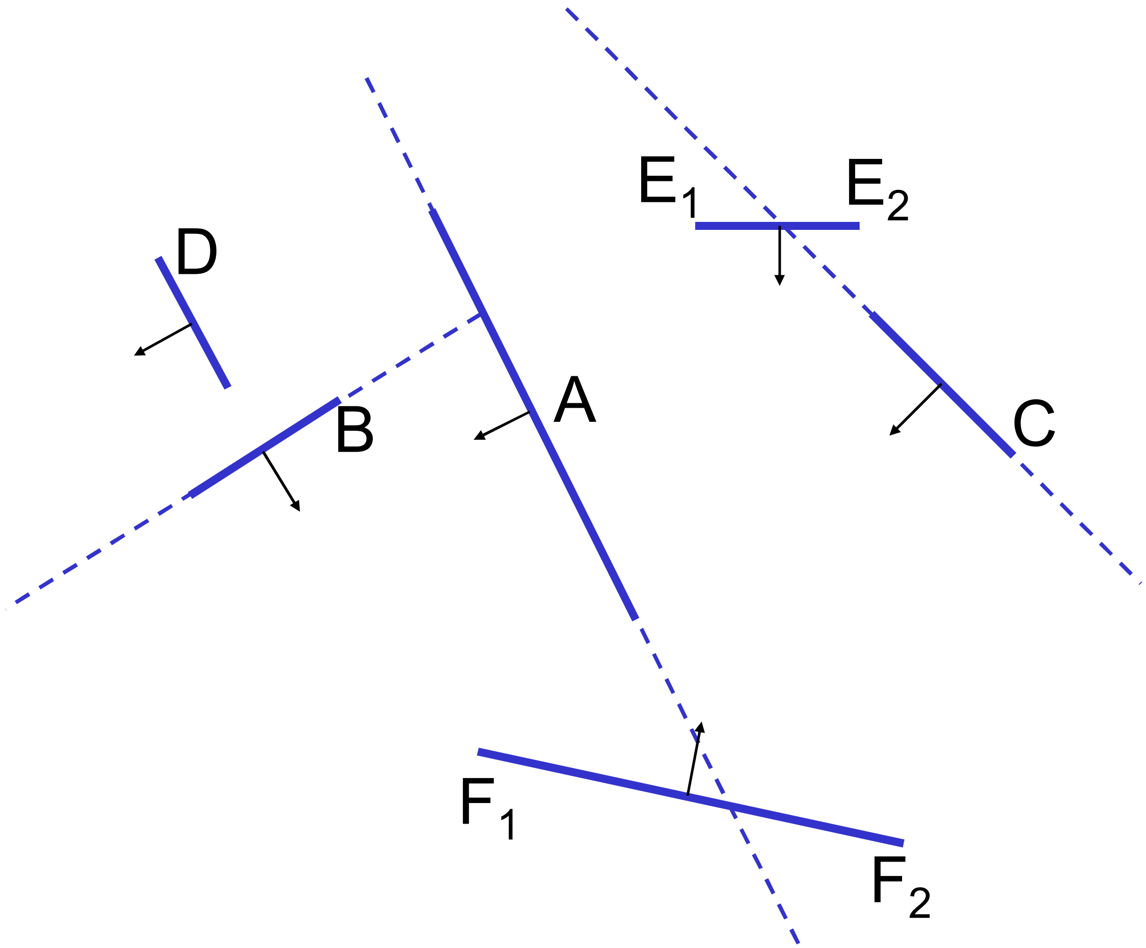

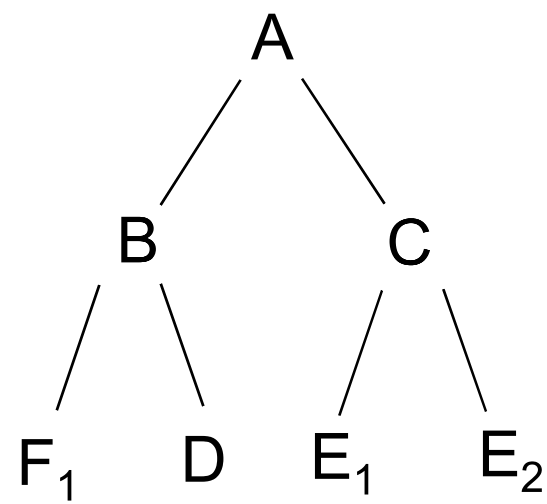

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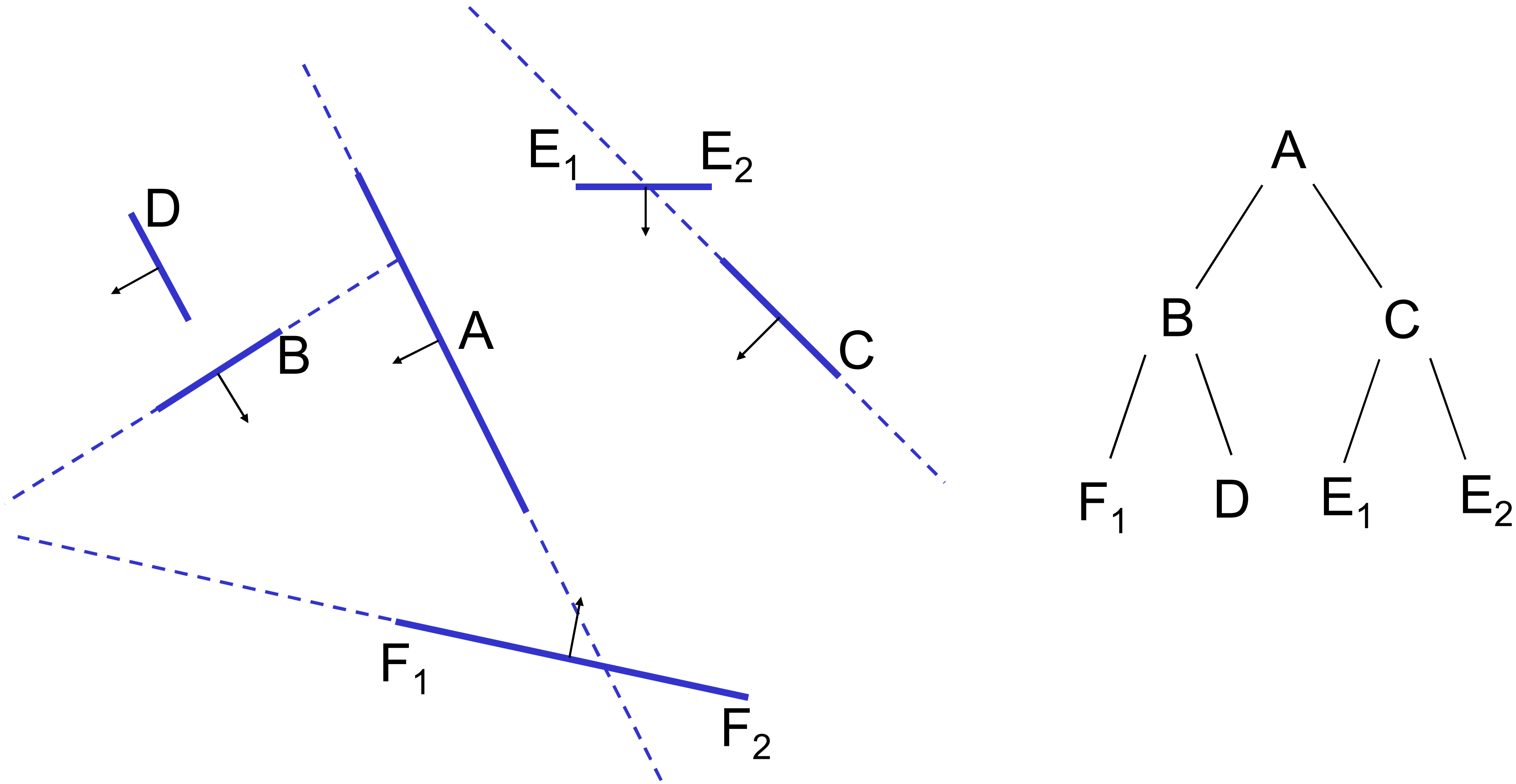

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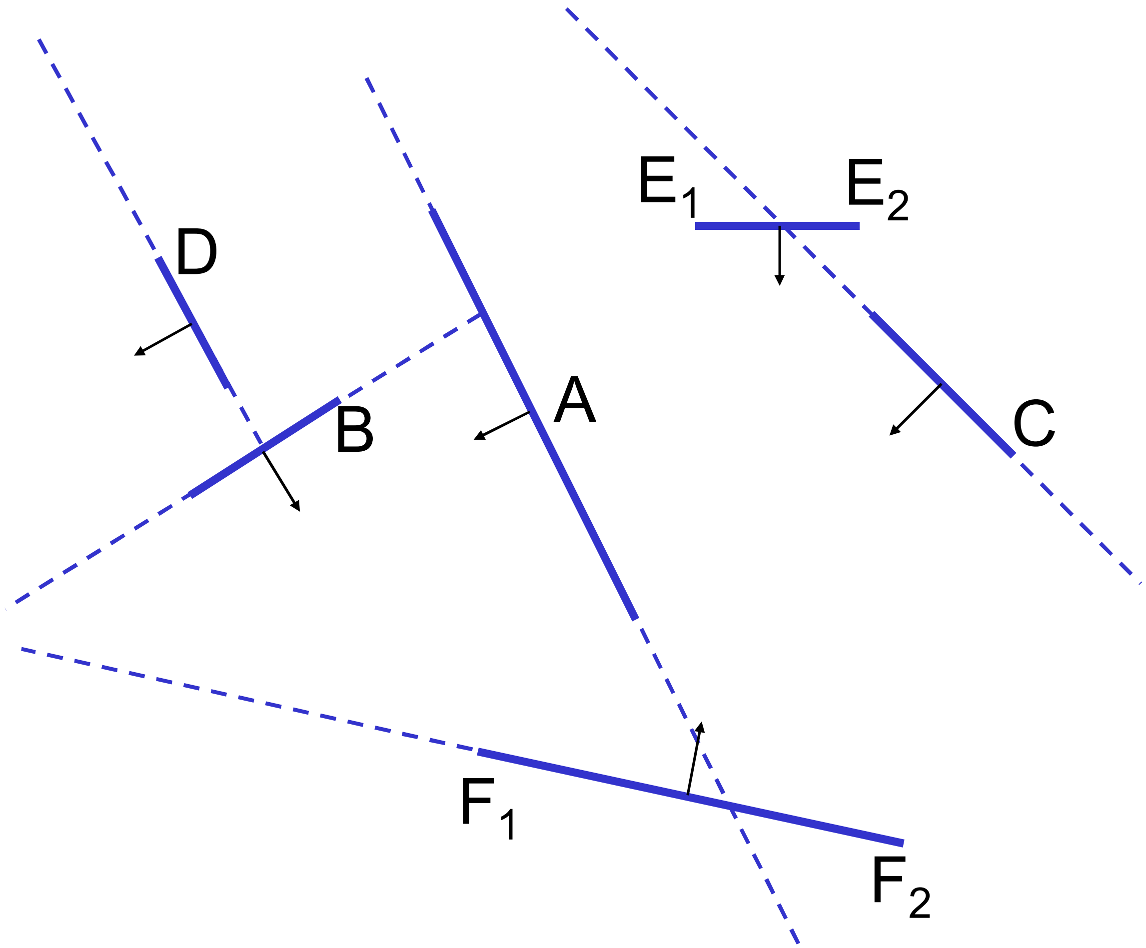

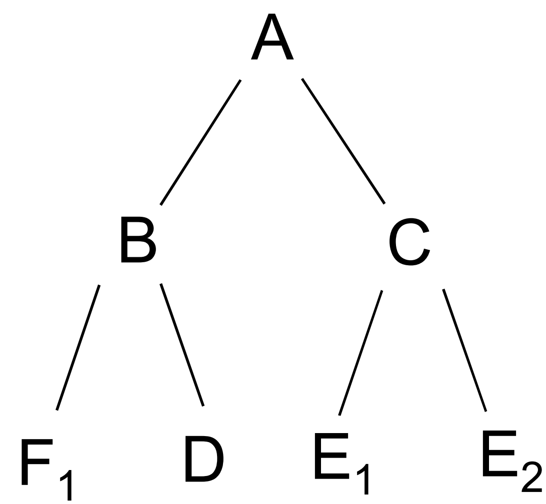

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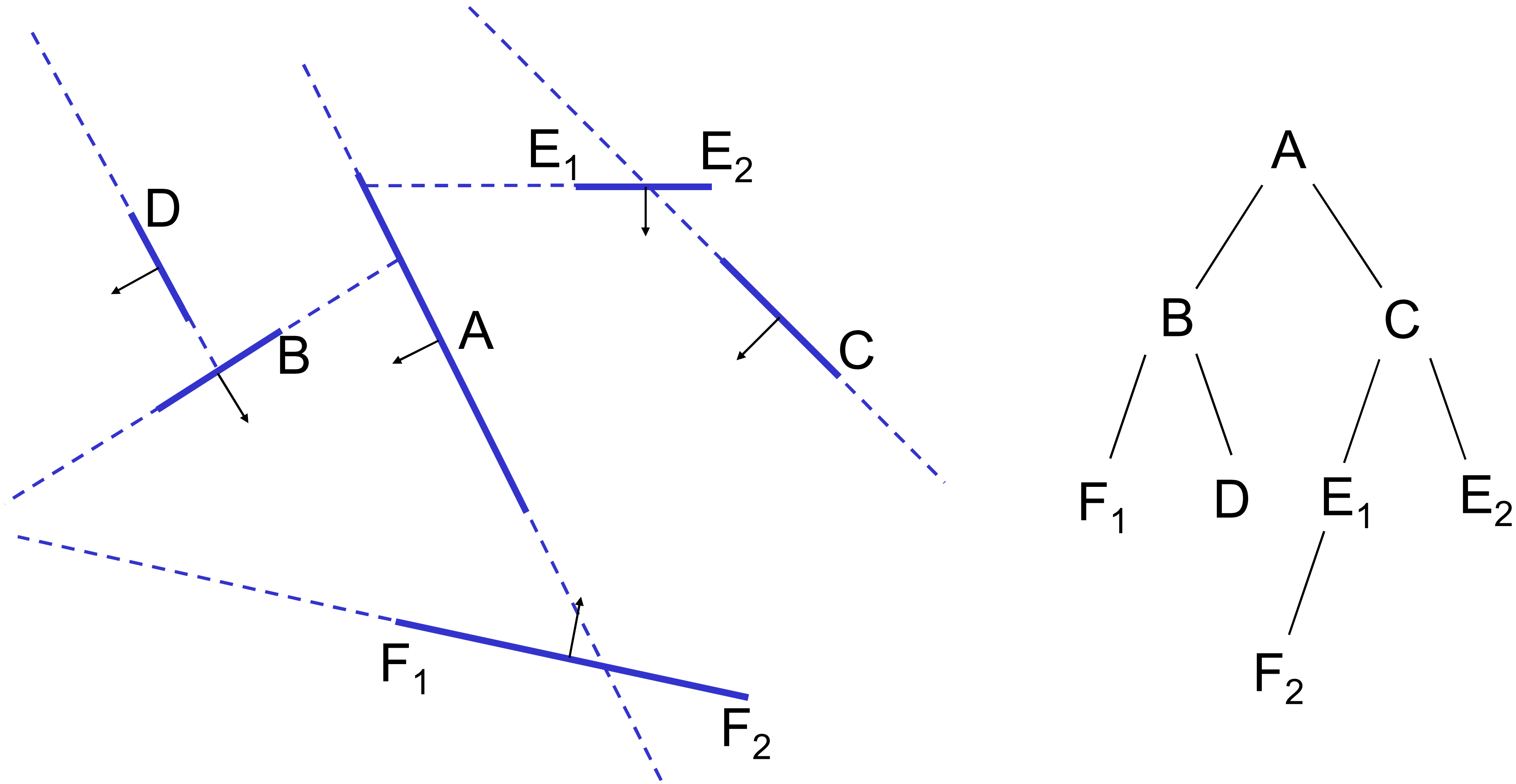

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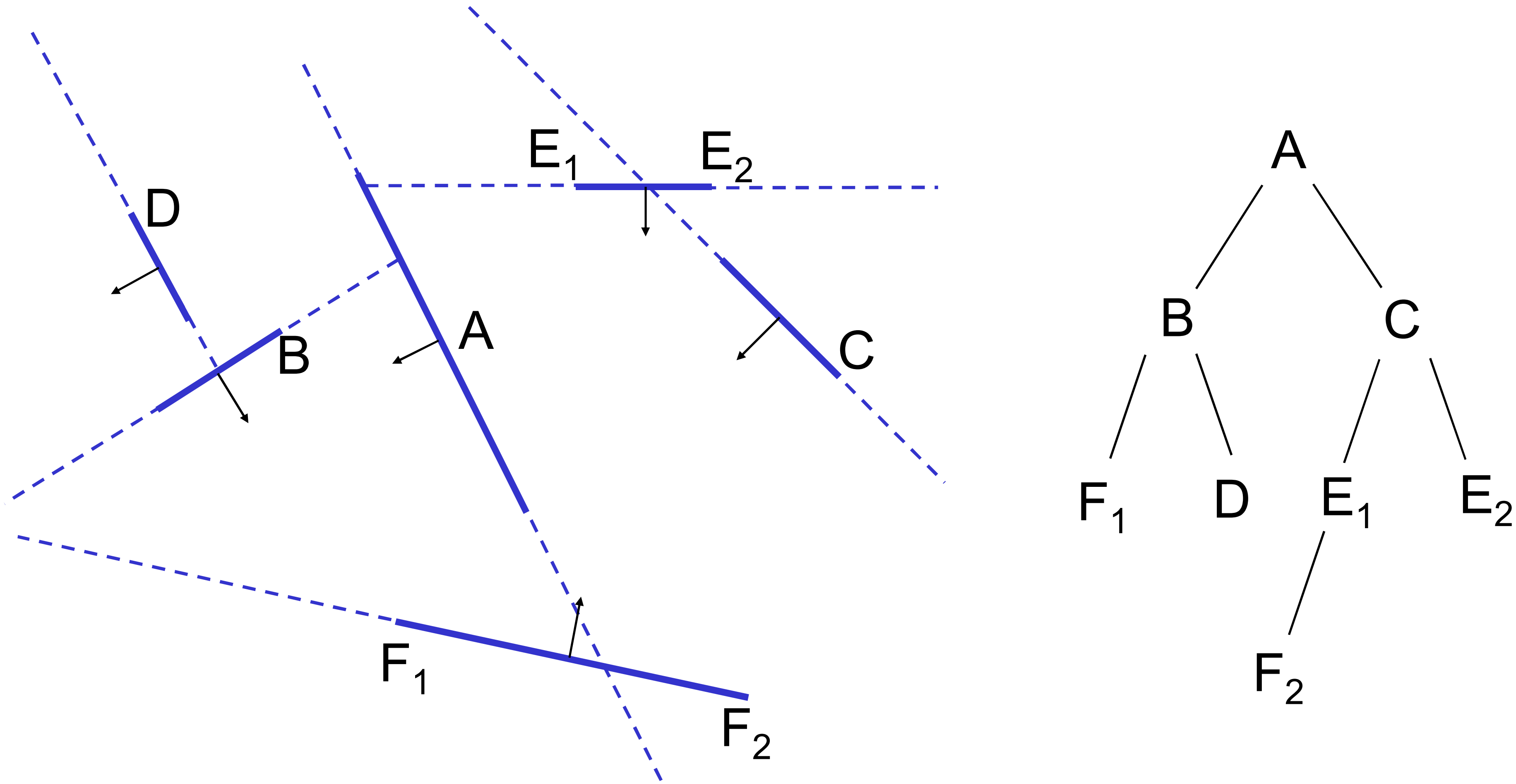

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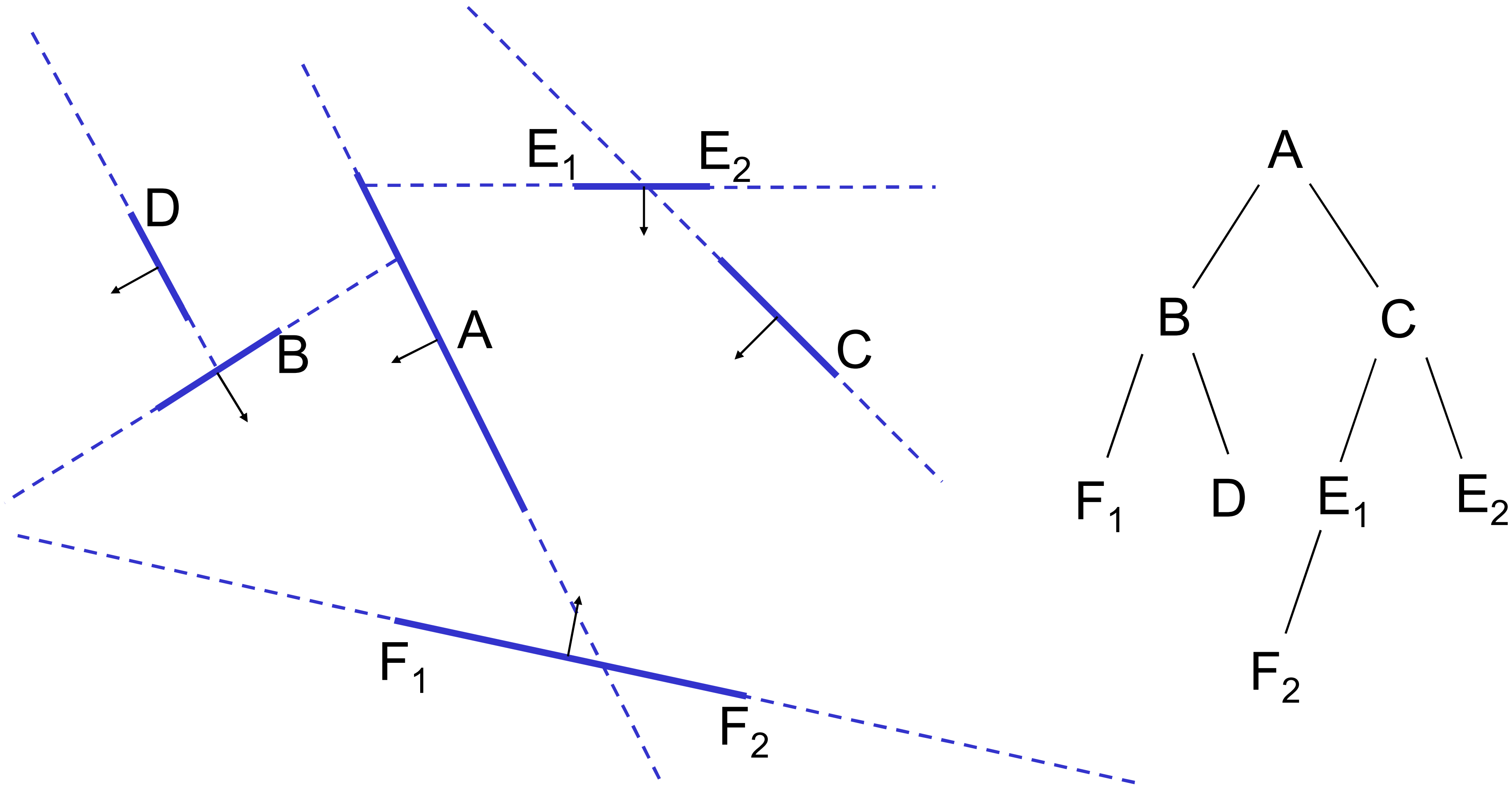
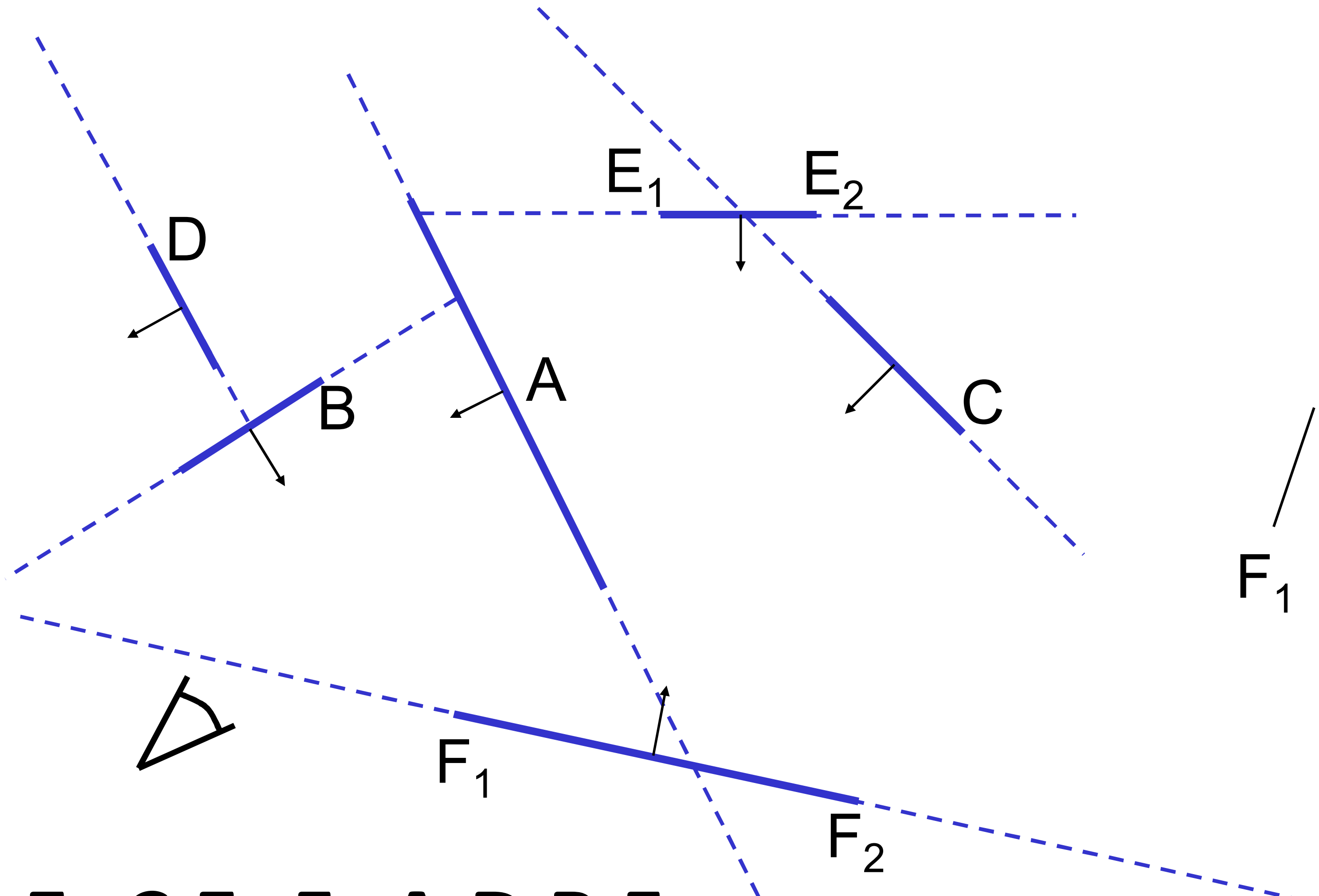


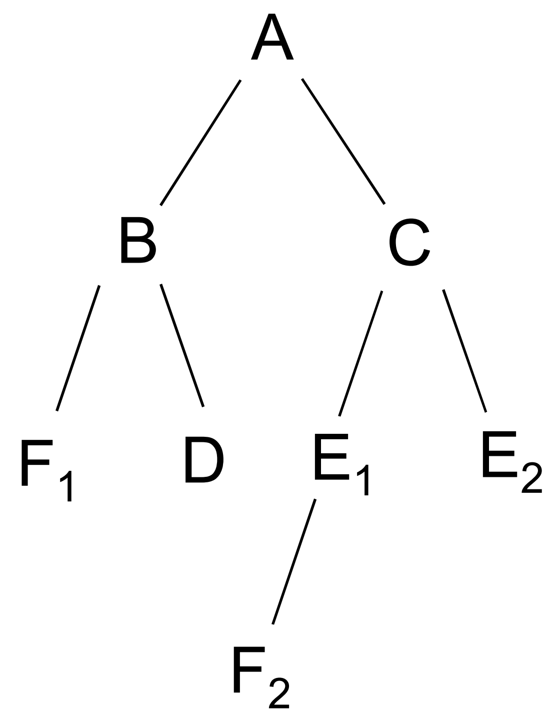
Binary space partion (BSP)

- Ordered list of polygons by traversal
- Identify half-space **H** of eye position

- Traversal ordering
  - Other half-space
  - Polygon (node)
  - Containing half-space **H**

Binary space partion (BSP)





E_2,C,E_1,F_2,A,D,B,F_1

Binary space partion (BSP)

- Some issues
  - Which plane to chose as the splitting plane in each step?
  - How to balance the tree?
  - How to avoid excessive polygon splitting?
- Solution
  - Re-run the algorithm!
    - "Perfect" BSP is in NP (exponential complexity)
    - Randomized version works well, has good expected performance

Image precision

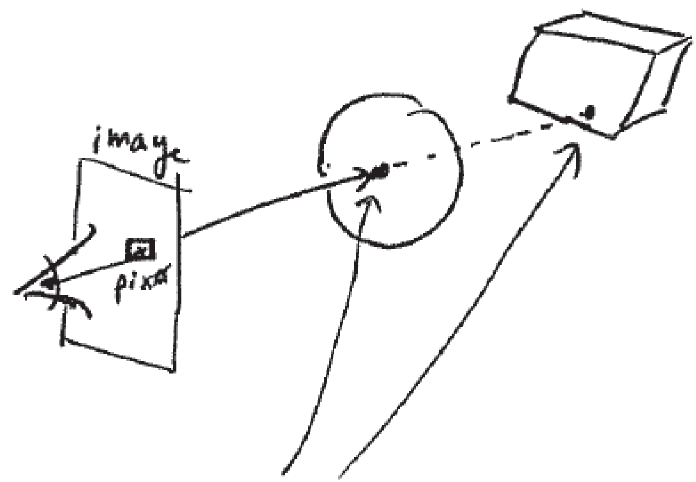
- You already know one: **z-buffer**
- Z-buffer algorithm is an **output sensitive** algorithm (only looks at rendered pixels)
- Brute force
  - For each pixel
    - Find object closest to camera which projects to here
    - Draw that object
- Complexity is **O(nP)**, while z-buffer is **$O(nP_R)$**

Image precision

- You already know one: **z-buffer**
- Z-buffer algorithm is an **output sensitive** algorithm (only looks at rendered pixels)
- Z-Buffer
  - Initialize depth image **D** to farthest distance
  - For each pixel **p** of each polygon with depth **d**
    - If d(x,y) < D(x,y)
      - Replace D(x,y) with d(x,y) and write color of **p** into image

Ray casting

- Preview for next lecture
- Associate a ray with each pixel



- Find object-ray intersection points
- Choose closest point to the camera