Realtime Computer Graphics on GPUs

What did not fit elsewhere

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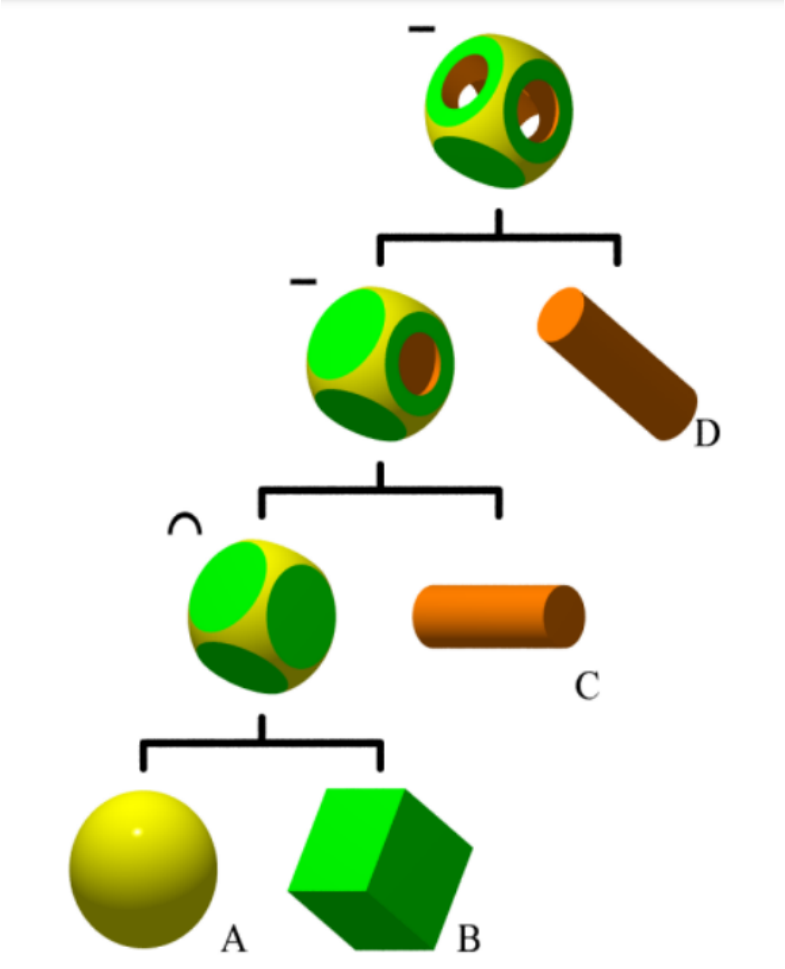
Constructive Solid Geometry

What is CSG?

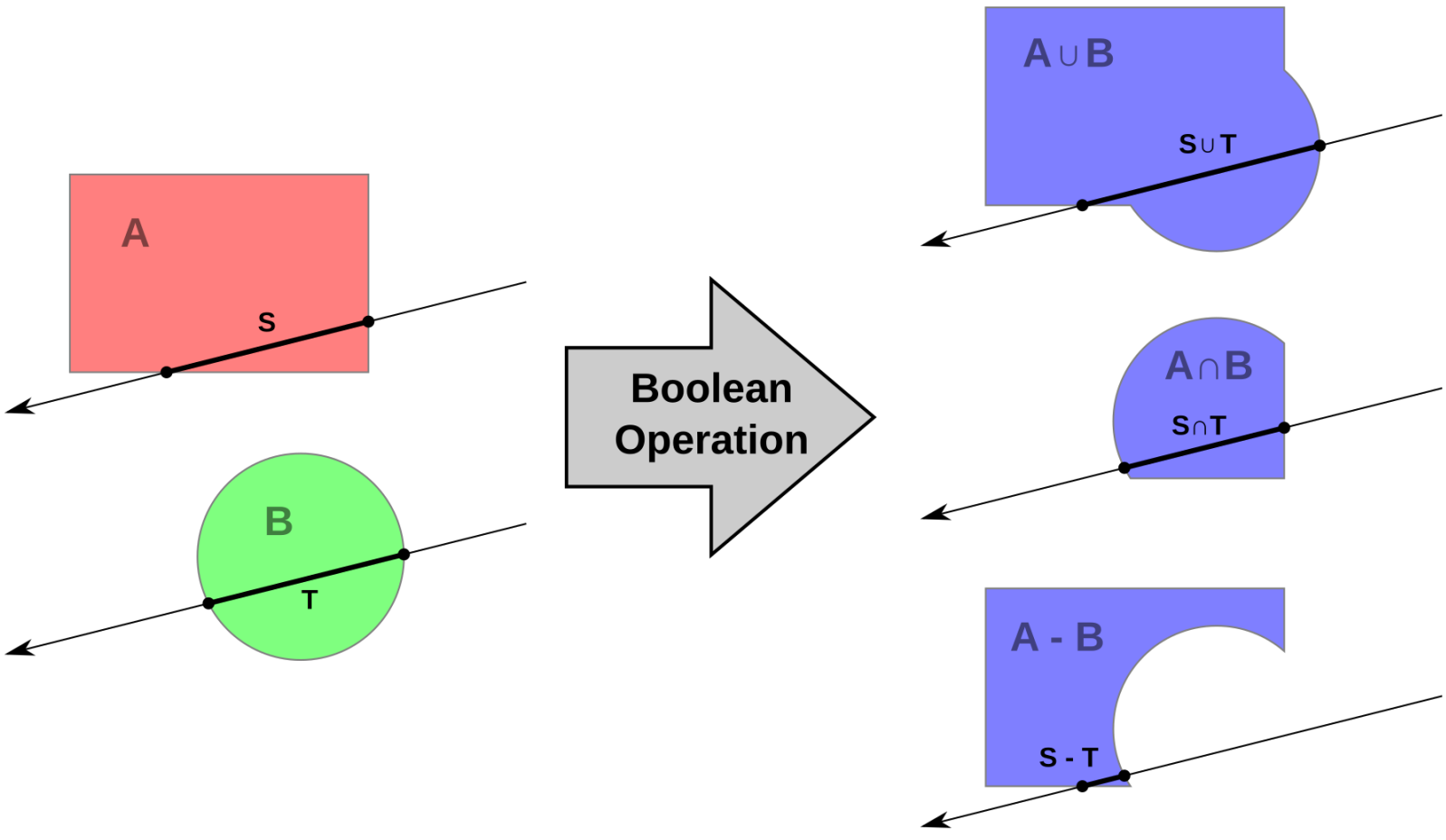
- Used by CAD applications
- Set operations on geometry primitives
  - Union
  - Intersection
  - Subtraction



How to render?

- Conversion to tri-mesh
- Raytracing
- Rasterization pipeline

RAYTRACING



Rasterization Pipeline

- Elementary solids converted to polyhedra
- set operations evaluated on the GPU
  - union is trivial (default depth-buffer based rendering)
  - intersection and subtraction: use of stencil buffer, considering front vs. back facesunion is trivial (default depth-buffer based rendering)

GOLDFEATHER

- 1989: Goldfeather et al.
- normalization of a CSG tree – decomposition to union of ”products” (intersections and differences)
- implementation uses several depth-buffers and a stencil buffer (needs to copy depth-buffers)

SEQUENCED CONVEX SUBTRACTION

- 2000:Stewart et al. – Sequenced Convex Subtraction (SCS)
- does not need depth-buffer copying, complex depth-tests
- all elementary solids have to be convex

SCS Phases

1. preprocessing (CSG normalization, sorting of subtraction sequences /front-to-back/)
2. depth-buffer processing (for every product + merge)
3. final rendering to frame-buffer

INTERSECTION OF N SOLIDS

- init: depth = near; stencil = 0;
- passing through front faces of individual solids

```
if ( front > depth ) depth = front;
```

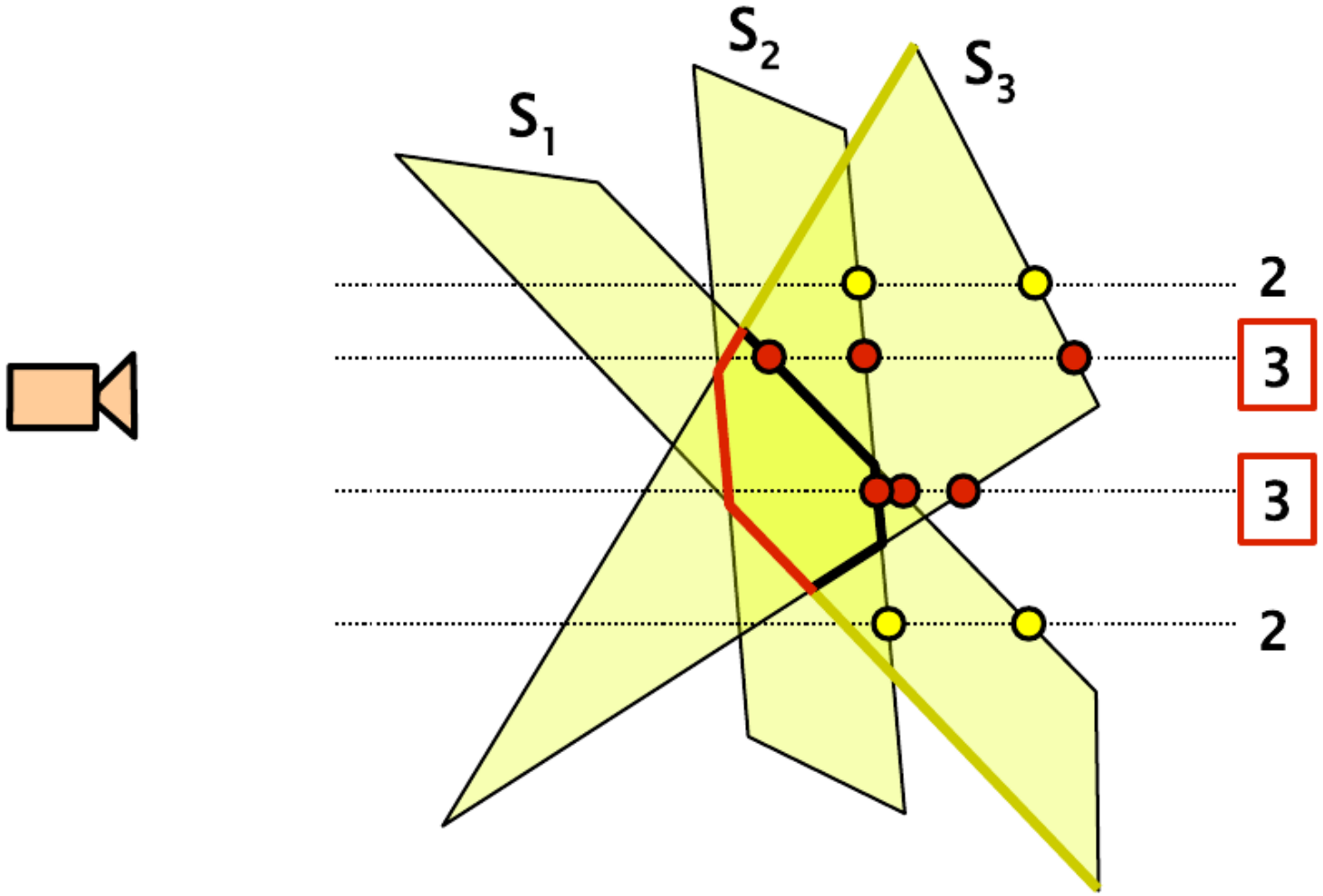
- passing through back faces (occlusions)

```
if ( back > depth ) stencil++;
```

- removing pixels with occlusion number ¡ n

```
if ( stencil < n )
{
stencil = 0;
depth = far;
}
```

INTERSECTION – EXAMPLE



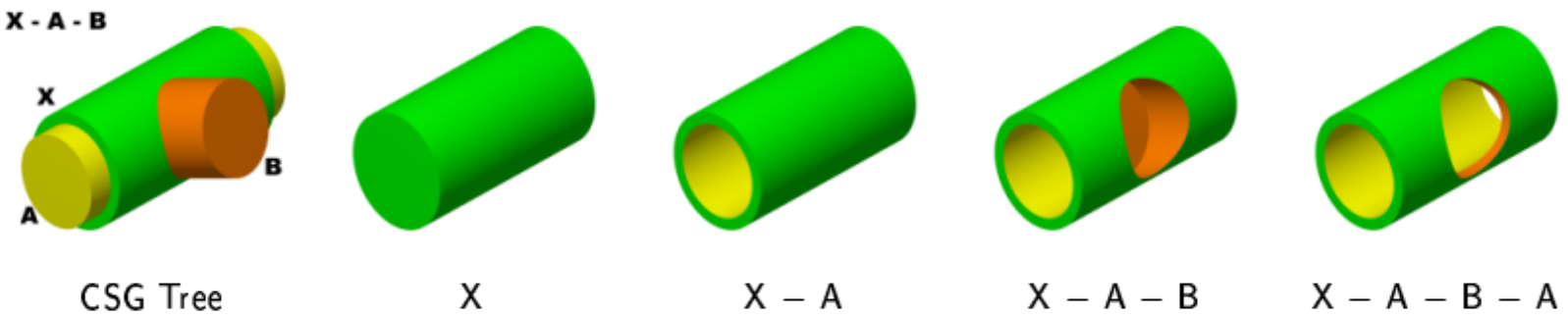
SUBTRACTING SEQUENCES

- determining correct subtracting sequence;
  - front-to-end subtraction
  - universal subtractin sequence – contains all occlusion permutations
- subtracting from the front: passing all subtr. solids

```
if ( front < depth ) stencil = 1;
else stencil = 0;
```

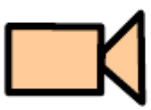
- every back-face is processed immediately as well

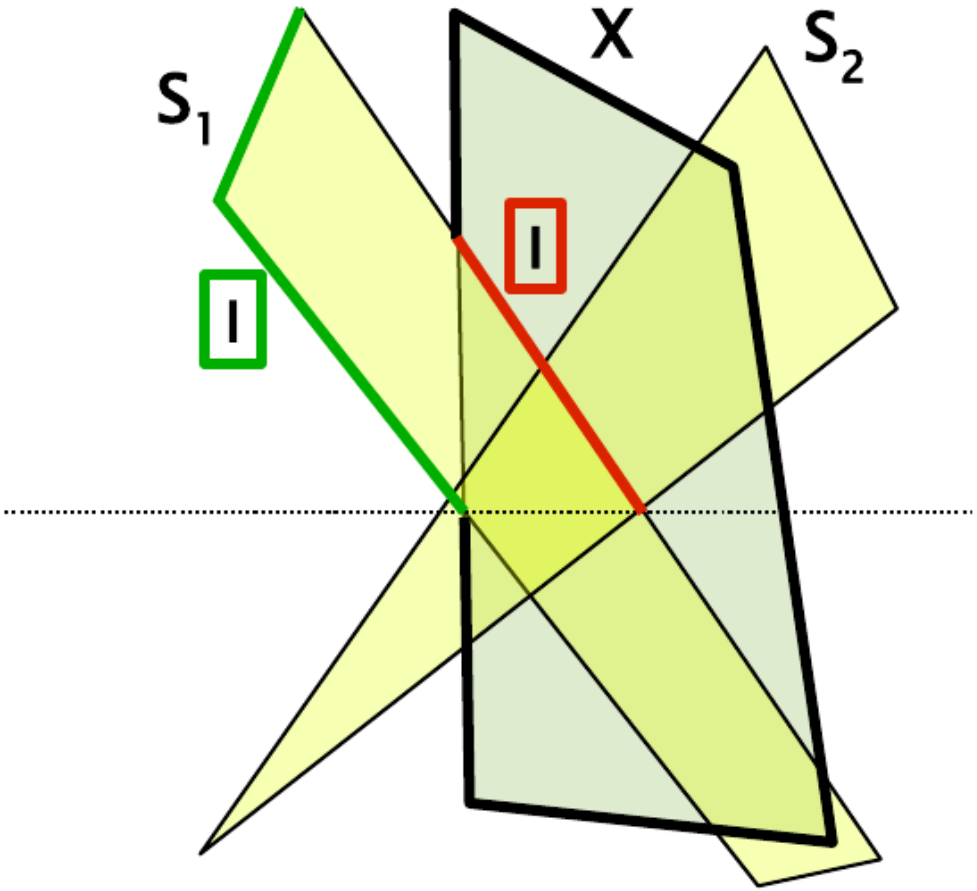
```
if ( back > depth && stencil == 1 )
depth = back;
```



SUBTRACTION – STEP I

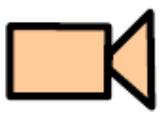
$X - S_1 - S_2 - S_1$

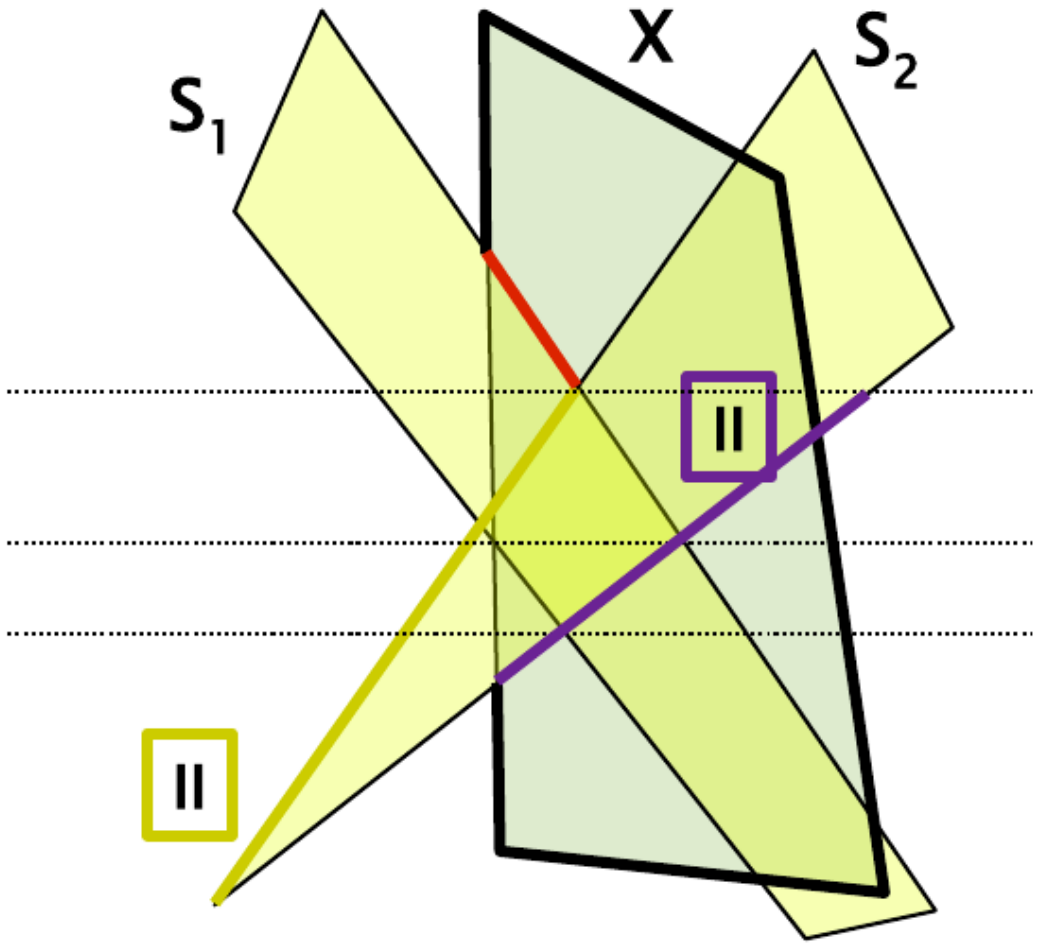




SUBTRACTION – STEP II

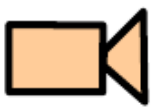
$X - S_1 - S_2 - S_1$

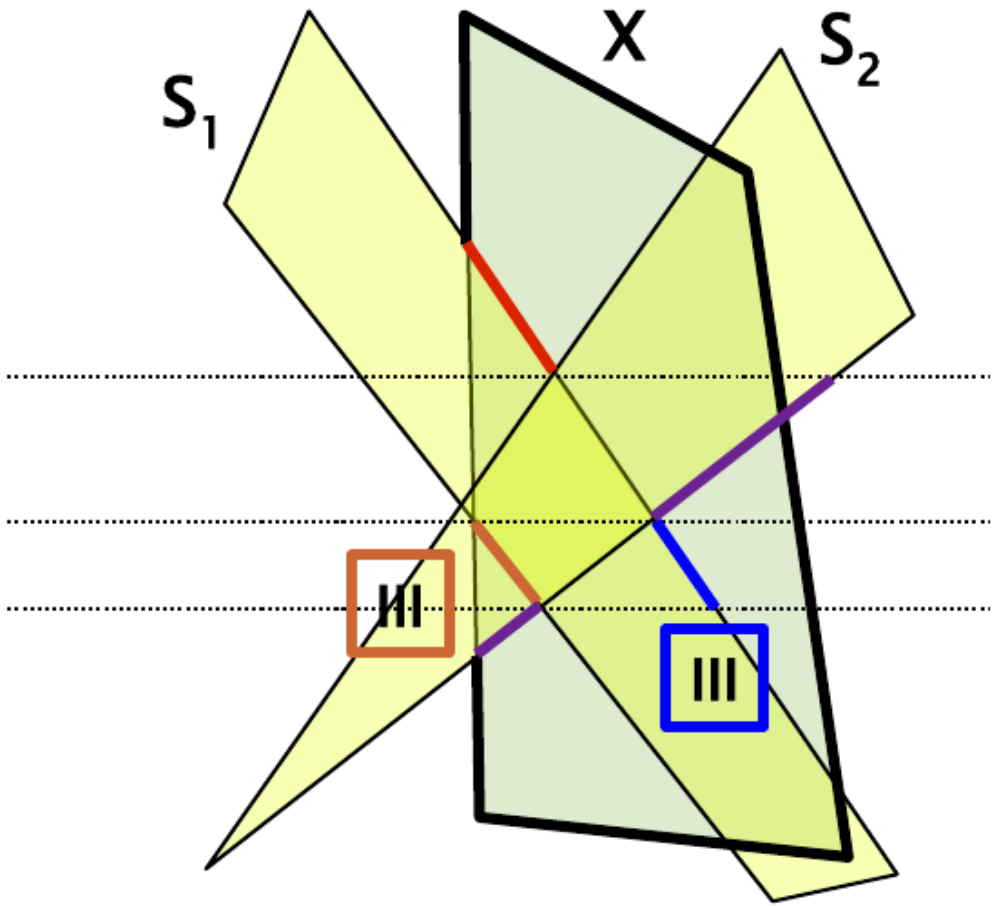




SUBTRACTION – STEP III

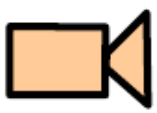
$X - S_1 - S_2 - S_1$

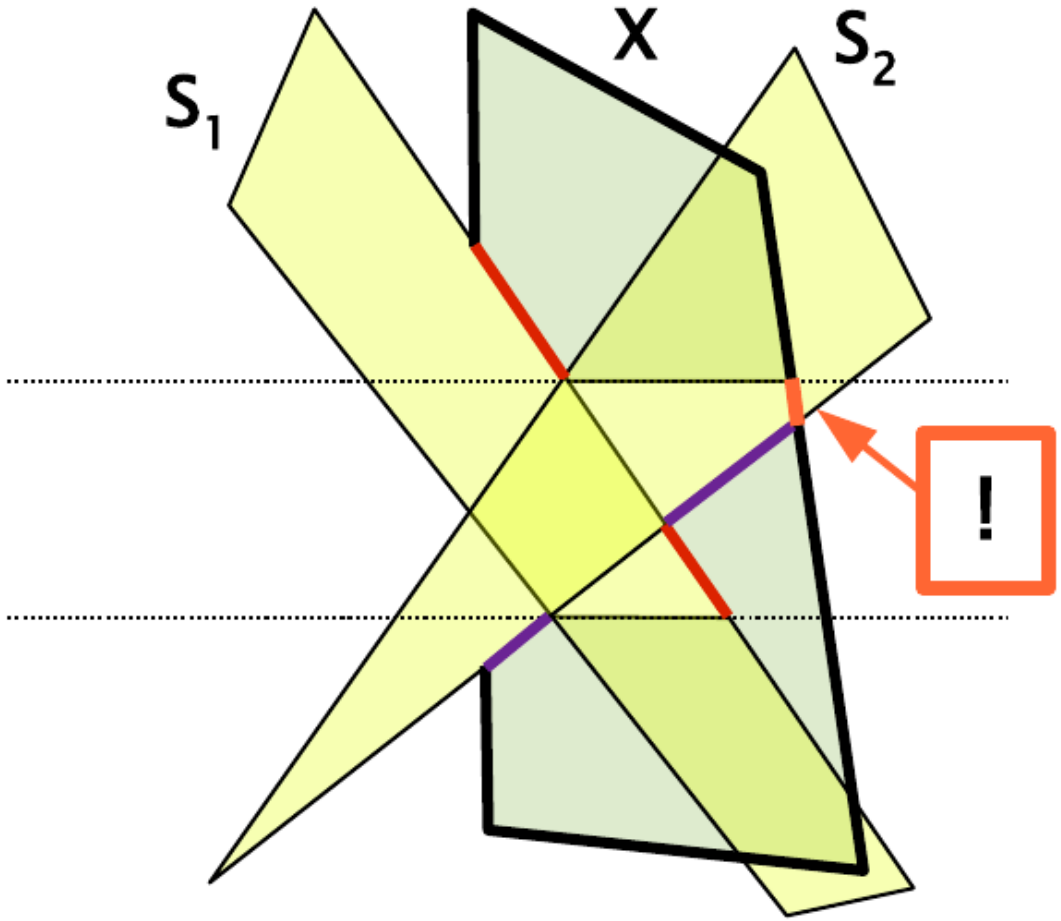




SUBTRACTION – RESULT

$X - S_1 - S_2 - S_1$





COMPLETELY SUBTRACETED PARTS

- removing parts of common intersection, which were eliminated completely
- passing through all intersection solids (back faces only – looking for empty results)
- elimination of completely subtracted parts

Merging products and final rendering

- product result = its depth buffer
- merging results of one product (i.e. union operation)
- intersections render front faces
- subtractions render back faces