Combining SDFs in a single draw call

https://github.com/PsychedelicOrange/byoe/pull/10

- Phani Srikar

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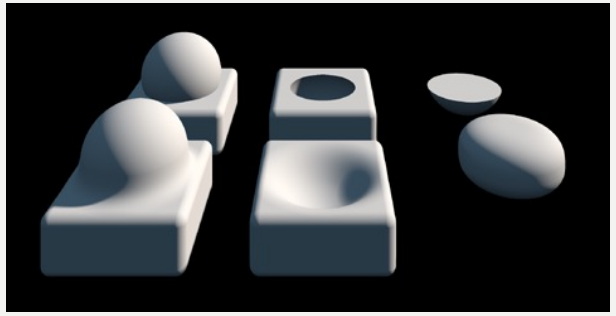
INTRO: Terminology

- **Primitives:** single SDF function drawn in a single draw call.
- **Object:** Made of one or more Primitives/Objects, more complex structure to combing primitives and complex SDF shapes in a single draw call.
  - Stores a binary hierarchy of node references and combines them using the blend operation

Primitives



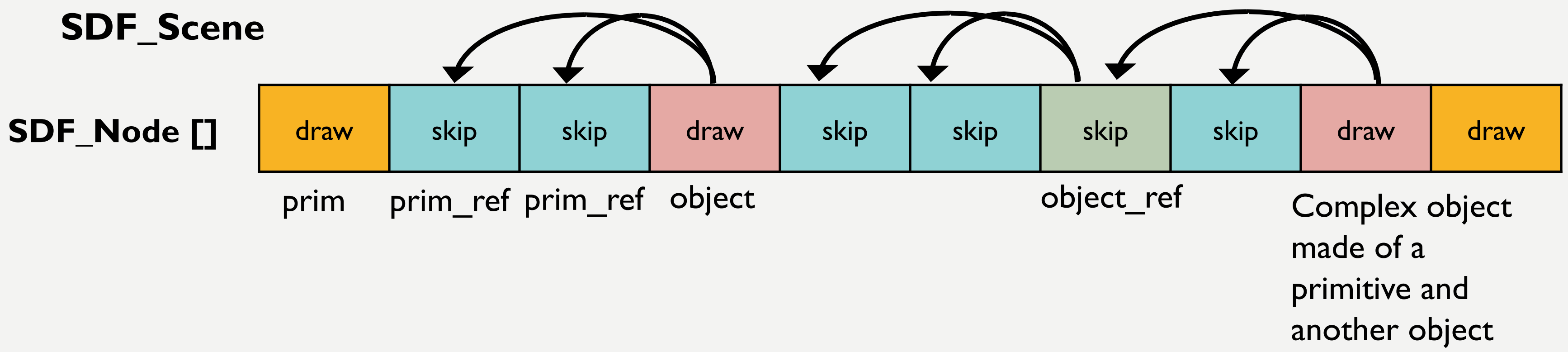
Objects made of one or more primitives/objects

```
typedef struct SDF_Primitive {
    SDF_PrimitiveType type;
    Transform transform;
    SDF_Material material;
} SDF_Primitive;
```

```
typedef struct SDF_Object {
    SDF_BlendType type;
    int prim_a;
    int prim_b;
} SDF_Object;
```

Scene storage: CPU

- Scene stores a linear hierarchy of nodes (primitives/objects) on the CPU, this is uploaded to the GPU
  - Those marked as ref nodes will be skipped from direct draw calls
  - Ref nodes are used for combining nodes of an object using the blend functions from within the raymarching shader

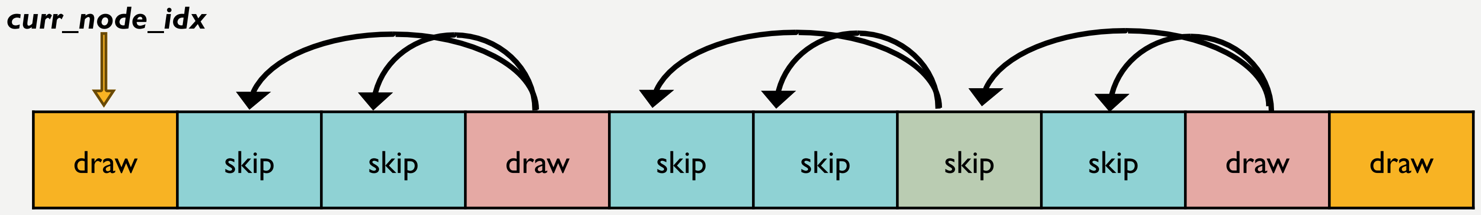


```
typedef enum SDF_NodeType
{
    SDF_NODE_PRIMITIVE,
    SDF_NODE_OPERATION
} SDF_NodeType;

typedef struct SDF_Node
{
    SDF_NodeType type;
    union
    {
        SDF_Primitive primitive;
        SDF_Object operation;
    };
    bounding_sphere bounds;
    bool            is_ref_node;
    bool            is_culled;
} SDF_Node;
```

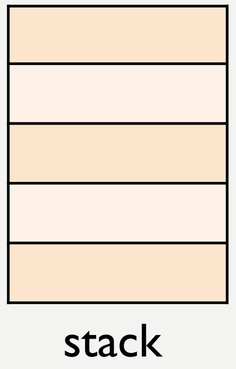
GPU drawing complex SDFs

- Consider the following scene nodes view from the GPU's POV



- **We simulate a stack on GPU** to combing SDFs in a linear fashion
- Let's explore each draw call and GPU shader execution node by node

draw 1: primitive



curr_node_idx:
Tells what node to draw from for the draw call, kind of like bindless access to node data

hit_info:
(global variable outside the while loop) stores the depth and material if the rays hit a surface

Basic ops:
- ***Union:*** *min(a, b)*
- ***Intersection:*** *max(a, b)*
- ***Subtraction:*** *max(a, -b)*
- + Smooth versions of above

Scene SDF Calculation
raymarch this function as usual

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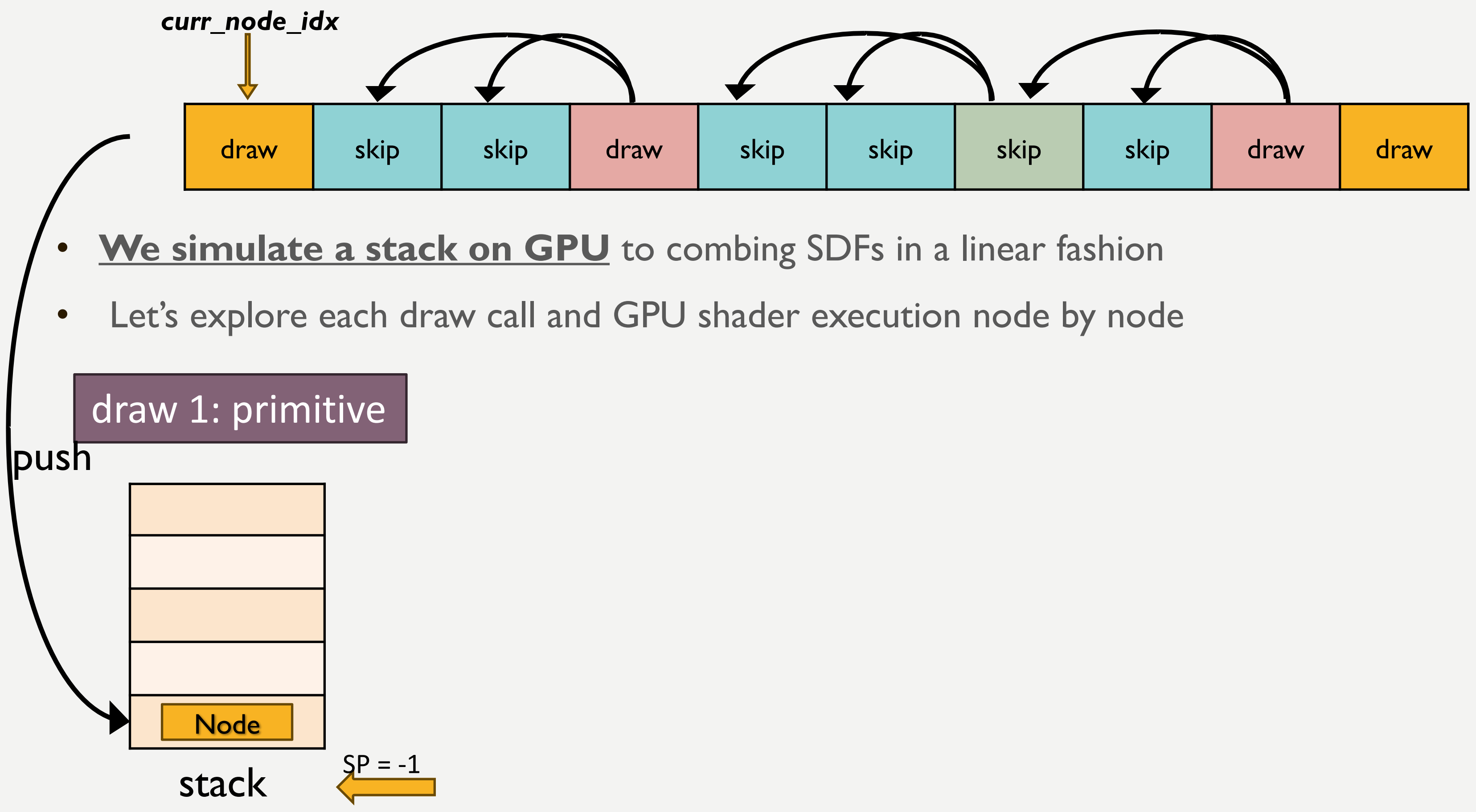

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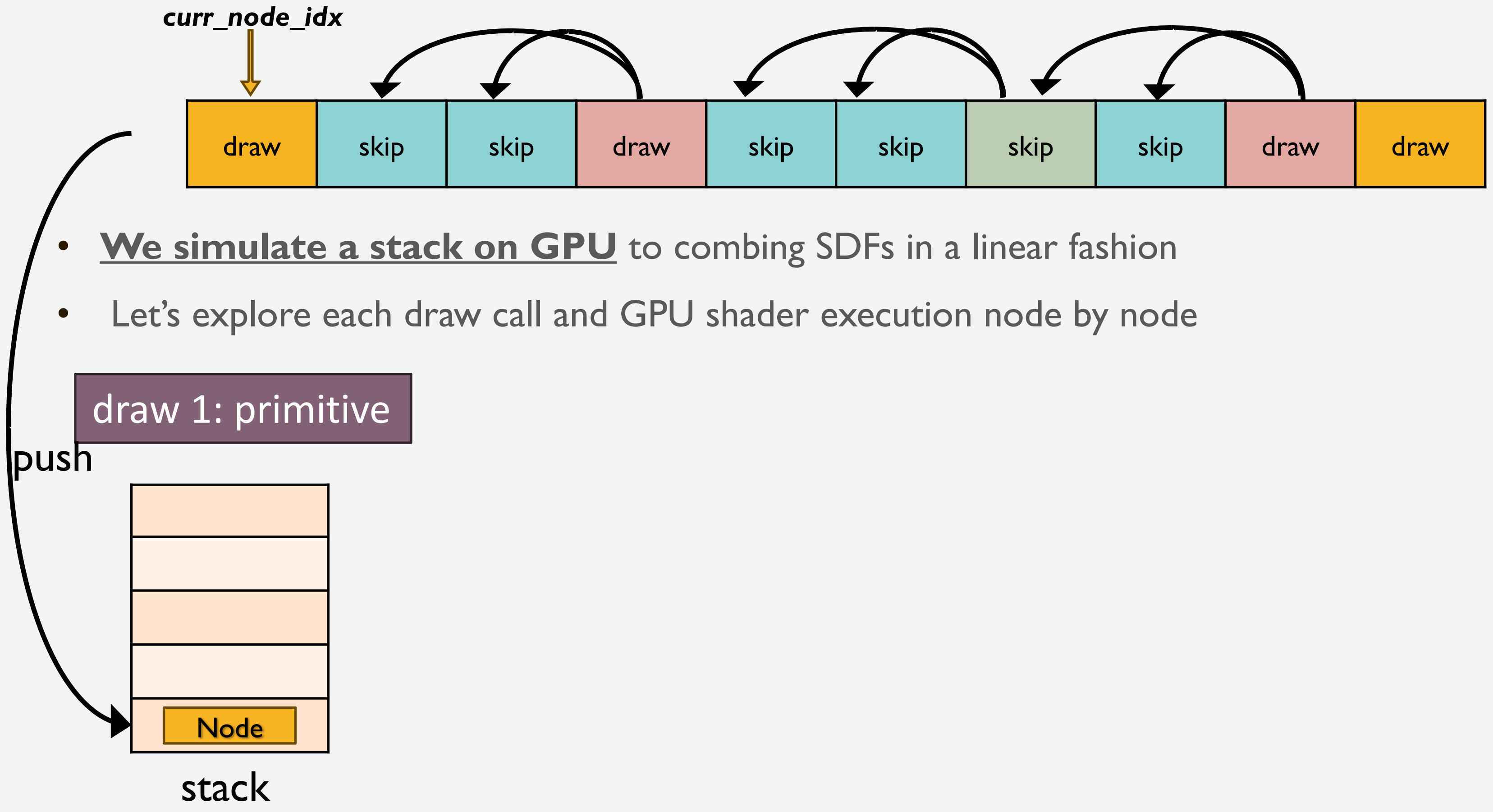

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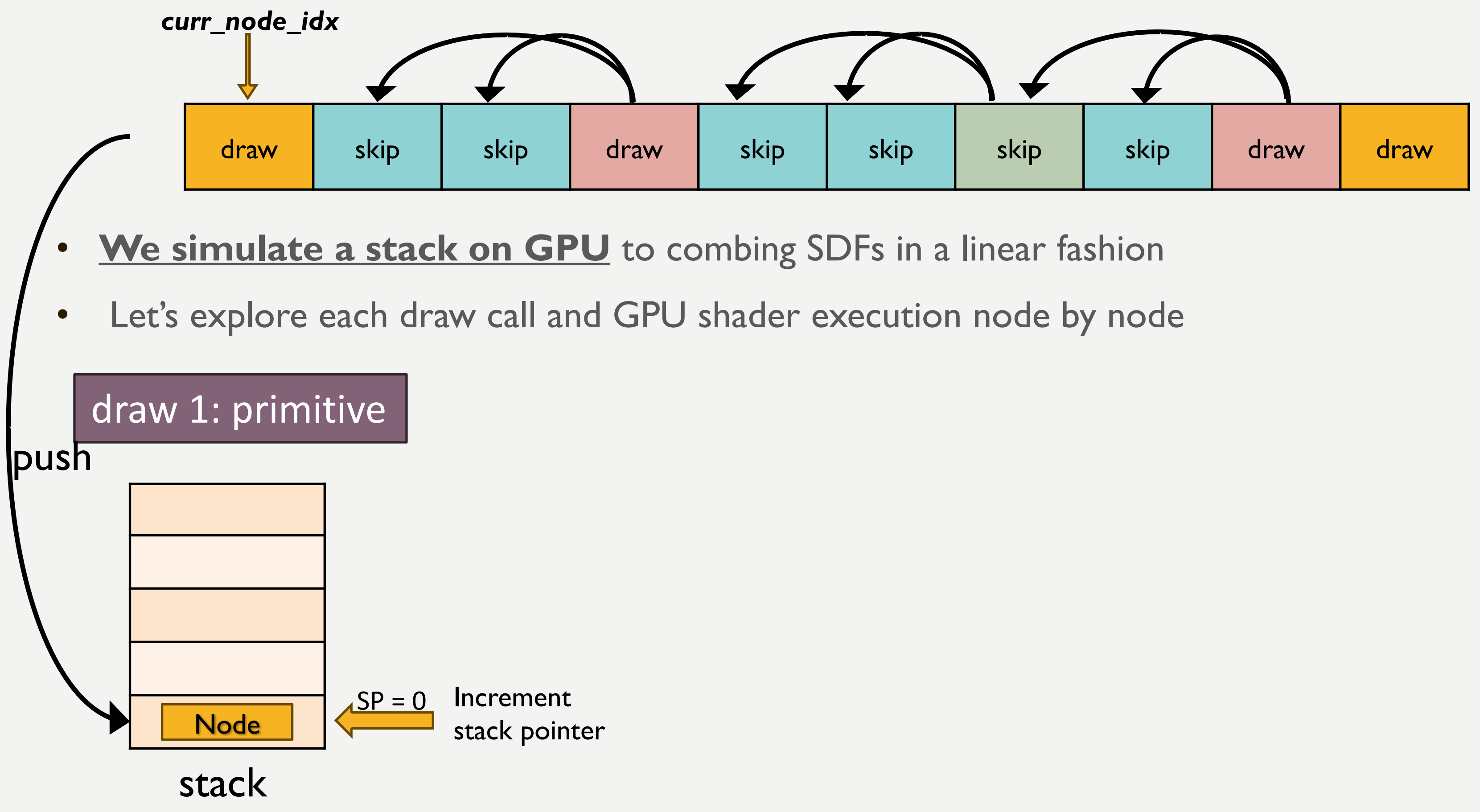

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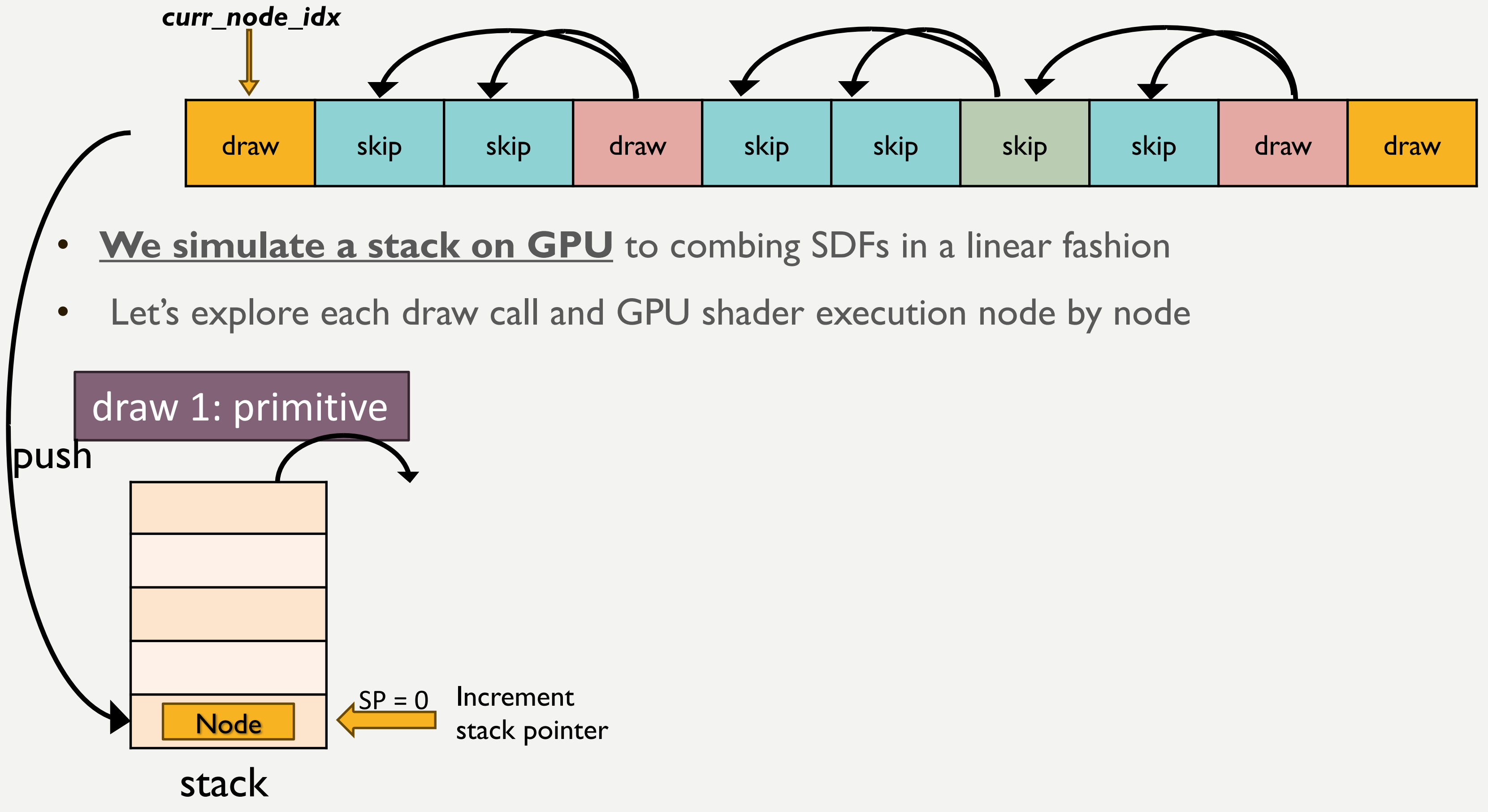

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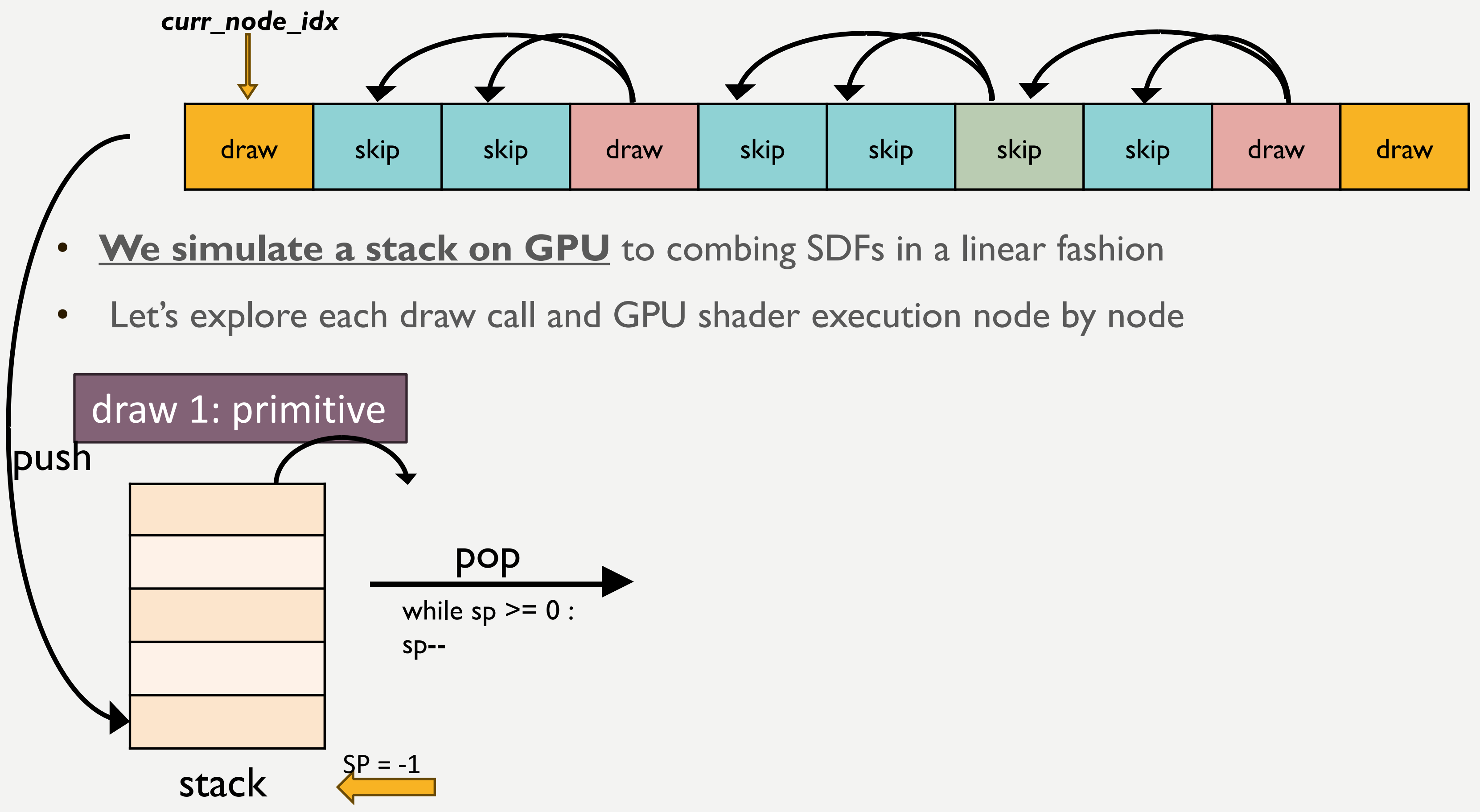

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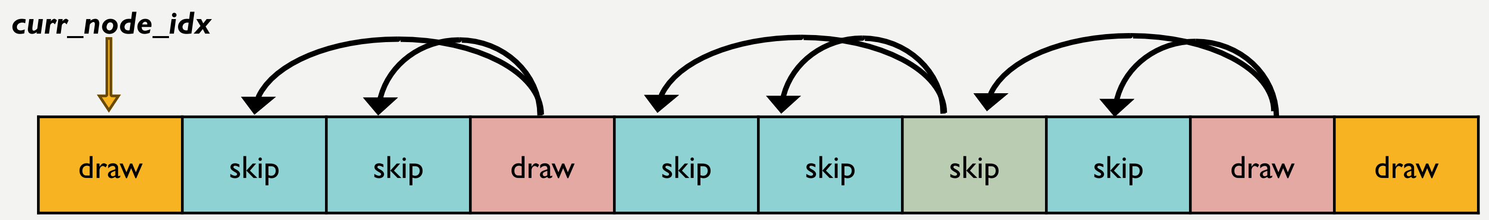

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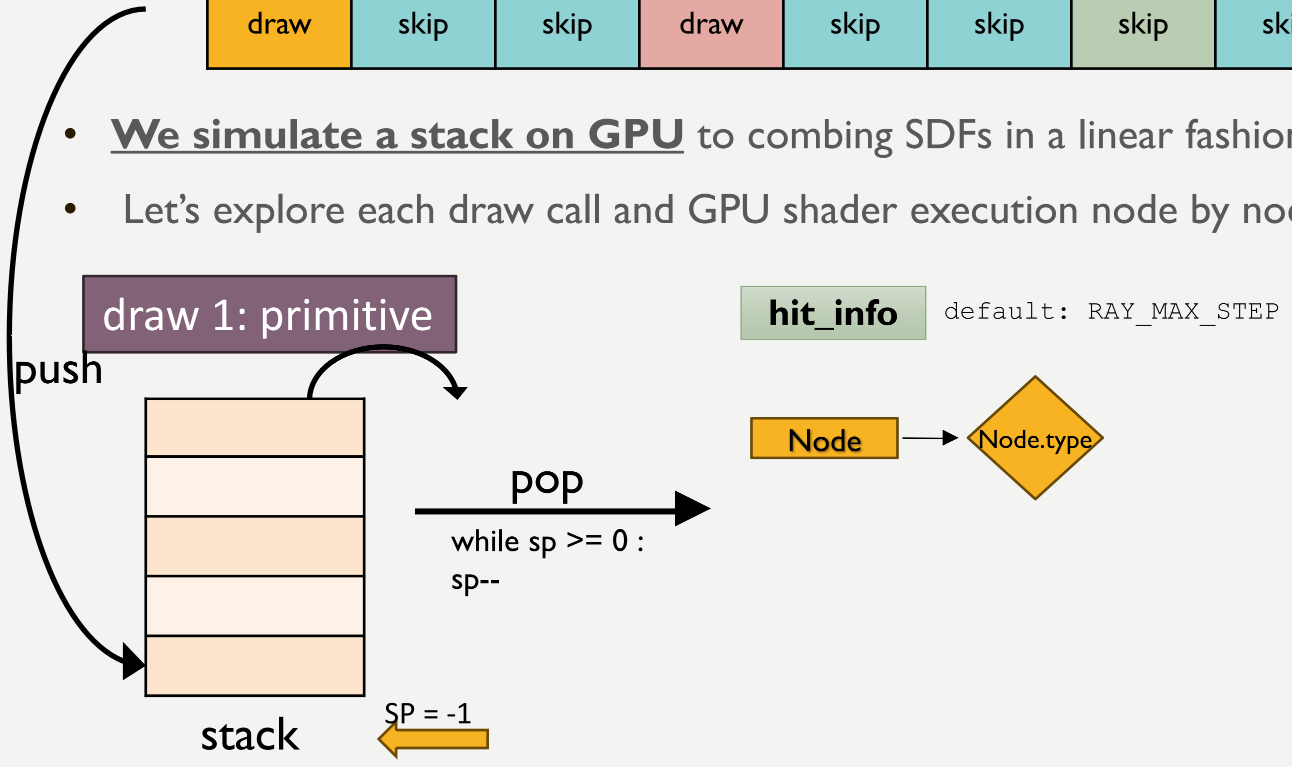

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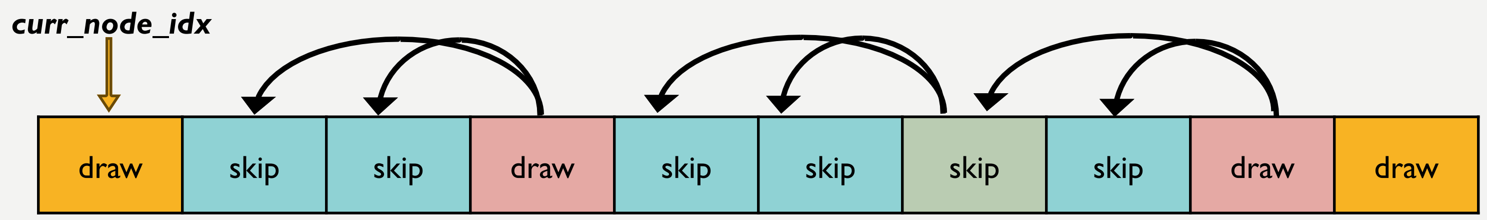

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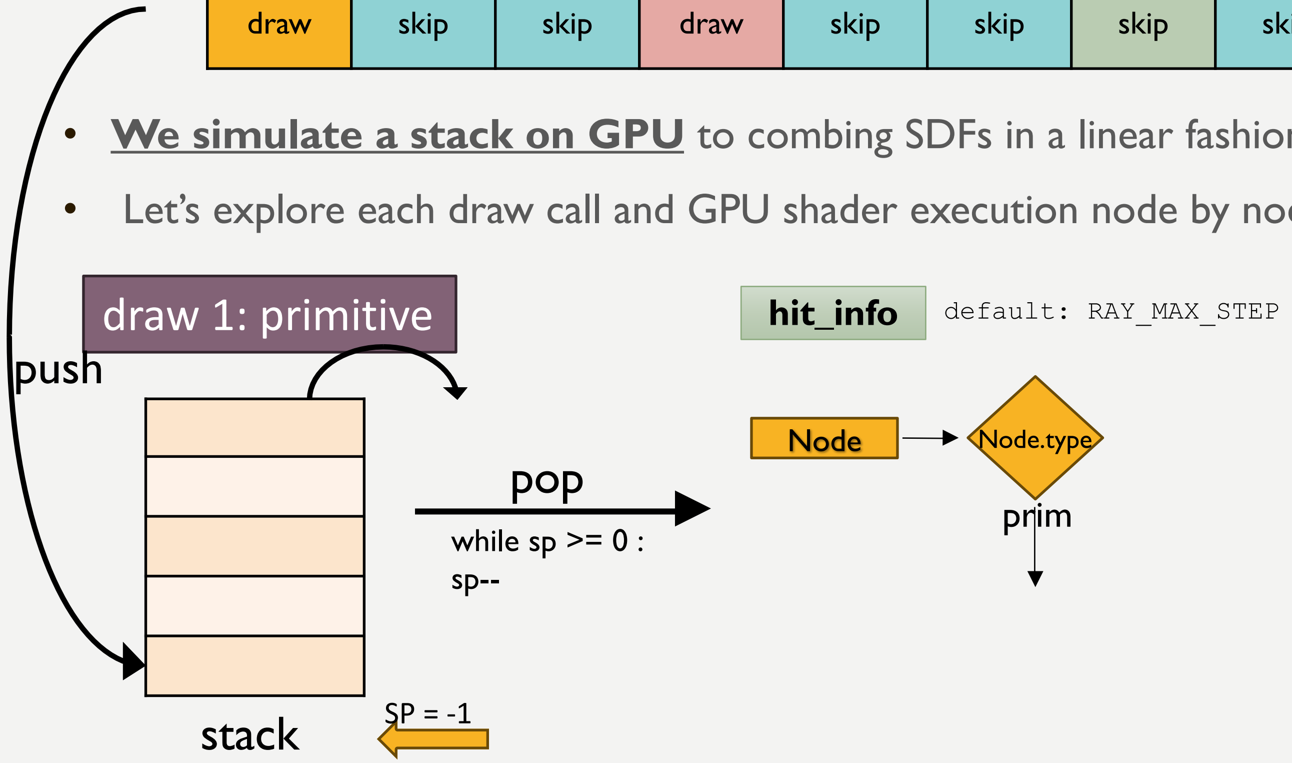

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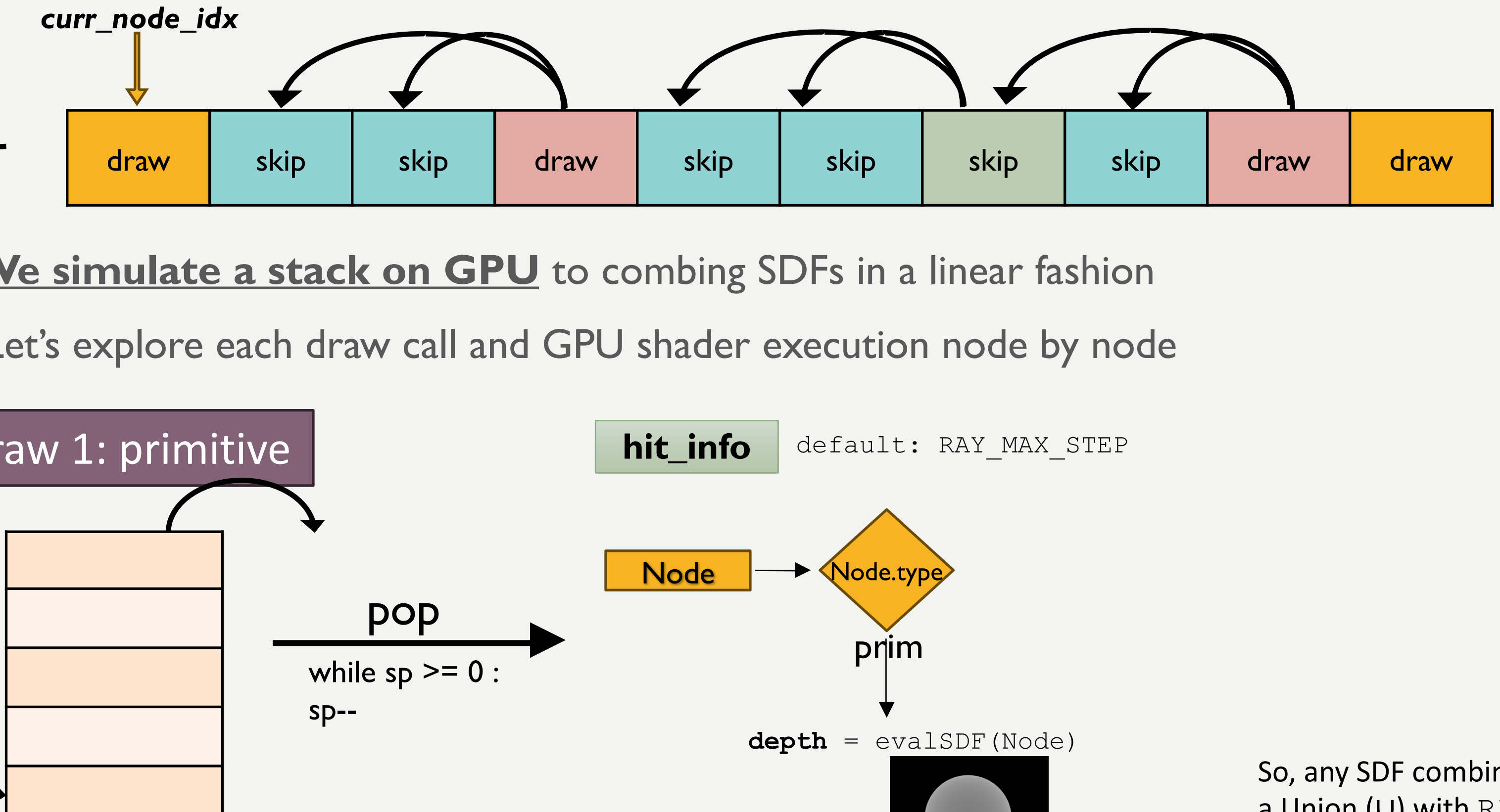

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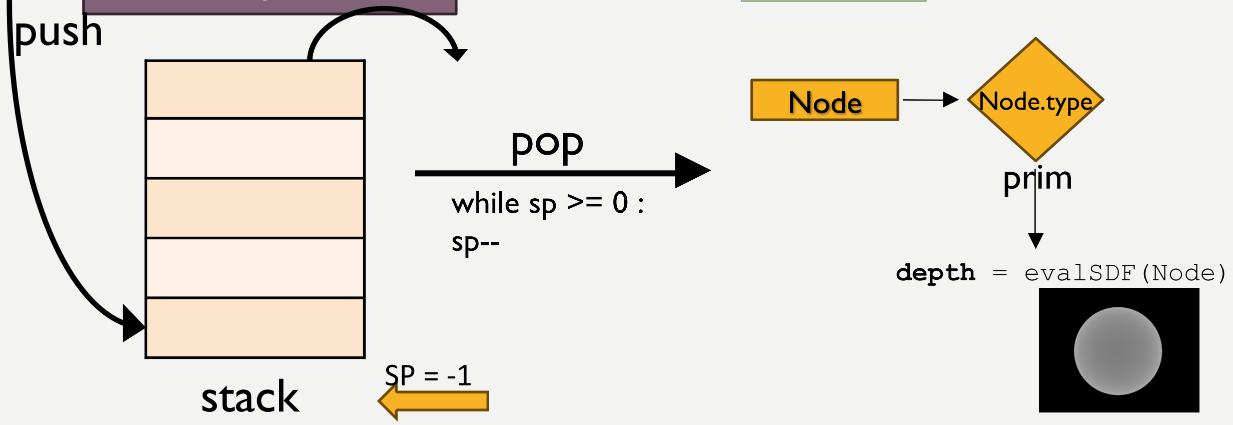

So, any SDF combination starts with a Union (∪) with `RAY_MAX_STEP`, since in this case there's just one, we evaluate and return once sp < 0.

Scene SDF Calculation

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GPU drawing complex SDFs

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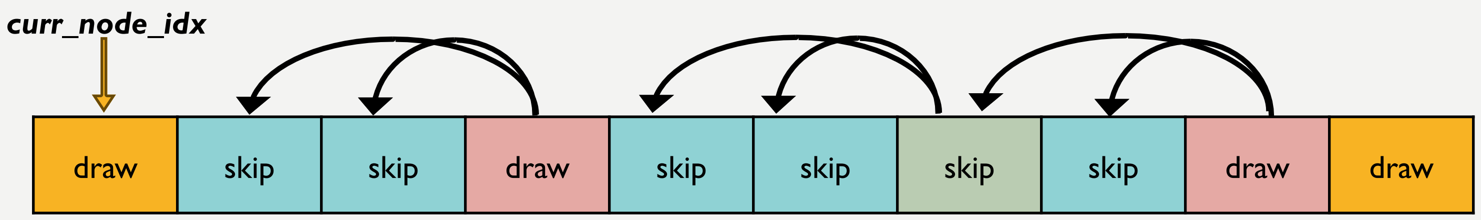

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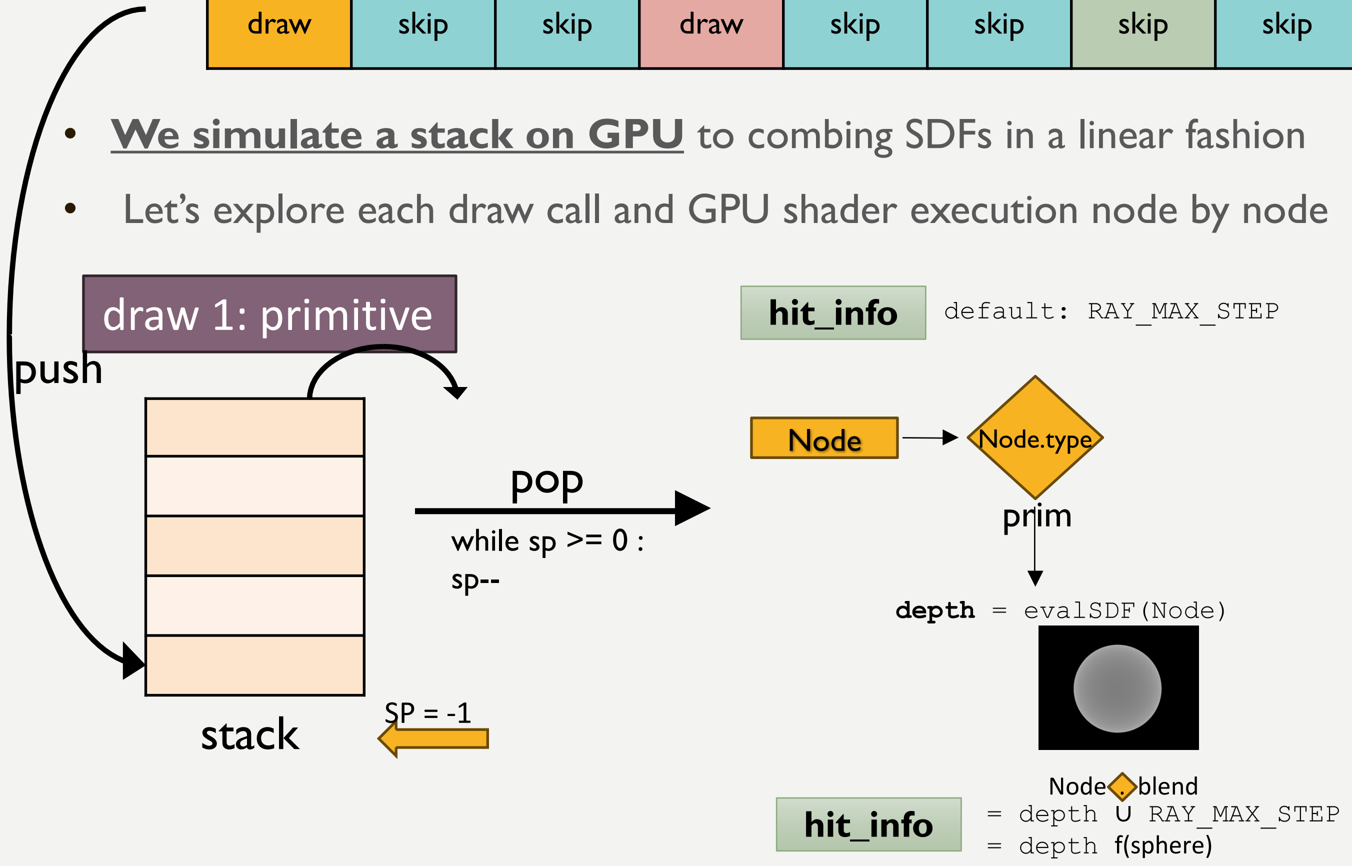

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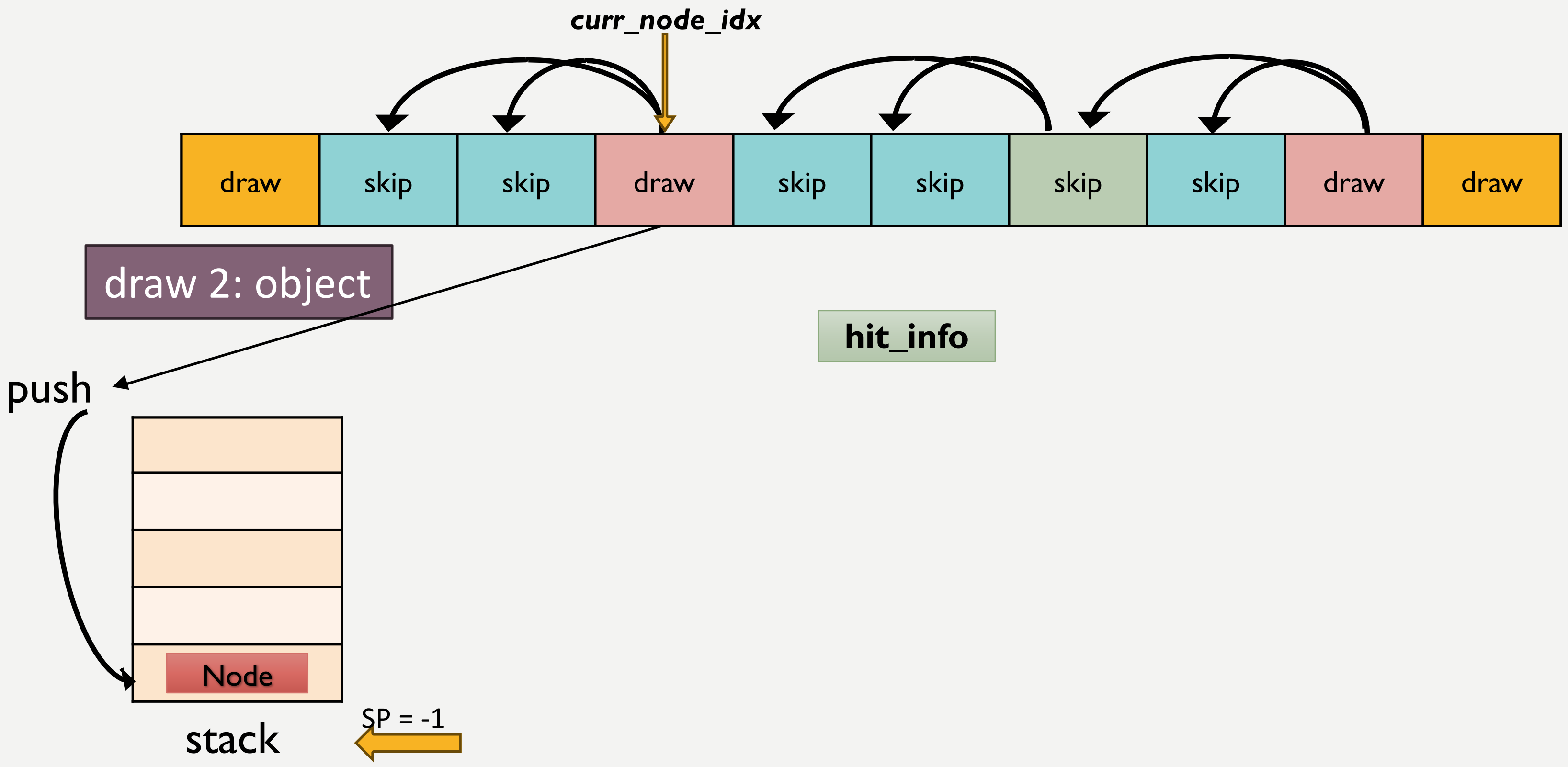

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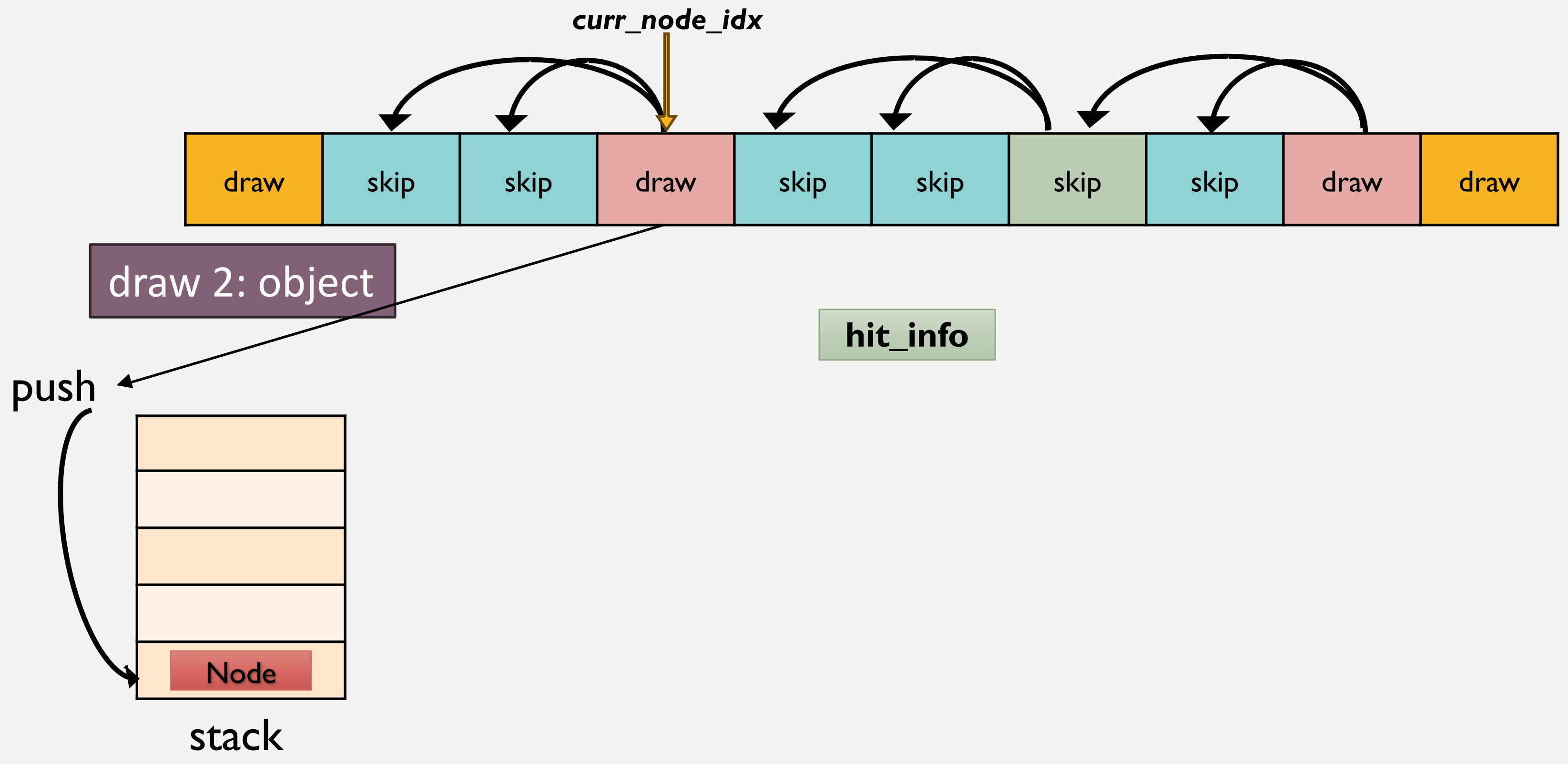

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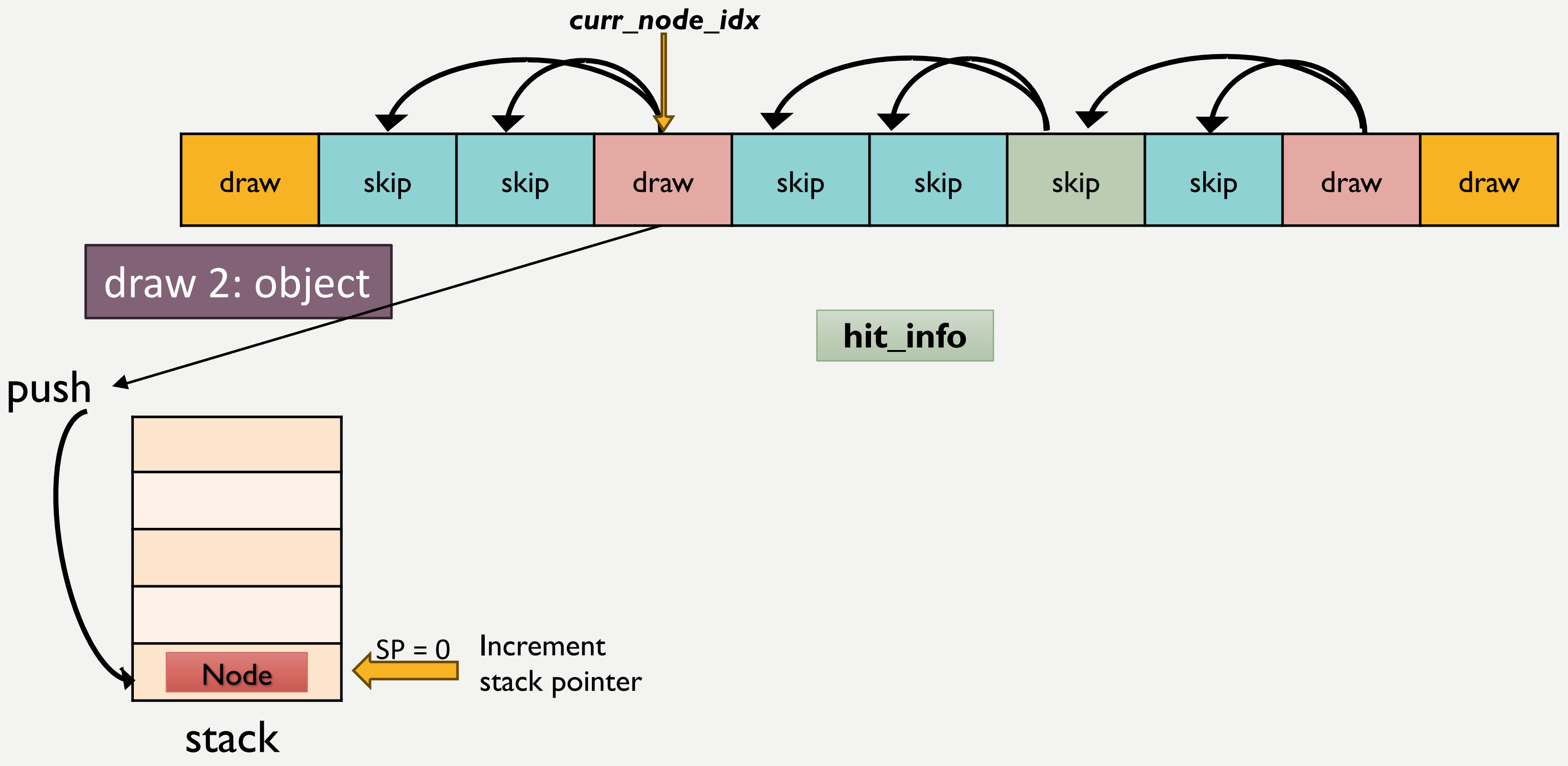

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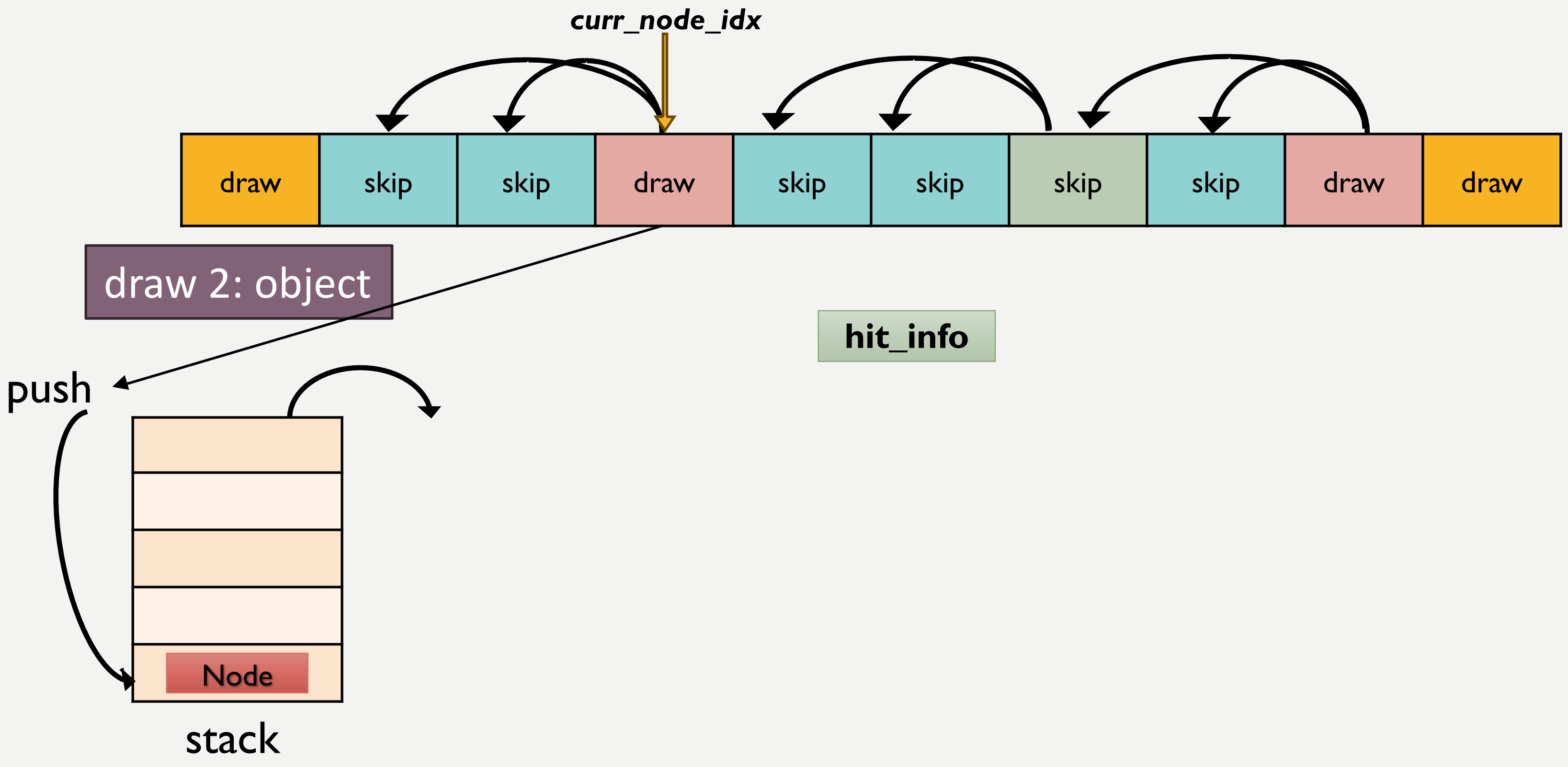

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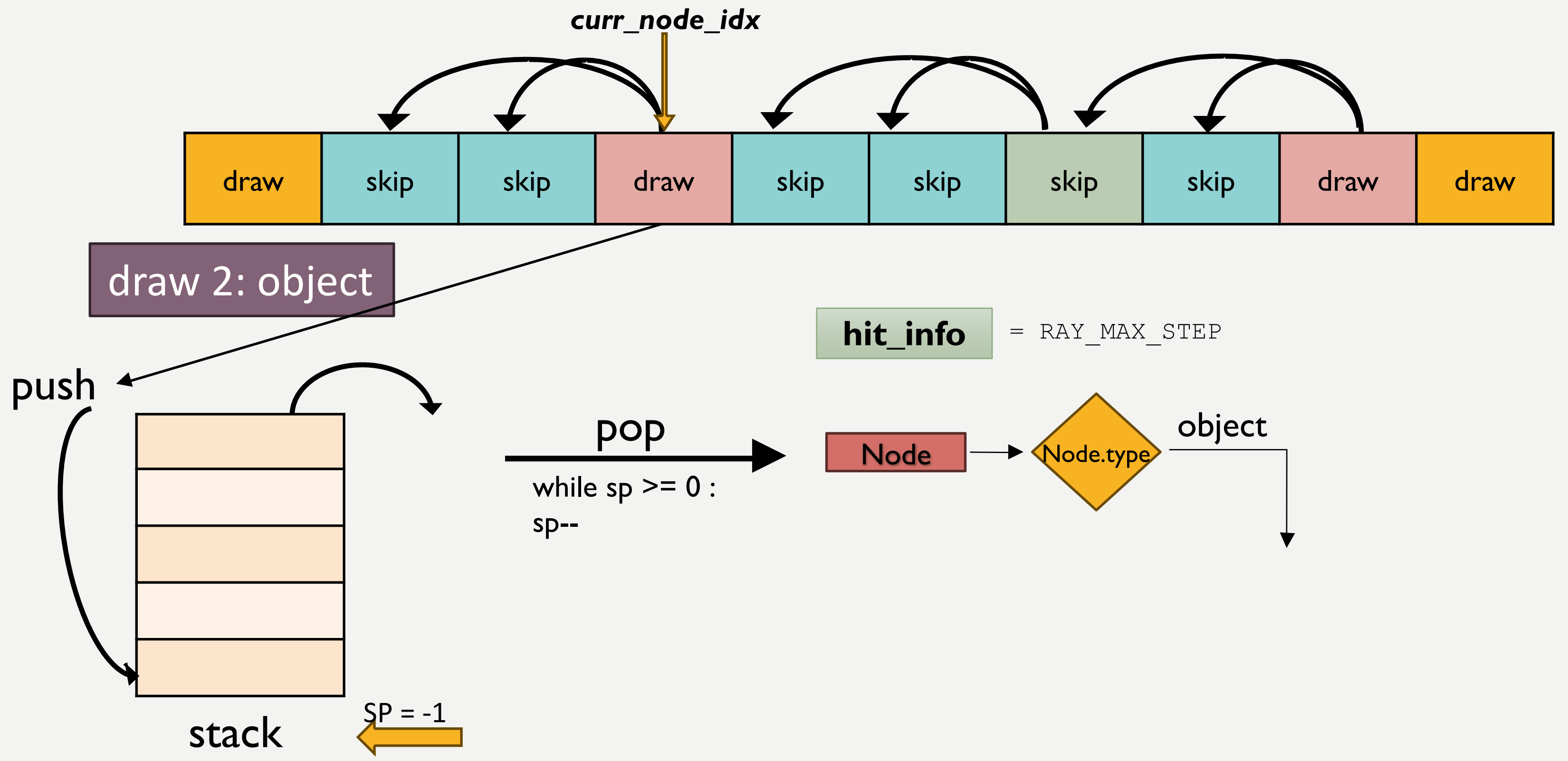

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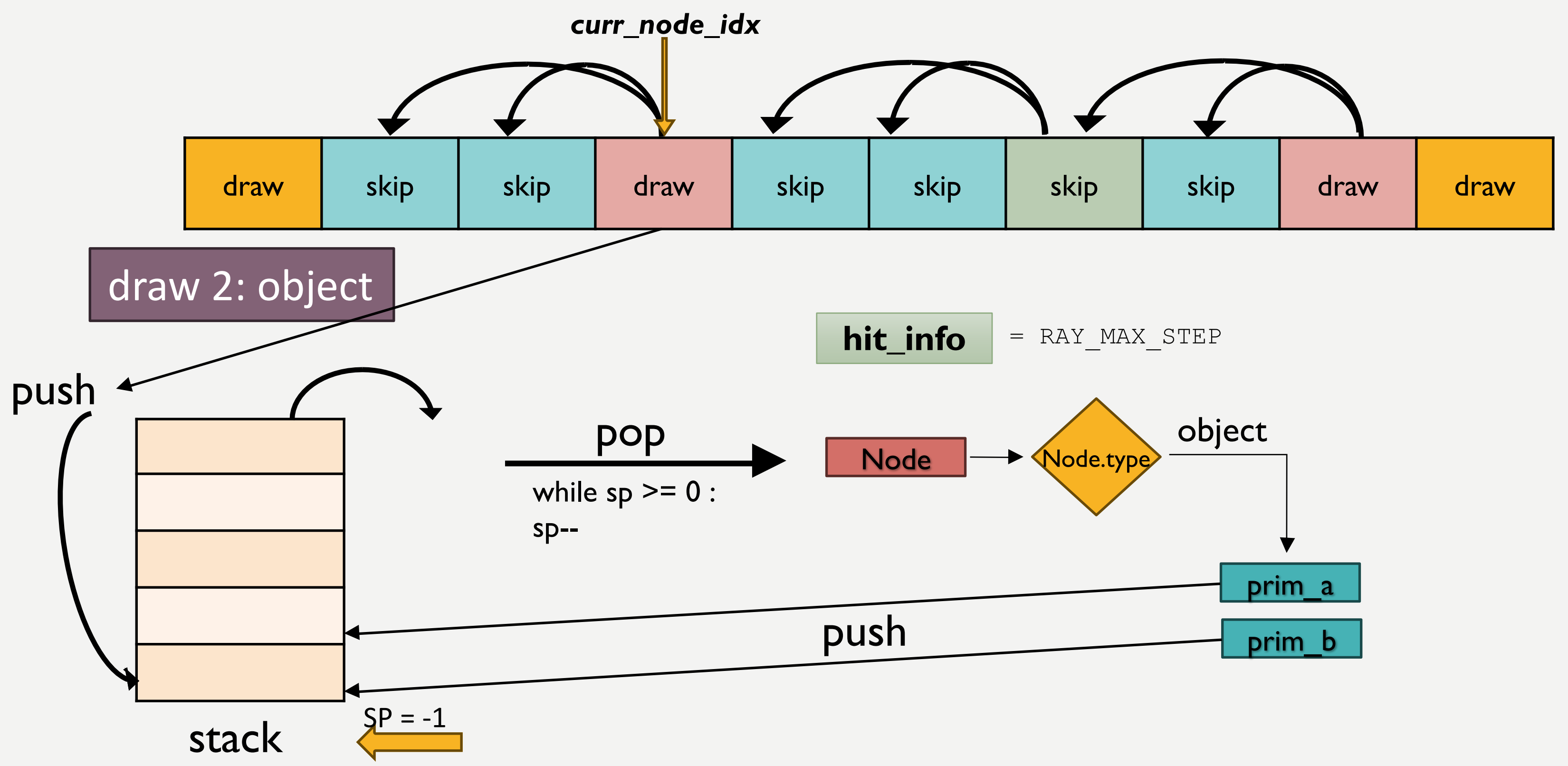

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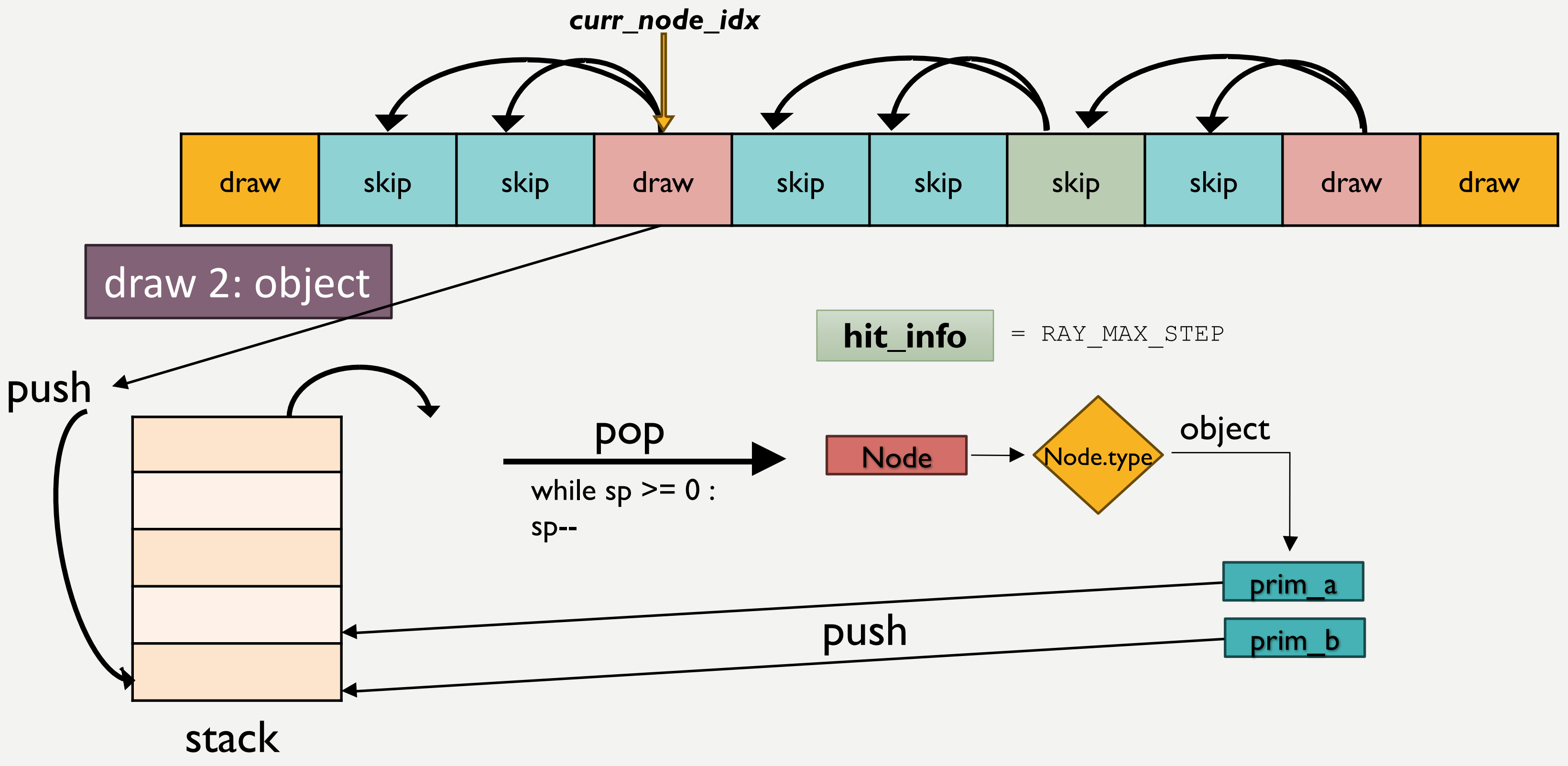

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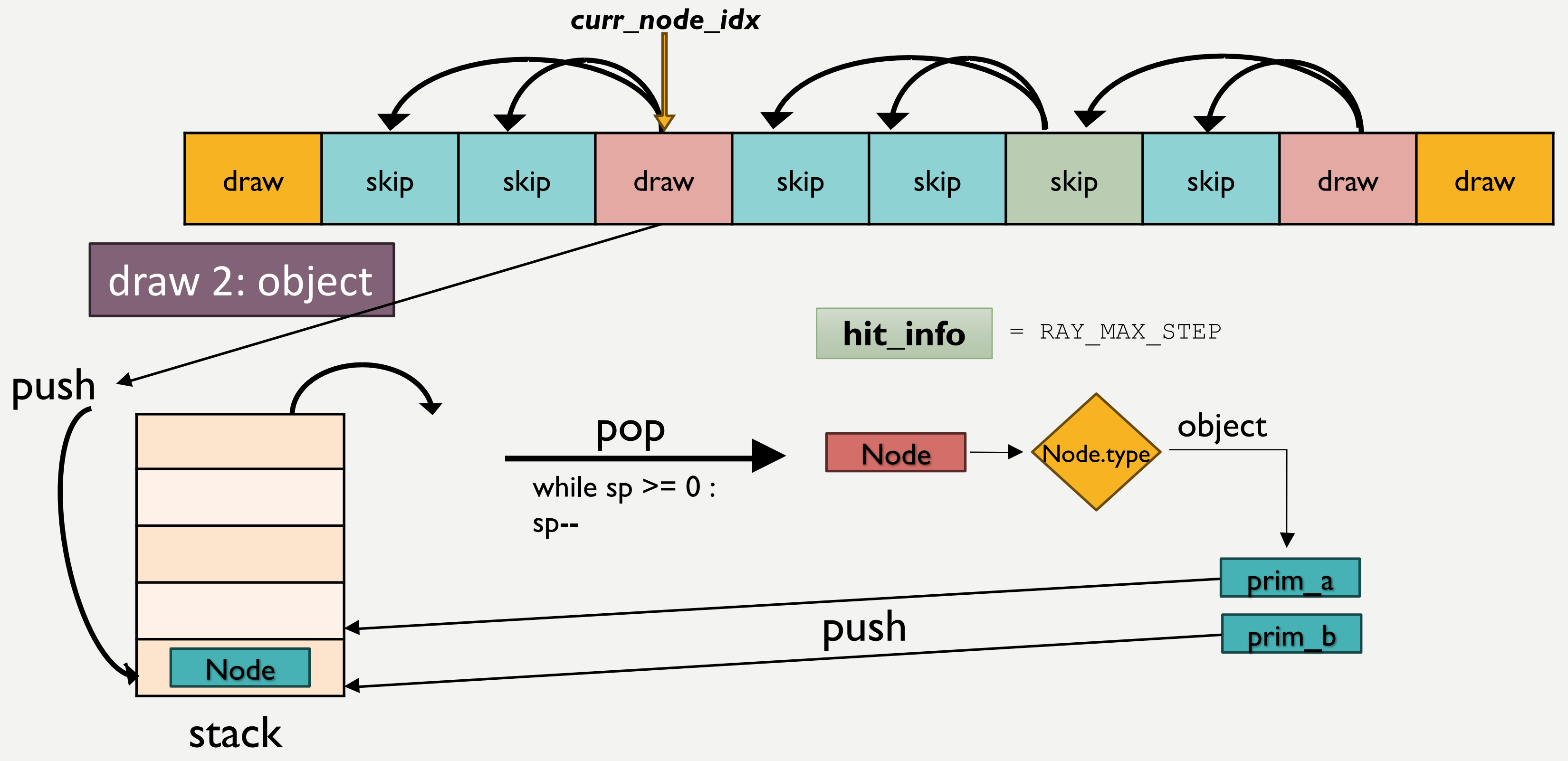

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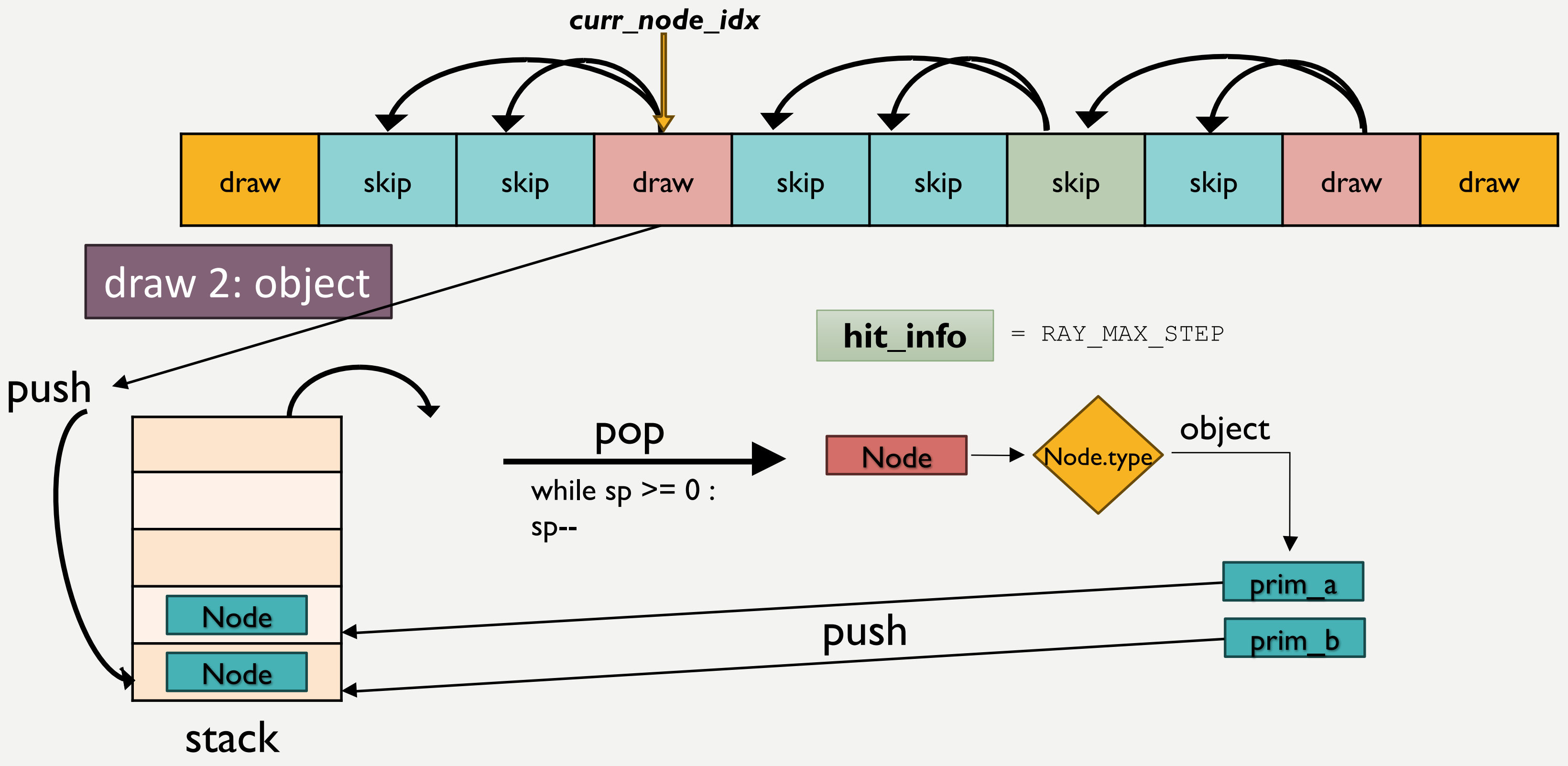

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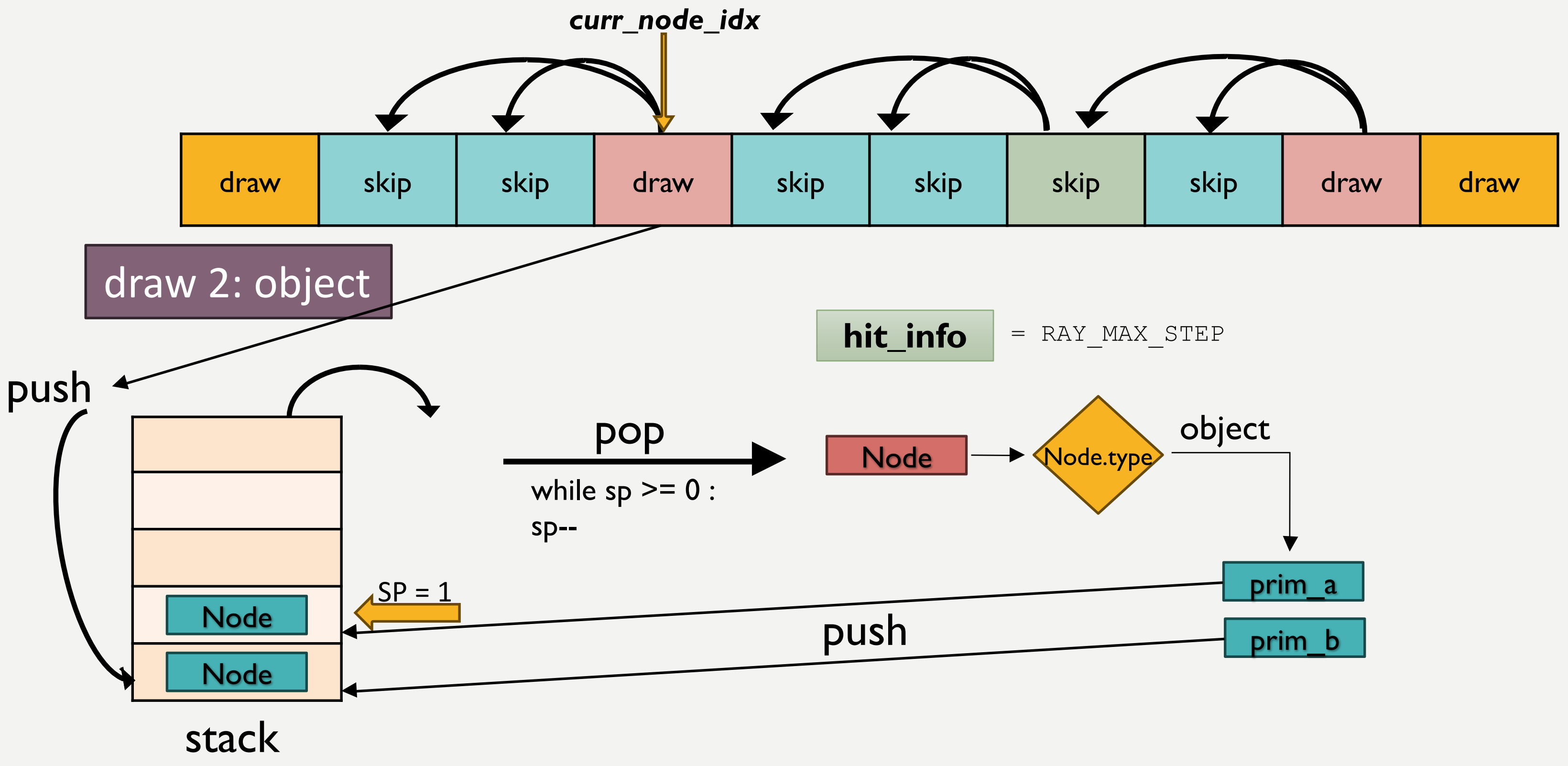

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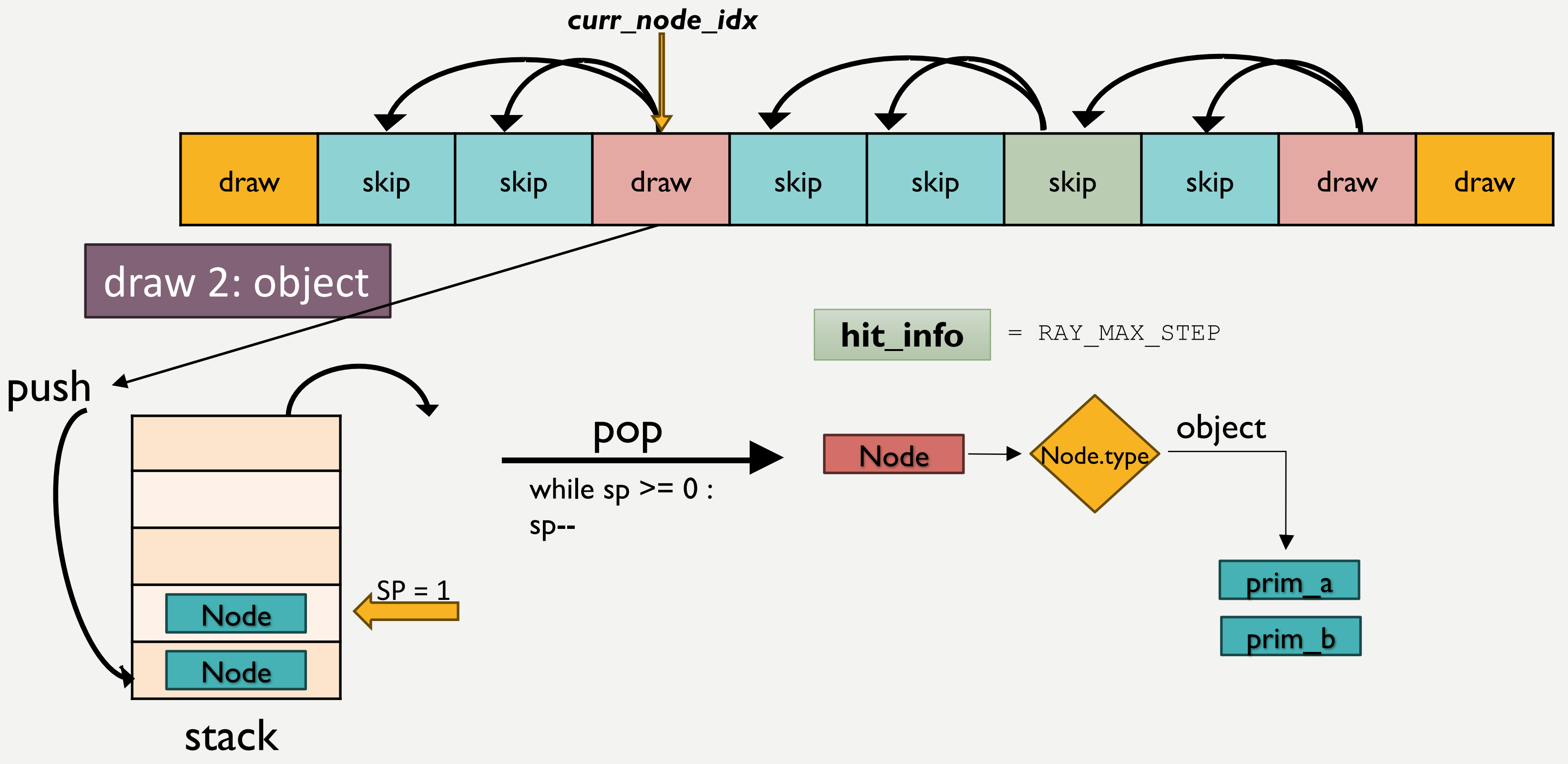

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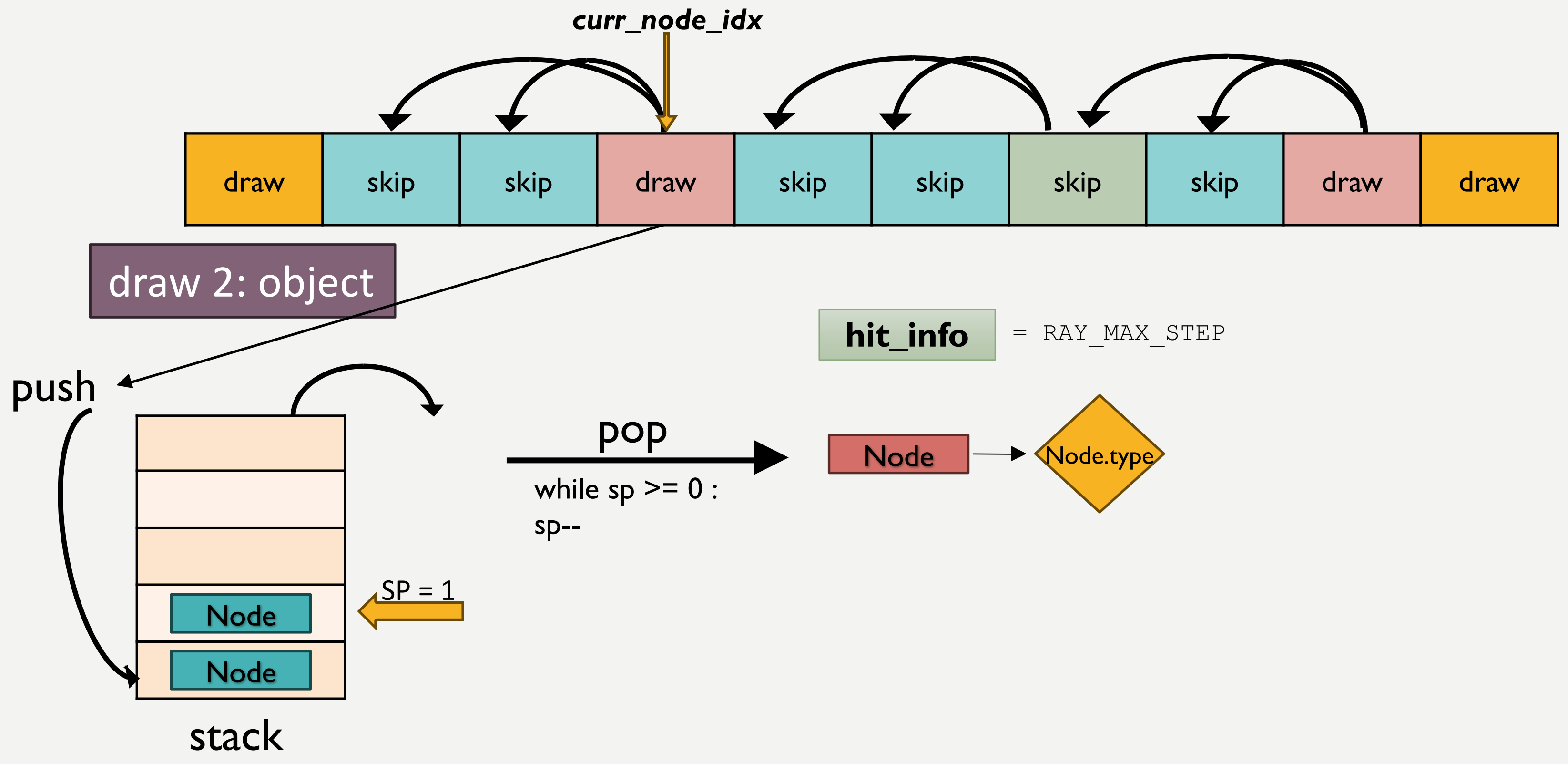

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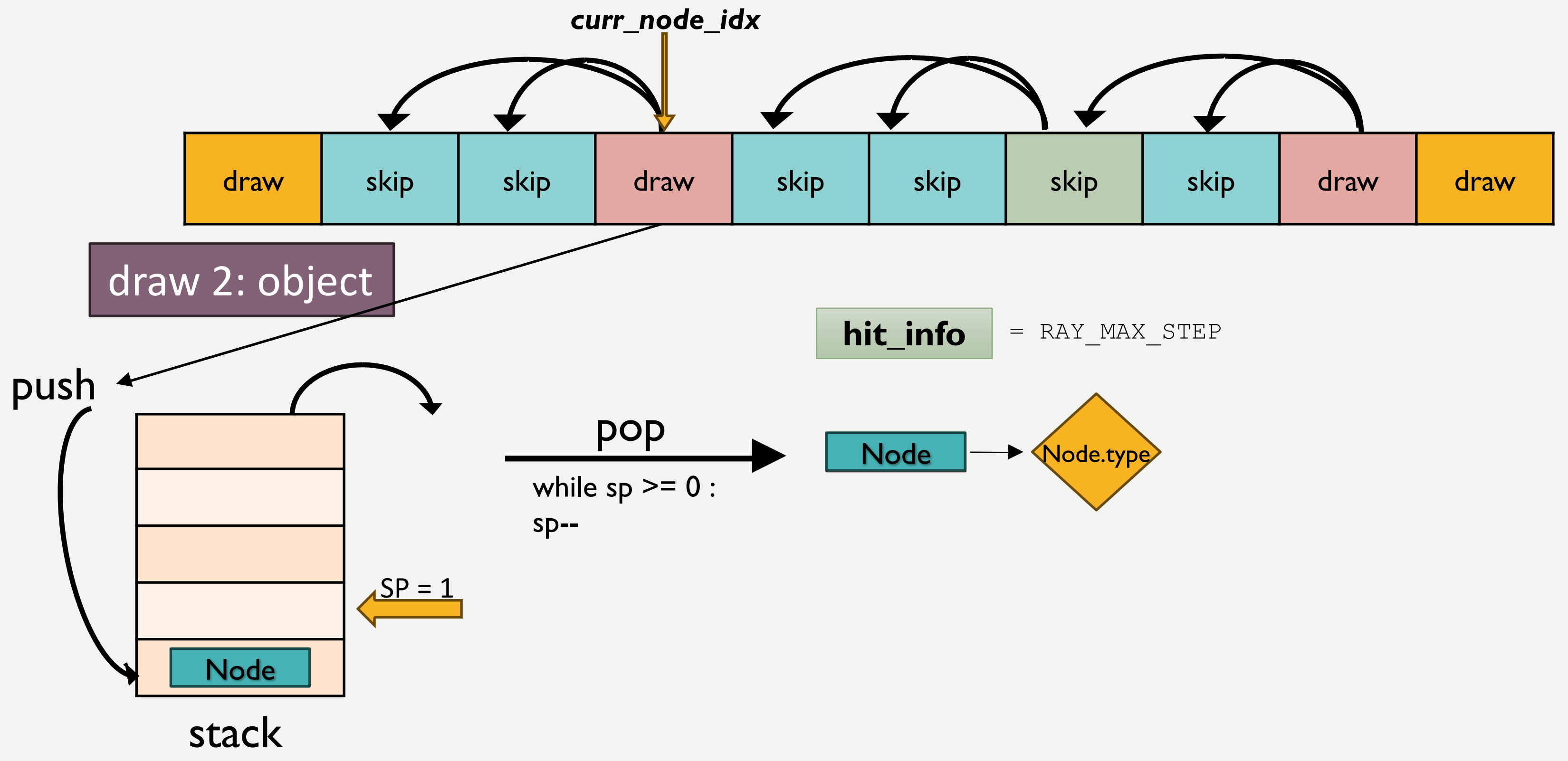

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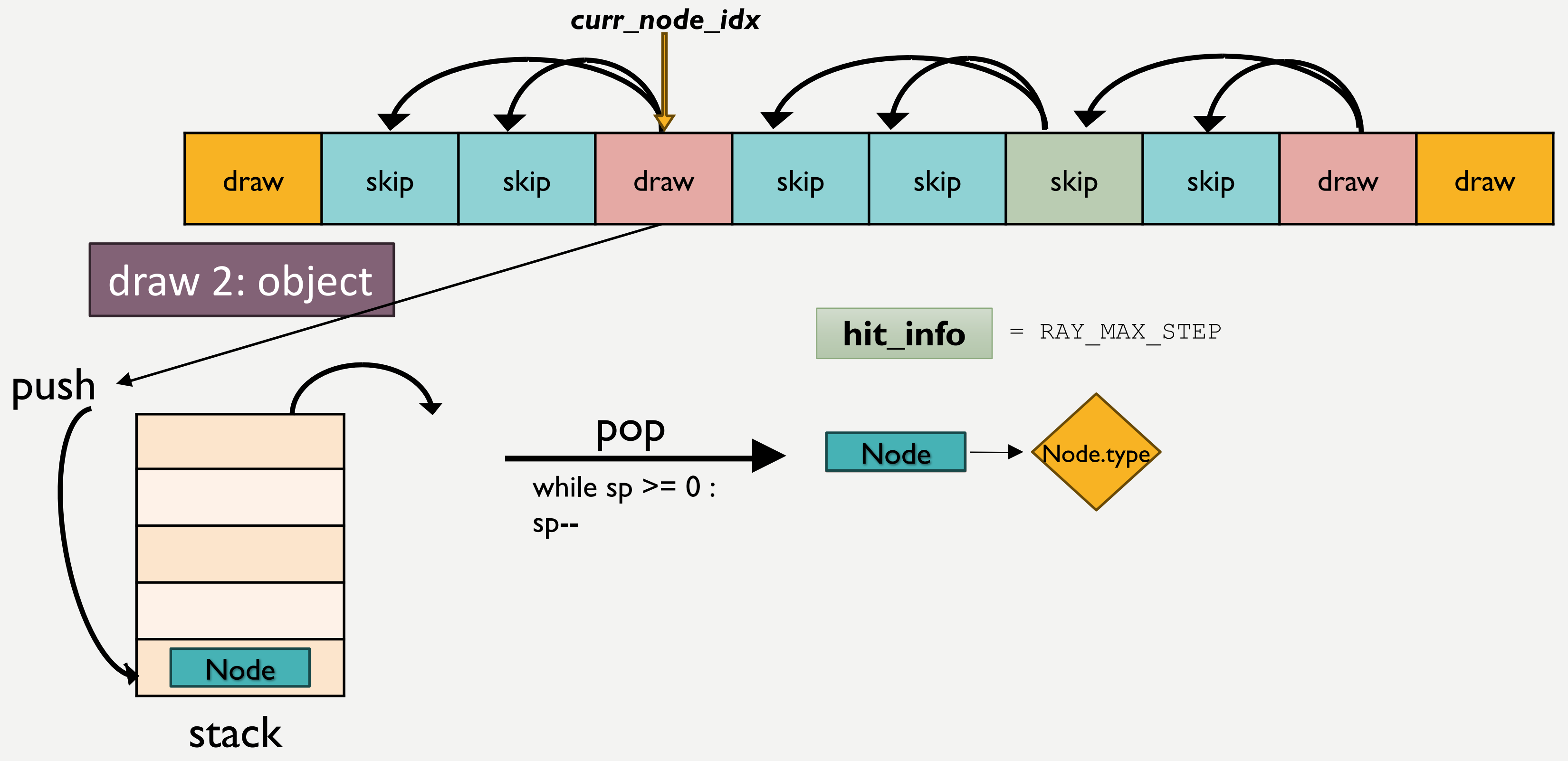

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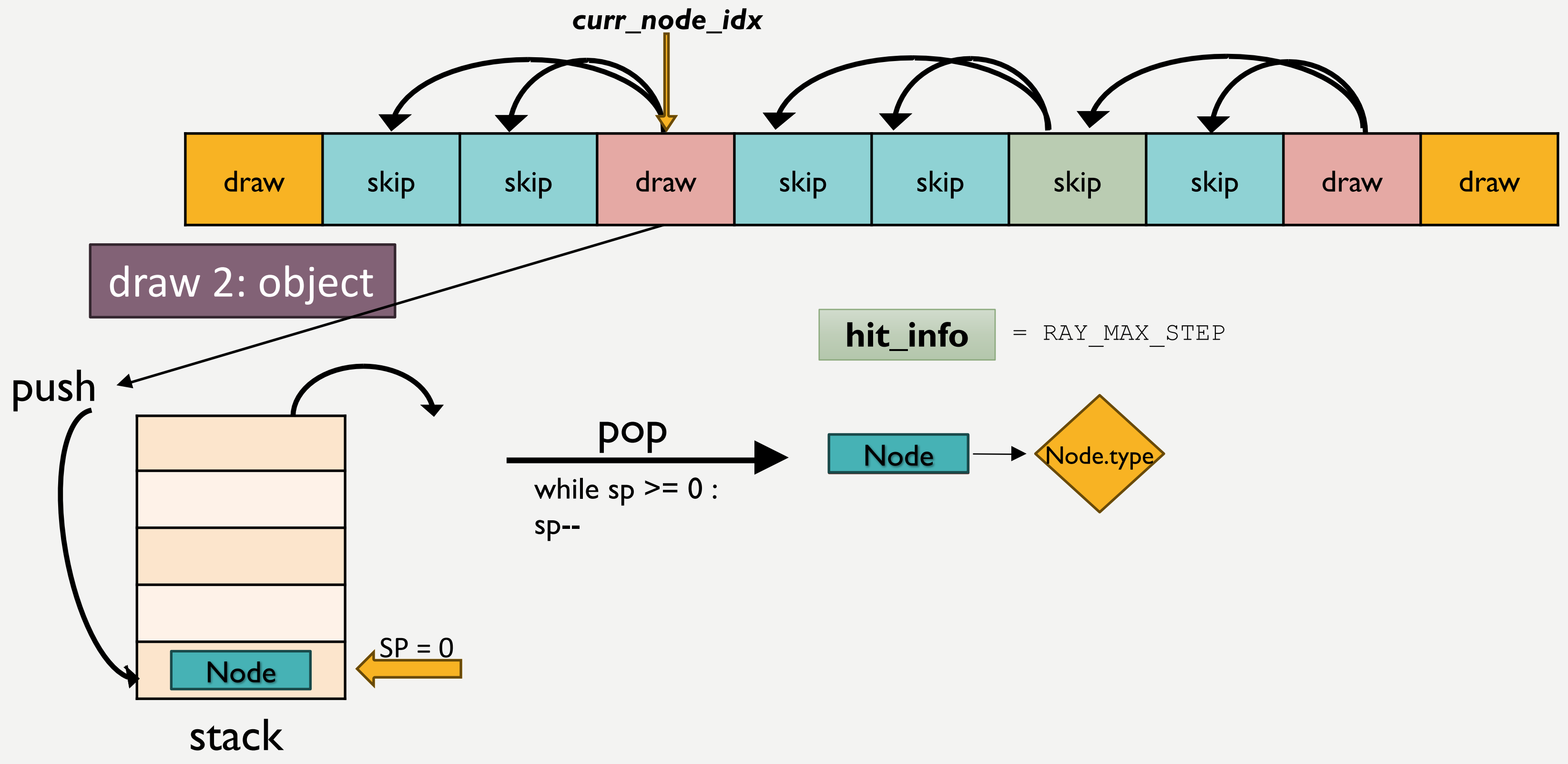

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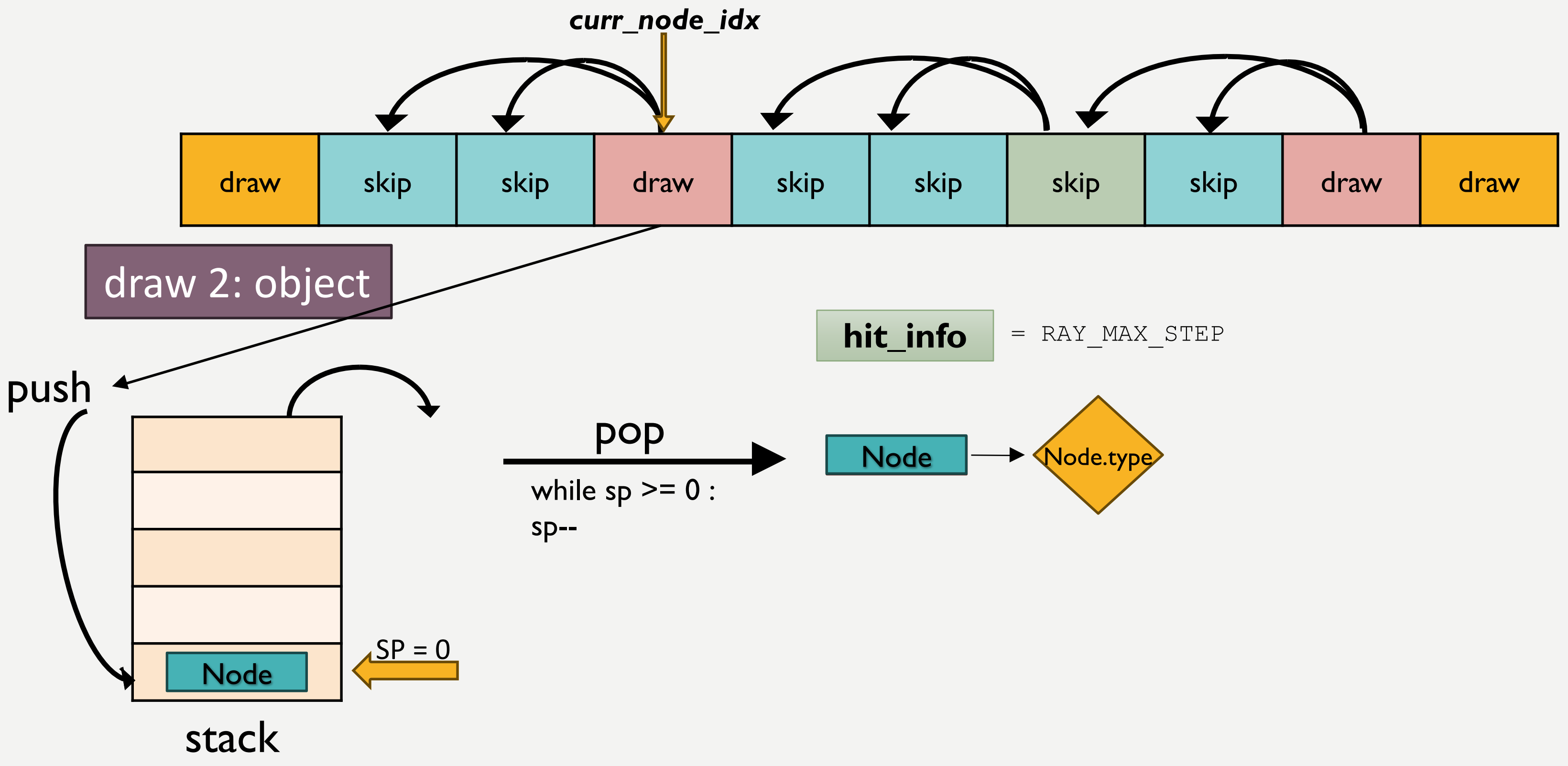

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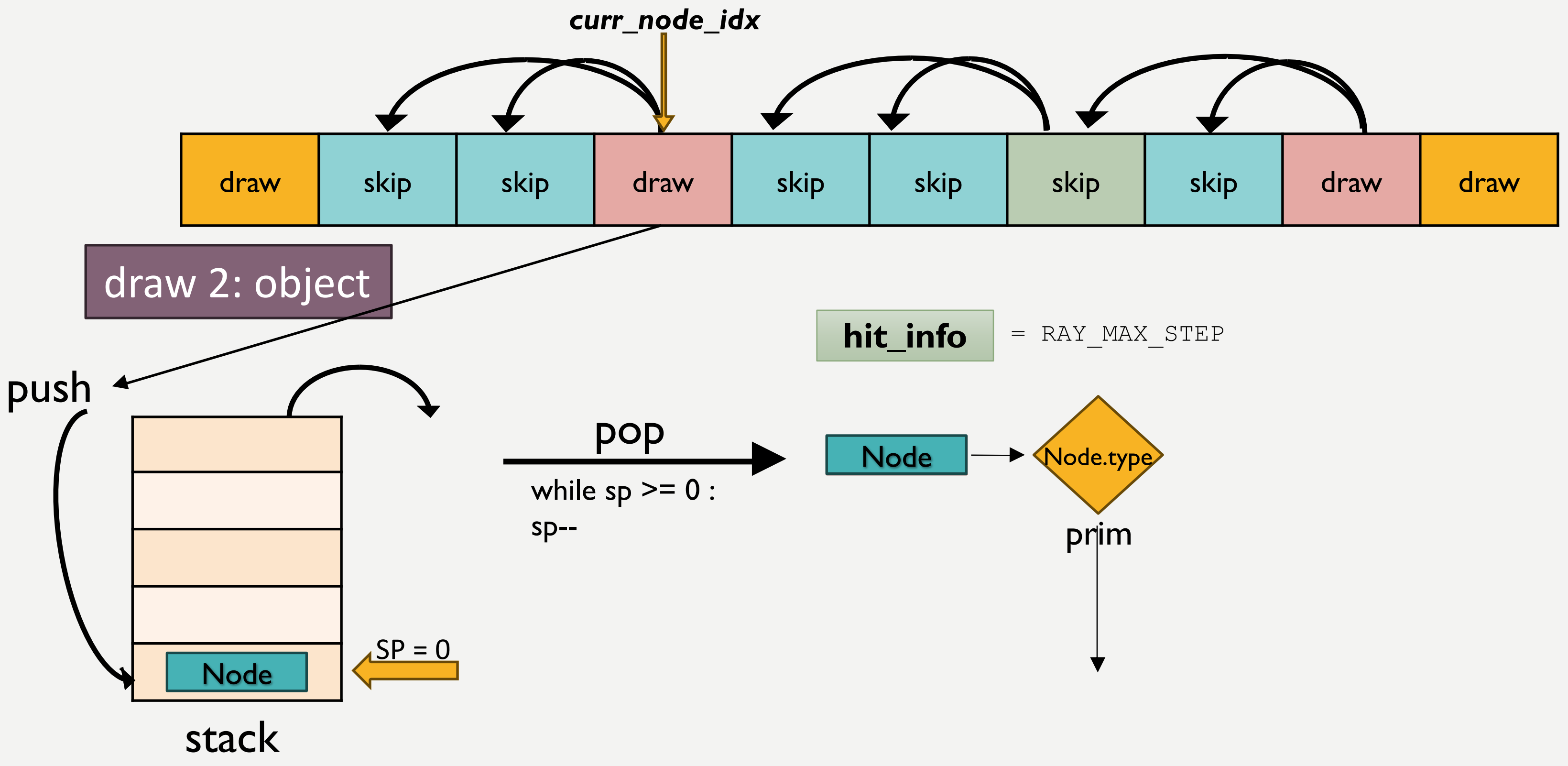

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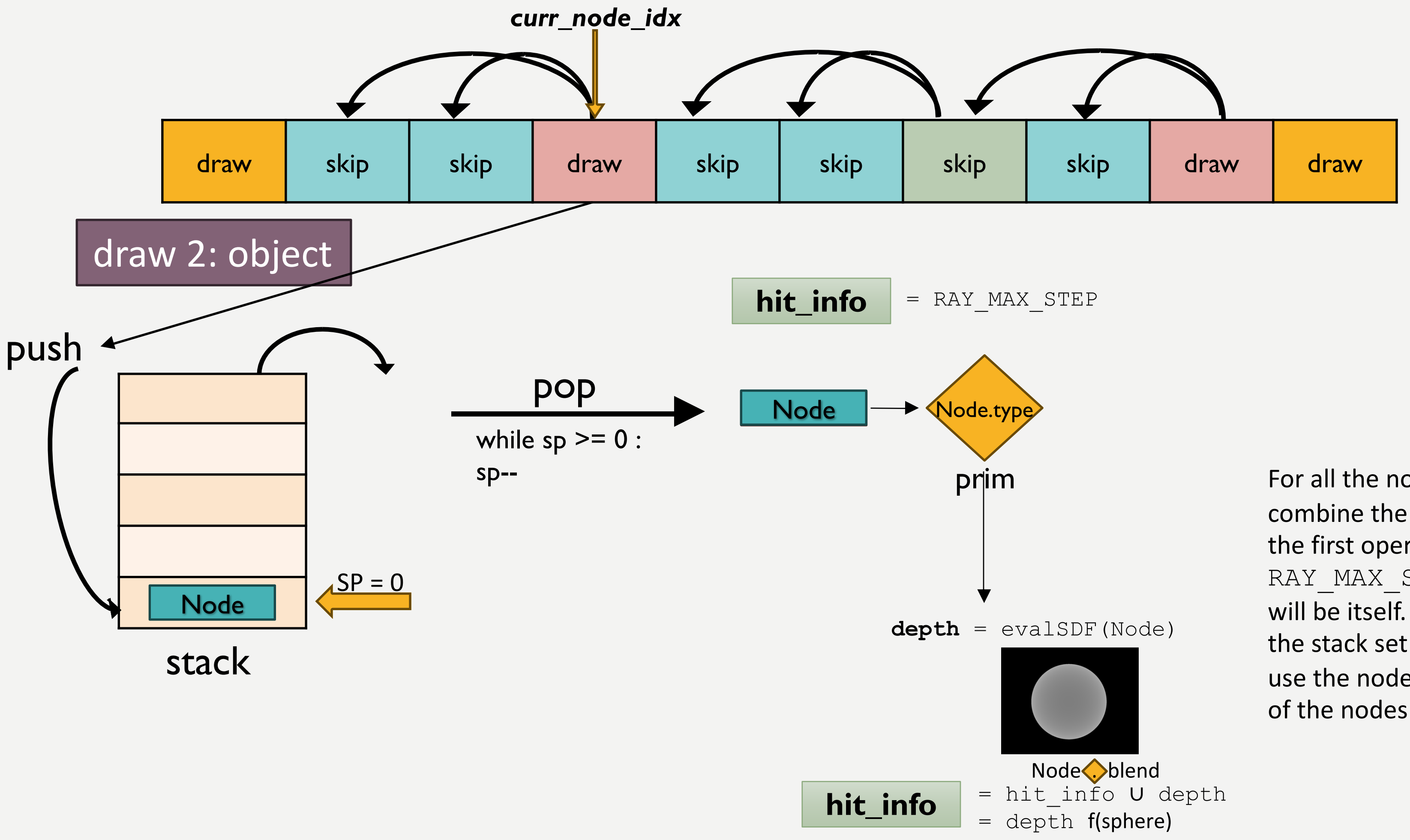

For all the nodes in the stack, as we combine the SDFs node after node, the first operations is a Union (∪) with `RAY_MAX_STEP`, basically the value will be itself. So, for the first node in the stack set the node.blend as ∪ and use the node.blend for the remaining of the nodes.

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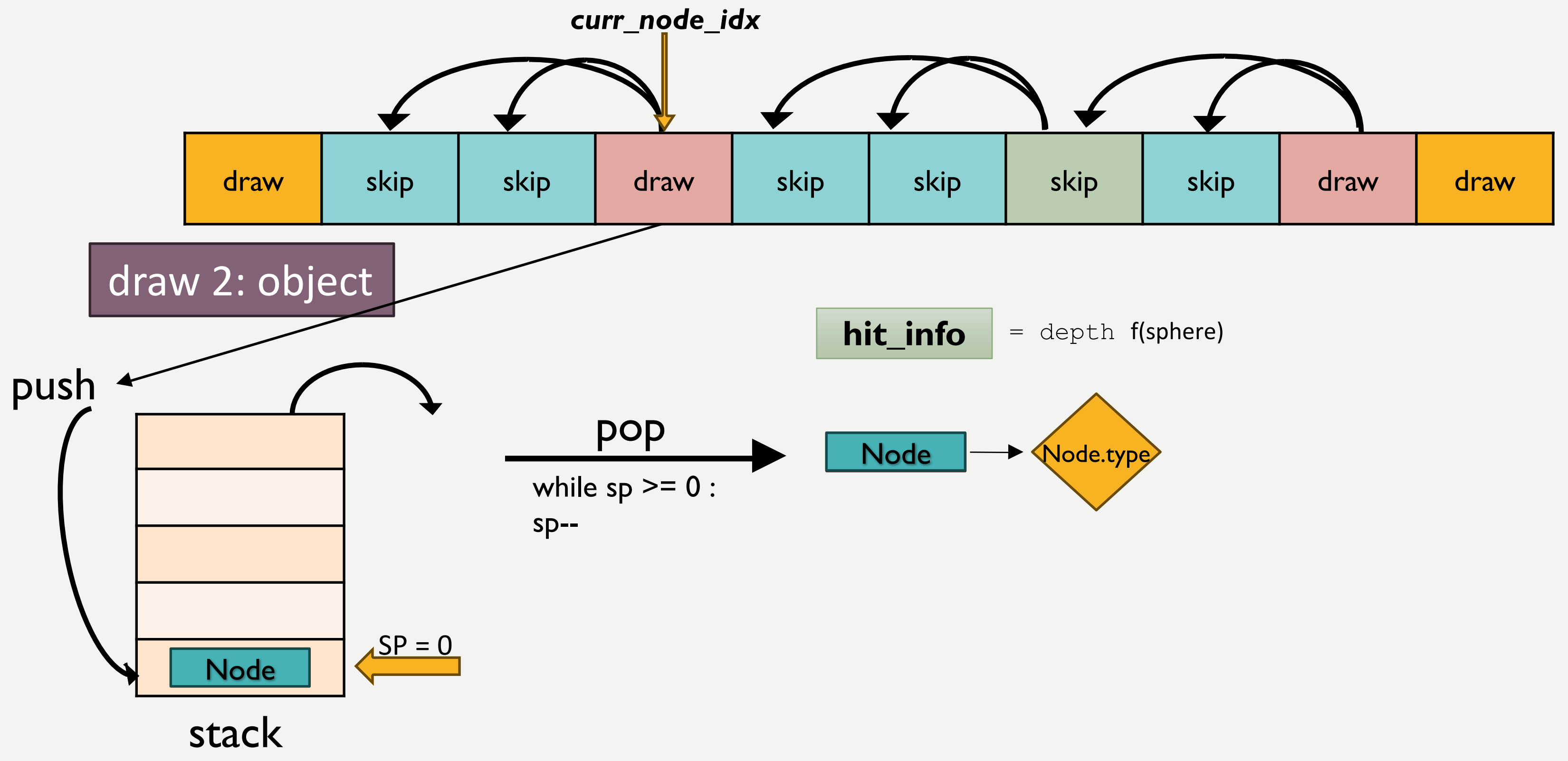

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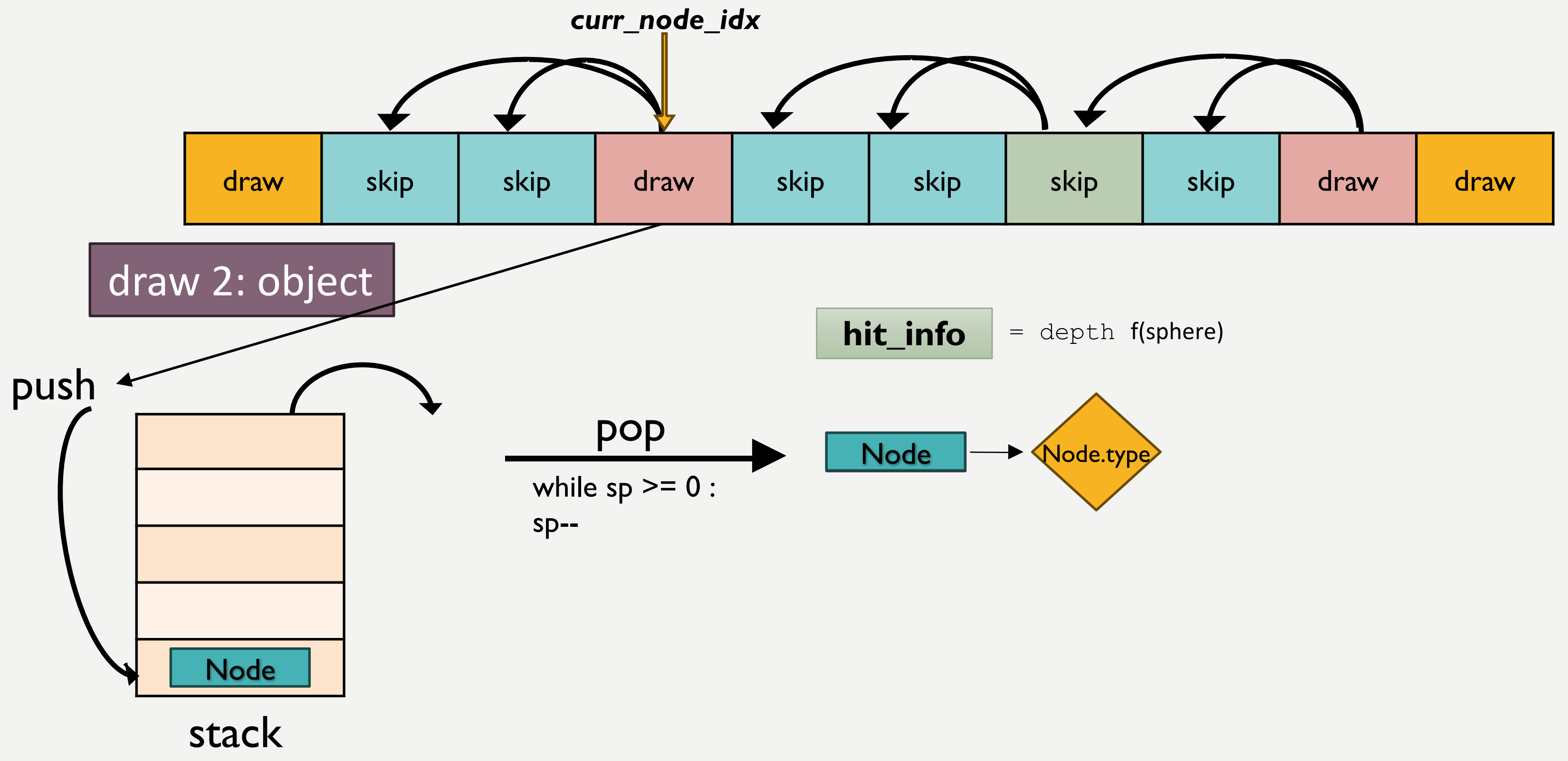

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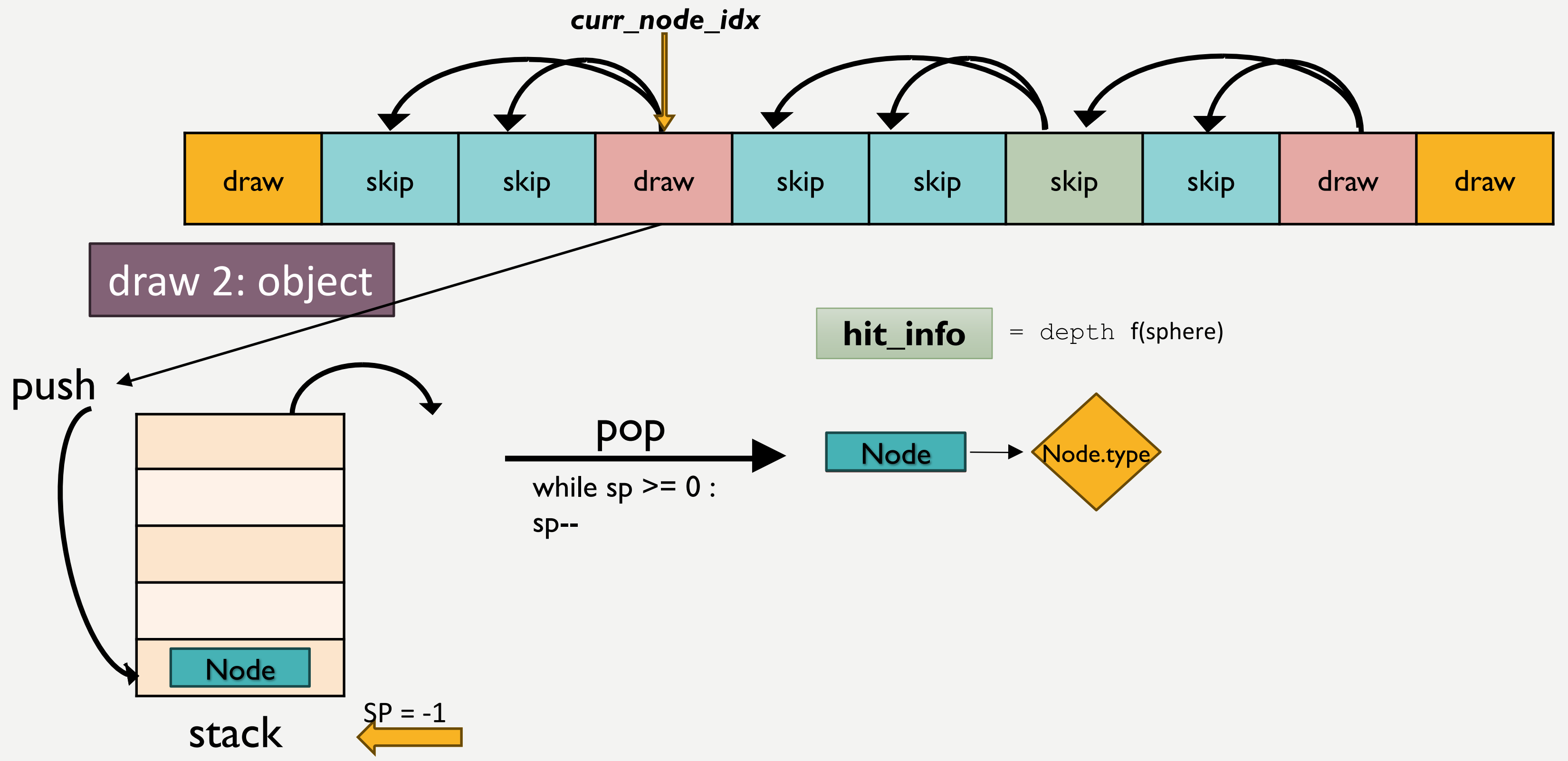

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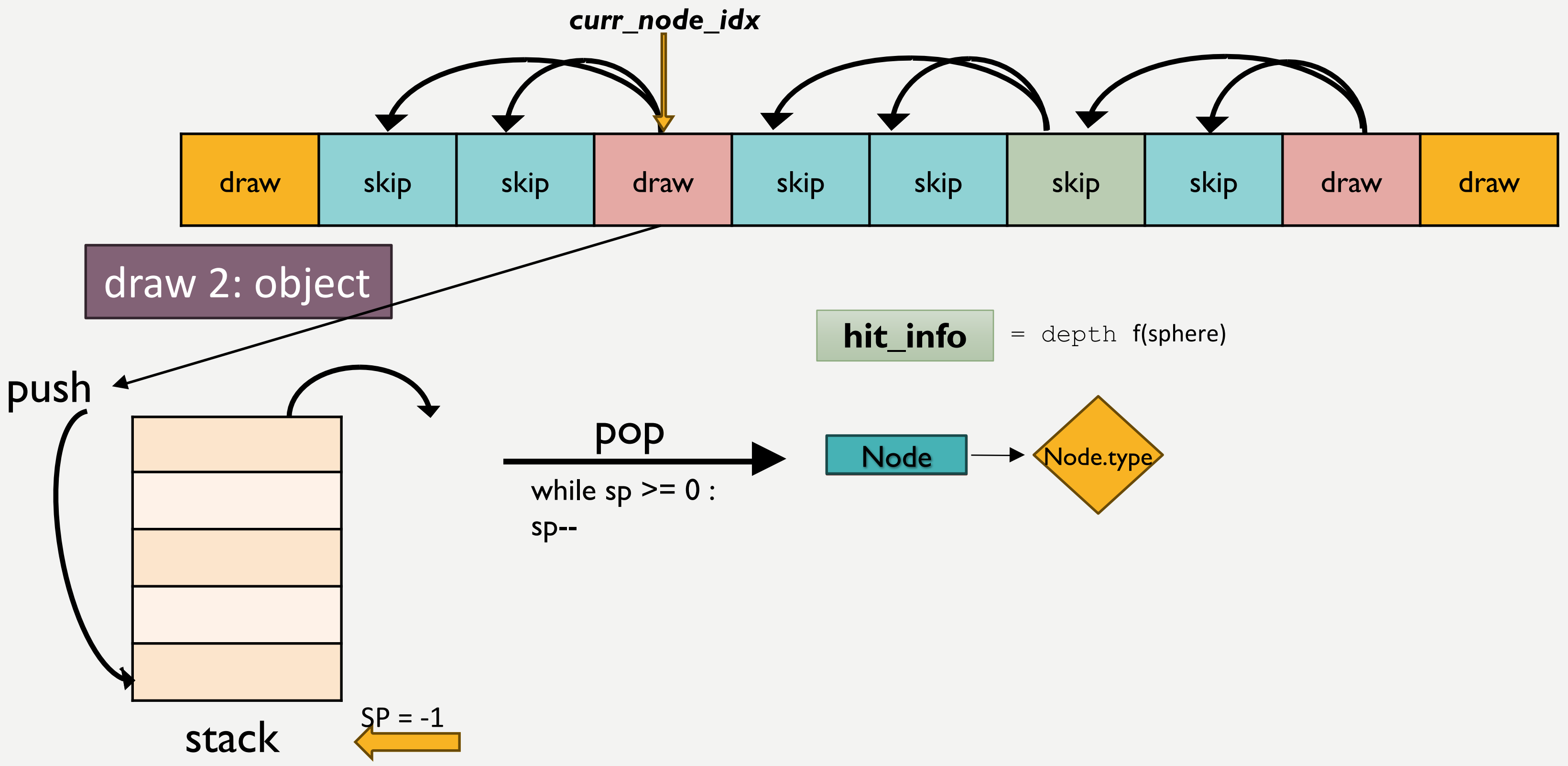

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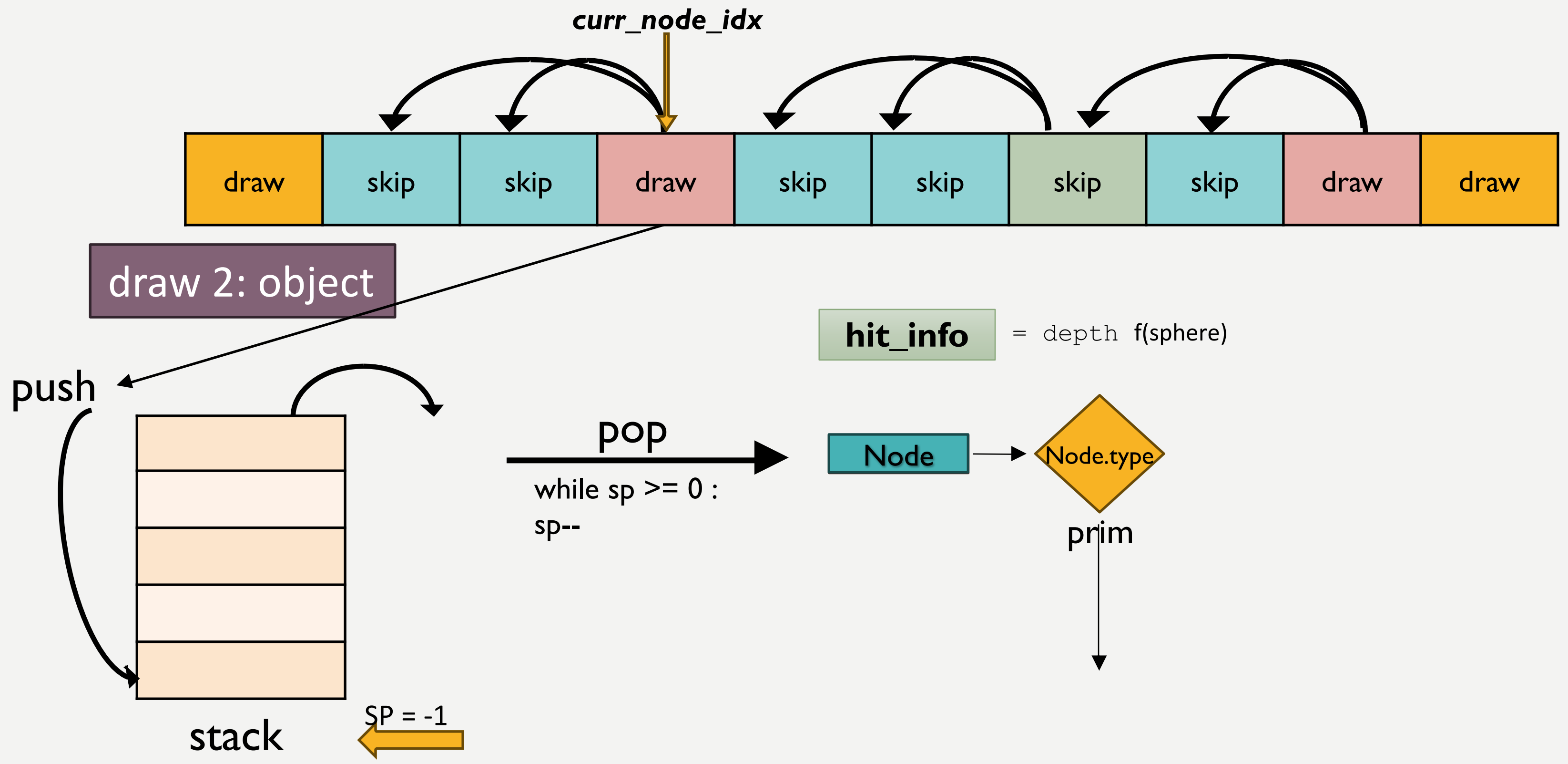

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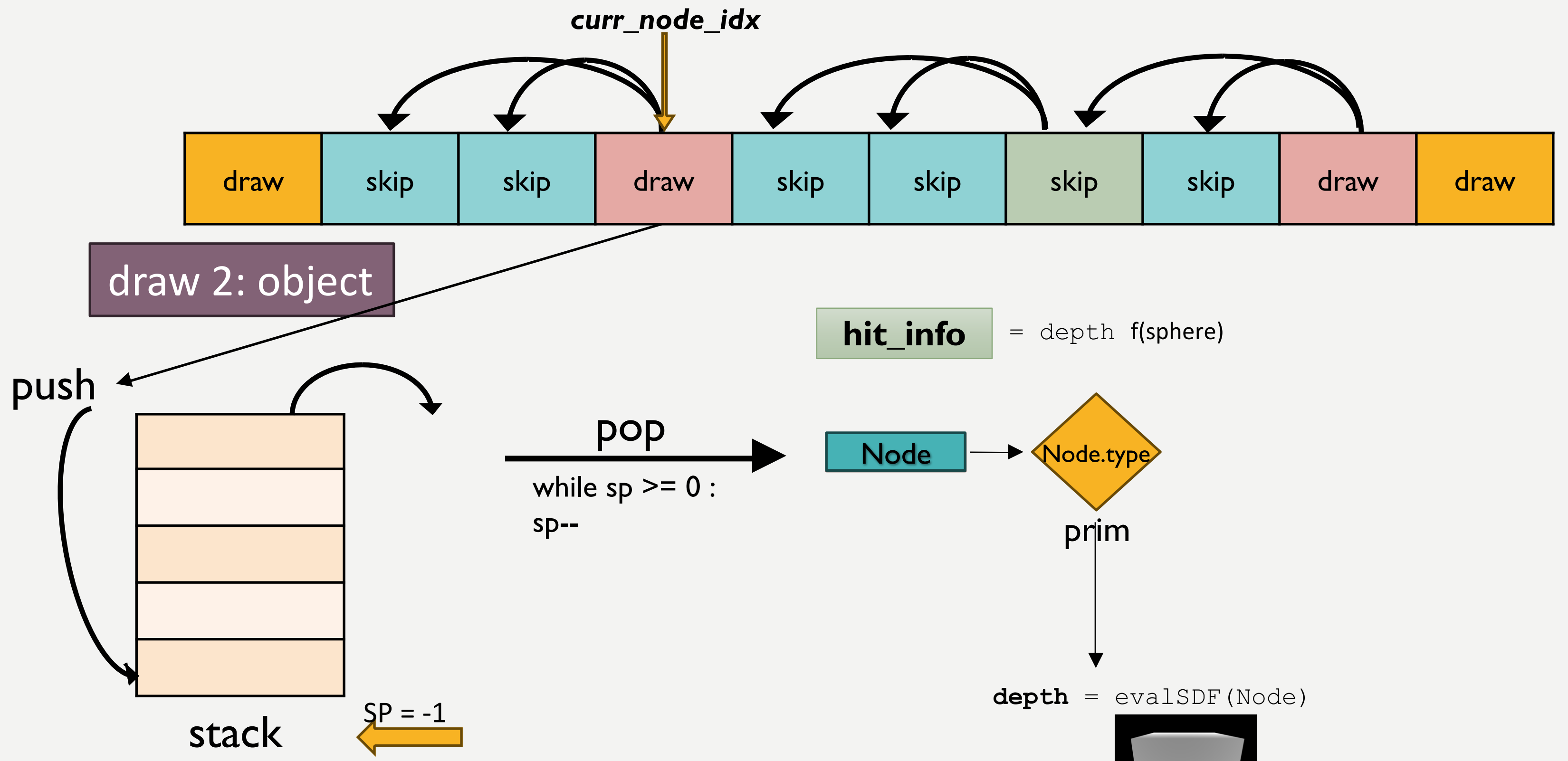
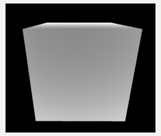


hit_info = depth f(sphere)

depth = evalSDF(Node)



hit_info = hit_info ∩ depth f(cube)
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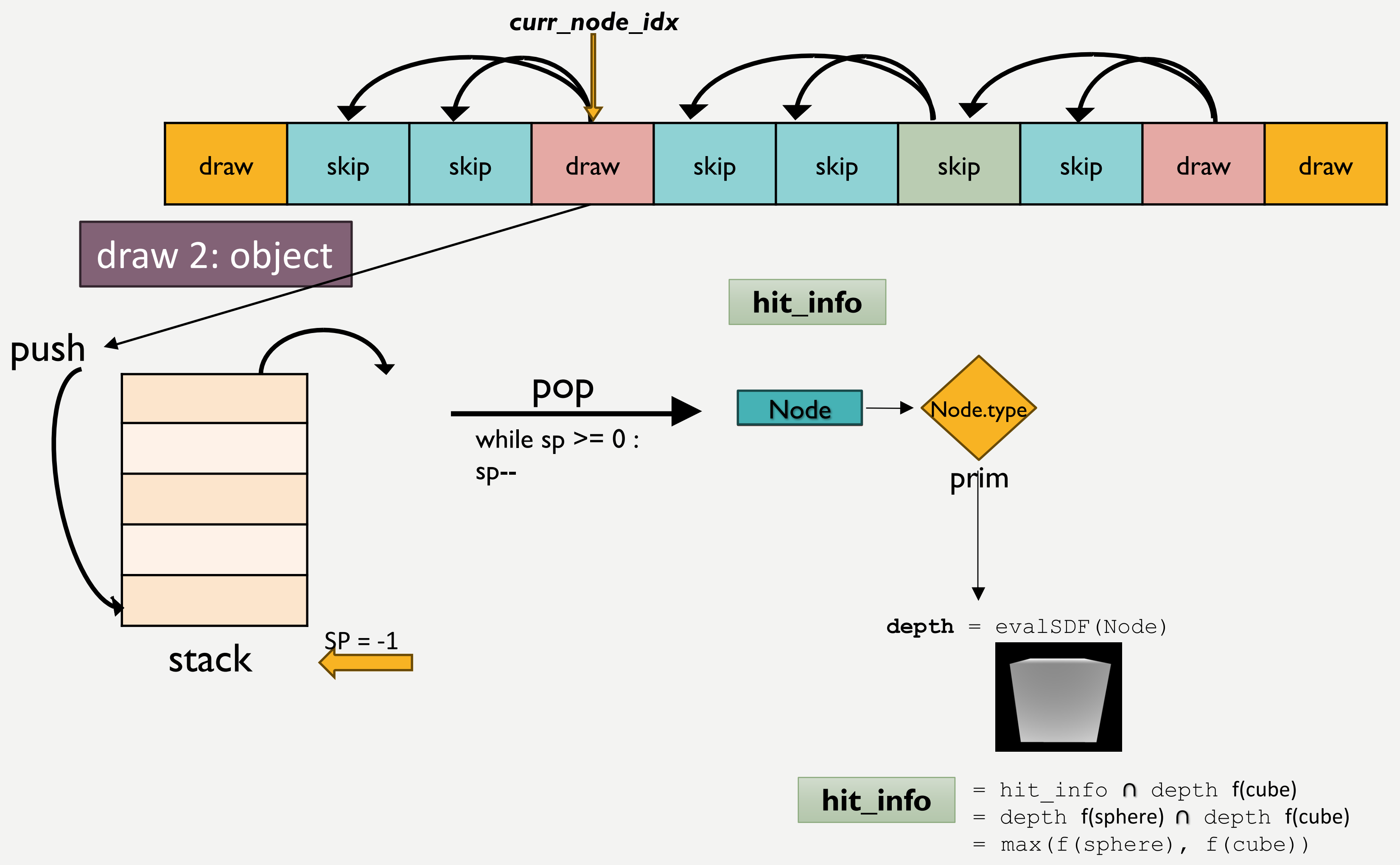

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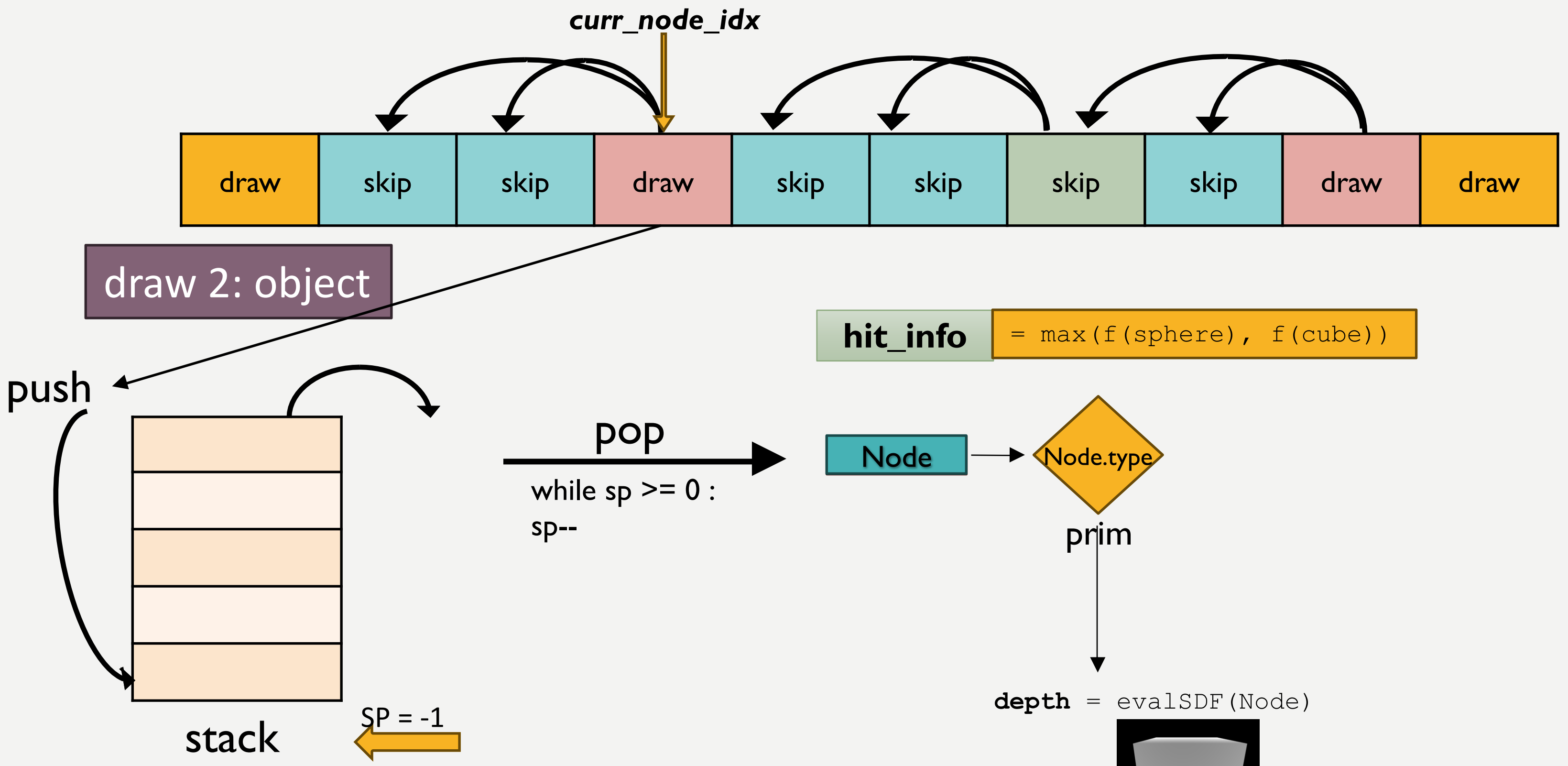

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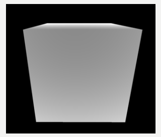

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Optimizing Ray Marching shader

- **PS to CS:** Moving the shader from a pixel shader to compute shader will results in a faster shader because a CS doesn’t follow ordered exports and can exit early if some rays don’t hit anything and can perform texture writes in any arbitrary order.
- **Improving Occupancy:**