Detección y resolución de colisiones usando Rust

Agustin Escobar - https://github.com/agustinesco

Contexto

- Champions of mirra

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- Estructura del backend principalmente en Elixir

```elixir
defmodule Physics do
  @moduledoc """
  Physics
  """
  use Rustler,
    otp_app: :arena,
    crate: :physics

  def check_collisions(_entity, _entities), do: :erlang.nif_error(:nif_not_loaded)
```

Contexto

- Champions of mirra
- Estructura del backend principalmente en Elixir
- ¿Por qué incluir rust?
  - Rustler
  - Módulo de físicas
  - Estructura de entidades

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defmodule Physics do
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  - Tiempo algorítmico: O(Z * N)
    - Z: Cantidad de polígonos
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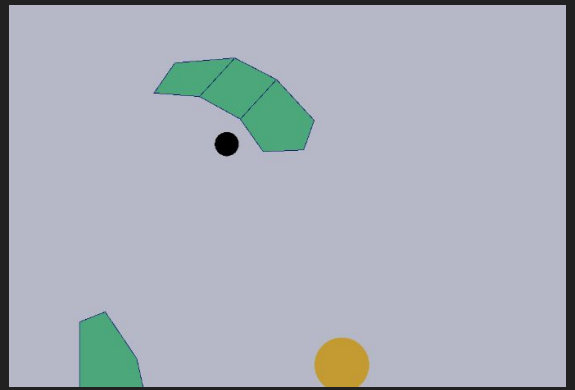
- Resolución de colisiones
  - S.A.T.



Representación 2d de un obstáculo y un jugador

Contexto

- Detección de colisiones
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  - Tiempo algorítmico: O(Z * N)
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  - Tiempo algorítmico: O(Z * N^2)
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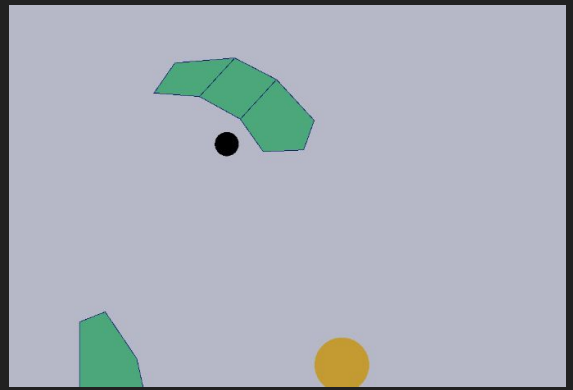


Representación 2d de un obstáculo y un jugador

Contexto

- Movimiento de los jugadores

```rust
fn move_entity_to_closest_available_position(
    entity: &mut Entity,
    external_wall: &Entity,
    obstacles: &HashMap<u64, Entity>,
) {
    if entity.category == Category::Player && !entity.is_inside_map(external_wall) {
        entity.move_to_next_valid_position_inside(external_wall);
    }

    let collides_with: Vec<u64> = entity.collides_with(entities: &obstacles.clone().into_values().collect());

    if entity.category == Category::Player && !collides_with.is_empty() {
        let collided_with: Vec<&Entity> = collides_with Vec<u64>
            .iter() Iter<u64>
            .map(|id: &u64| obstacles.get(id).unwrap()) impl Iterator<Item = &Entity>
            .collect();
        entity.move_to_next_valid_position_outside(collided_with, obstacles, external_wall);
    }
}
```

Contexto

- Movimiento de los jugadores
- Cuando entra S.A.T.

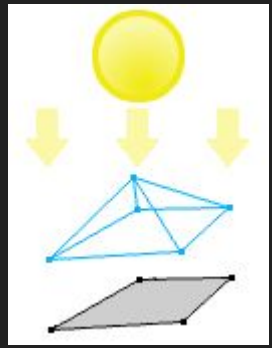
```rust
pub fn move_to_next_valid_position_outside(
    &mut self,
    collided_with: Vec<&Entity>,
    obstacles: &HashMap<u64, Entity>,
    external_wall: &Entity,
) {
    for entity: &Entity in collided_with {
        match entity.shape {
            Shape::Circle => {…
            Shape::Polygon => {
                let (collided: bool, direction: Position, depth: f32) =
                    intersect_circle_polygon(circle: self, polygon: entity, obstacles, external_wall);

                if collided {
                    let new_pos: Position = Position {
                        x: self.position.x + direction.x * depth,
                        y: self.position.y + direction.y * depth,
                    };
                    self.position = new_pos;
                }
            }
            _ => continue,
        }
    }
} fn move_to_next_valid_position_outside
```

S.A.T. Separated Axis Theorem

Si dos objetos convexos no están solapados, eso significa que existe un axis en el cual la proyección de esos objetos no están solapando.

- Que es la proyección



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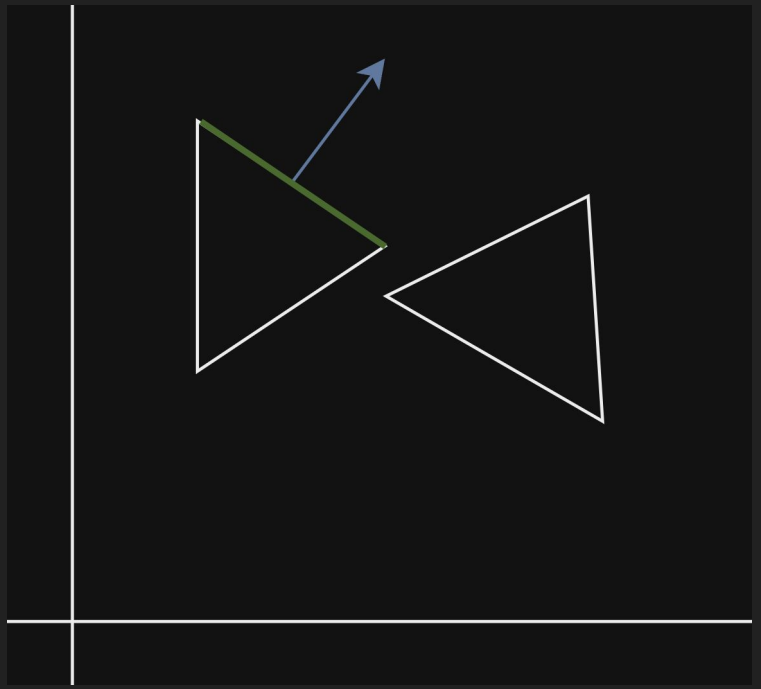
Si dos objetos convexos no están solapados, eso significa que existe un axis en el cual la proyección de esos objetos no están solapando.

- Que es la proyección
- Definir axis a proyectar
    - Elegir una normal



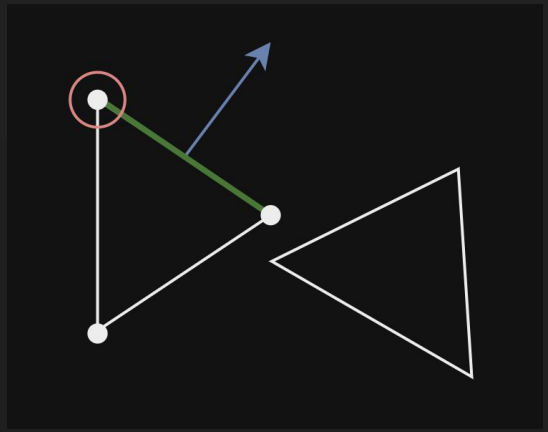
S.A.T. Separated Axis Theorem

```
// Check normal and depth for polygon
for current_vertex_index: usize in 0..polygon.vertices.len() {
    let mut next_vertex_index: usize = current_vertex_index + 1;
    if next_vertex_index == polygon.vertices.len() {
        next_vertex_index = 0
    };
    let current_vertex: Position = polygon.vertices[current_vertex_index];
    let next_vertex: Position = polygon.vertices[next_vertex_index];

    let current_line: Position = Position::sub(a: &current_vertex, b: &next_vertex);
    // the axis will be the perpendicular line drawn from the current line of the polygon
    axis = Position {
        x: -current_line.y,
        y: current_line.x,
    };

    axis.normalize();
```

S.A.T. Separated Axis Theorem



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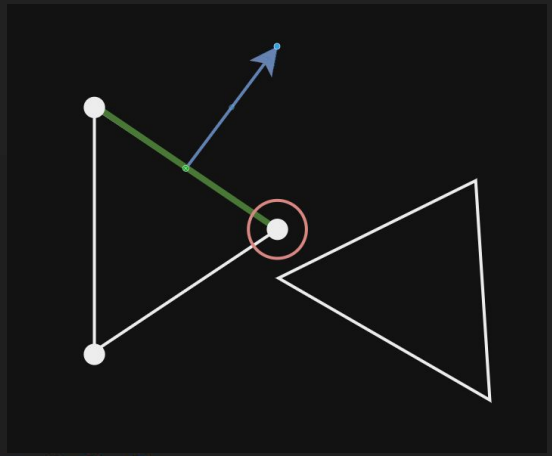

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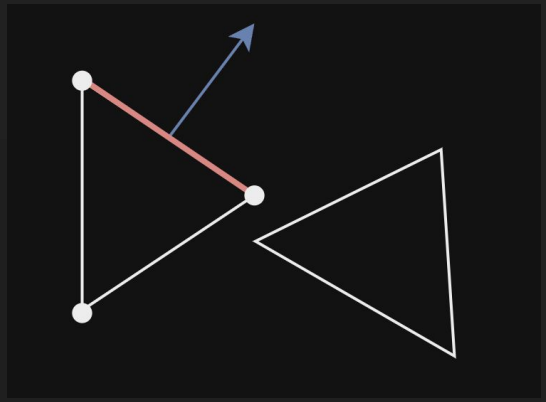

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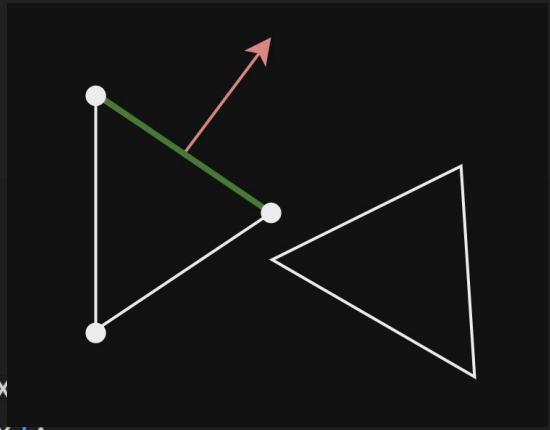

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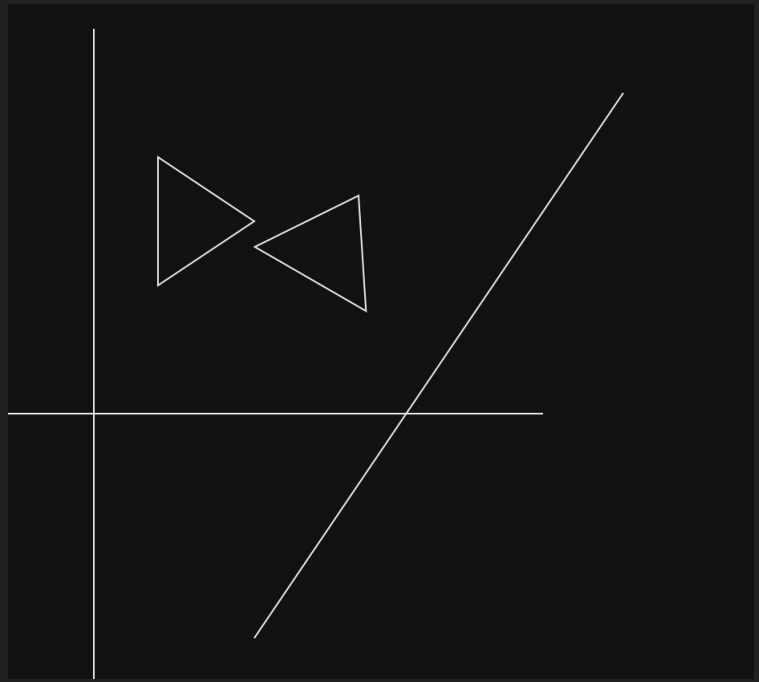


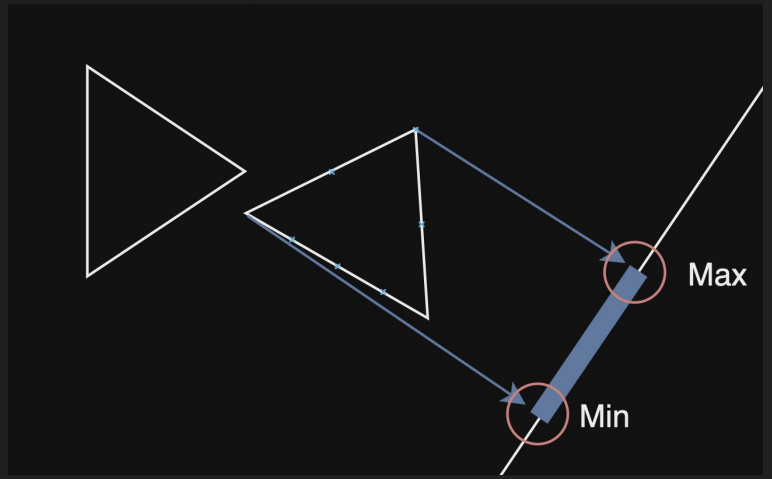
S.A.T. Separated Axis Theorem

```rust
// Get the min and max values from a polygon projected on a specific axis
fn project_vertices(vertices: &Vec<Position>, axis: Position) -> (f32, f32) {
    let mut min: f32 = f32::MAX;
    let mut max: f32 = f32::MIN;

    for current: &Position in vertices {
        let projection: f32 = dot(a: current, b: axis);

        if projection < min {
            min = projection
        };
        if projection > max {
            max = projection
        };
    }

    (min, max)
}
```



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- Que es la proyección
- Definir axis a proyectar
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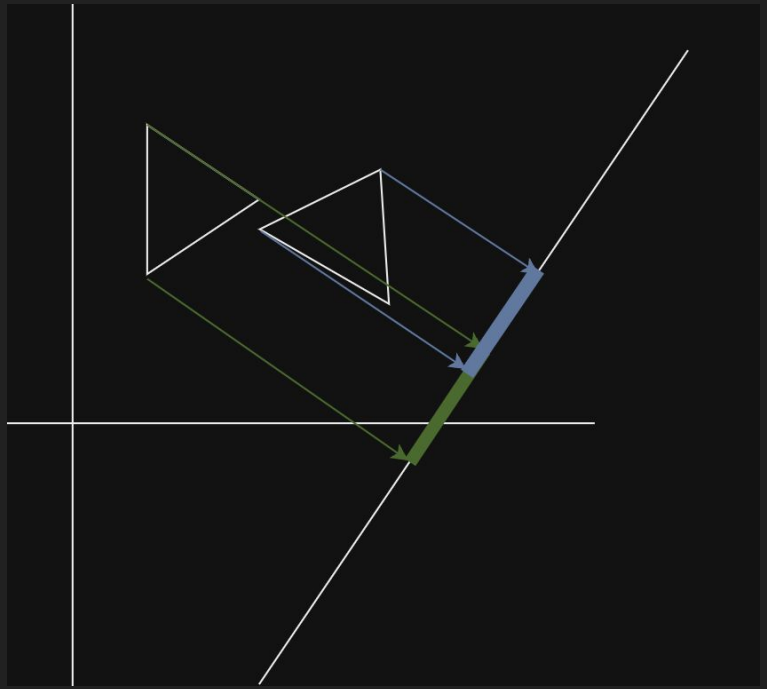
  - Proyección de sombras usando producto escalar



S.A.T. Separated Axis Theorem

```
let (min_polygon_cast_point: f32, max_polygon_cast_point: f32) = project_vertices(&polygon.vertices, axis);
let (min_circle_cast_point: f32, max_circle_cast_point: f32) = project_circle(circle, axis);

// If there's a gap between the polygon it means they do not collide and we can safely return false
if min_polygon_cast_point ⩾ max_circle_cast_point
    || min_circle_cast_point ⩾ max_polygon_cast_point
{
    return (false, normal, result_depth);
}
```

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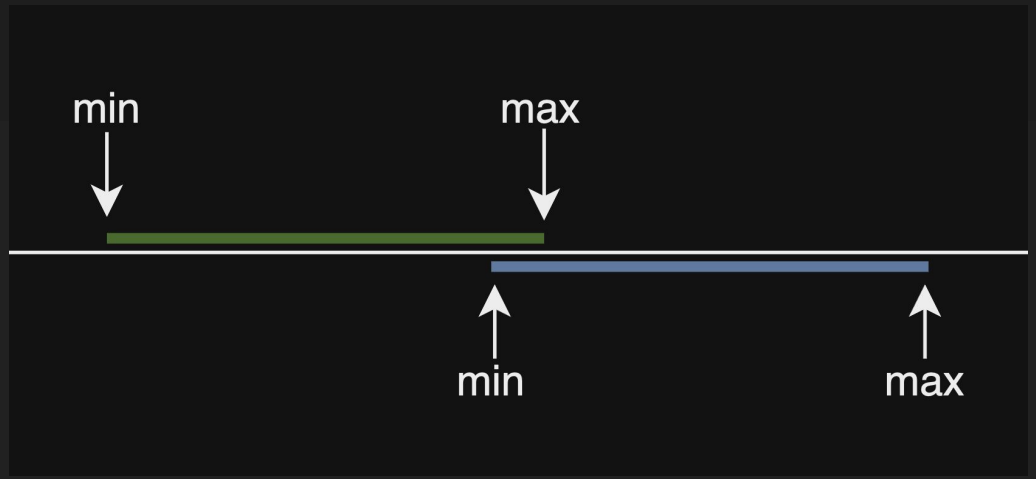

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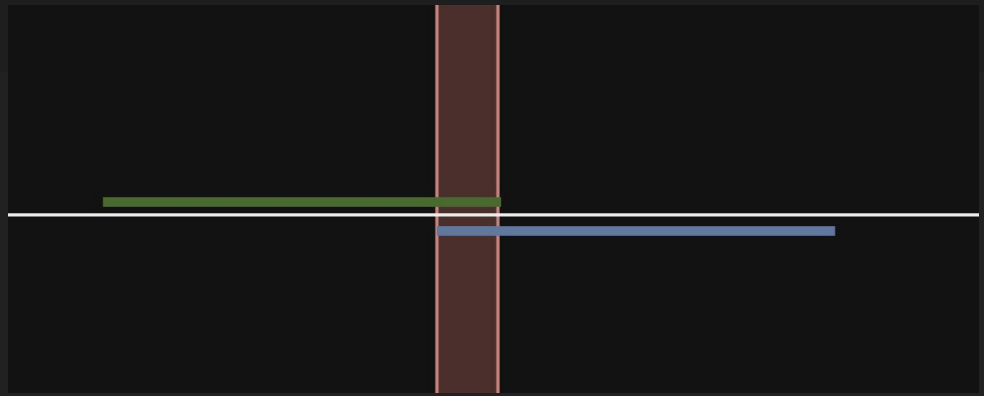

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{
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}
```

S.A.T. Separated Axis Theorem

Acumular la normal y la profundidad con el menor solapamiento

```
let circle_overlap_depth: f32 = max_circle_cast_point - min_polygon_cast_point;

let polygon_overlap_depth: f32 = max_polygon_cast_point - min_circle_cast_point;

let min_depth: f32 = f32::min(self: circle_overlap_depth, other: polygon_overlap_depth);

if min_depth < result_depth {
    normal = axis;
    result_depth = min_depth;
}
```

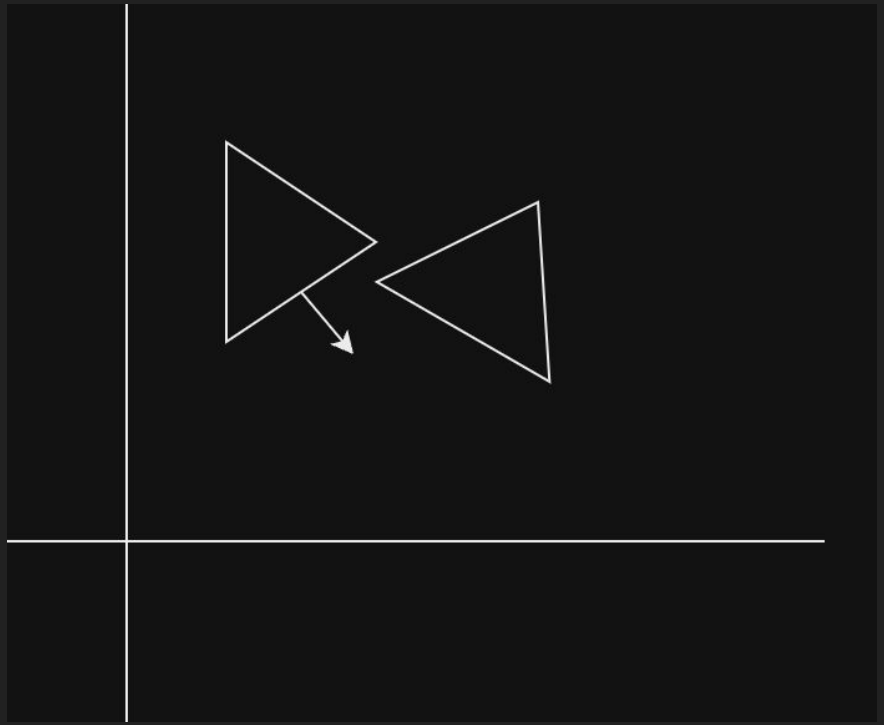
S.A.T. Separated Axis Theorem

Al finalizar de iterar todos los pares de vértices de ambos polígonos o el círculo se devuelve la normal con el menor solapamiento

```
    return (true, normal, result_depth);
} fn intersect_circle_polygon
```

S.A.T. Separated Axis Theorem

Ejemplo de axis separador:



S.A.T. Separated Axis Theorem

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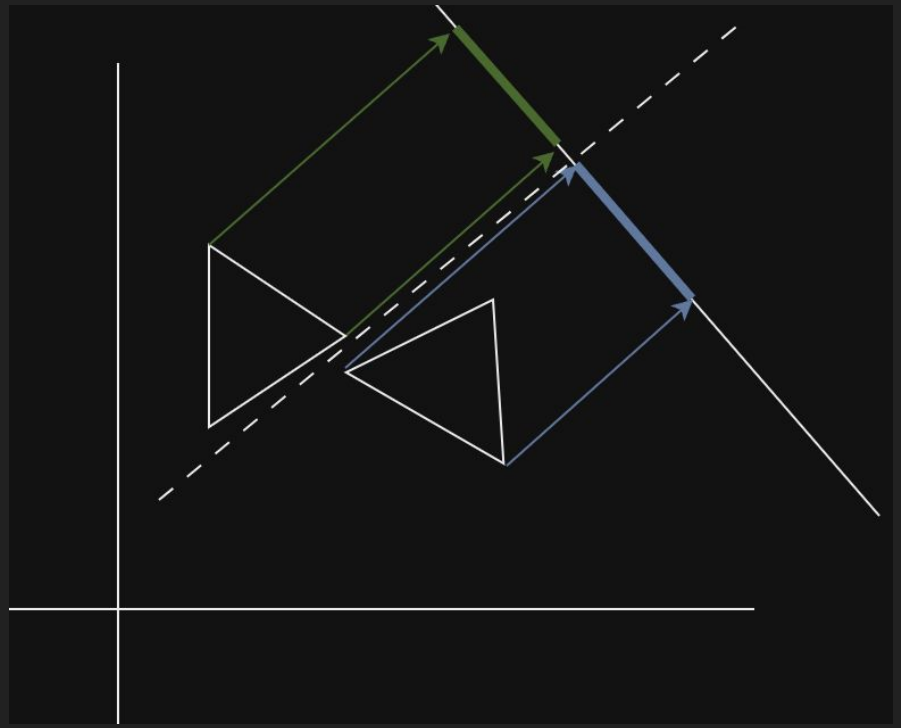
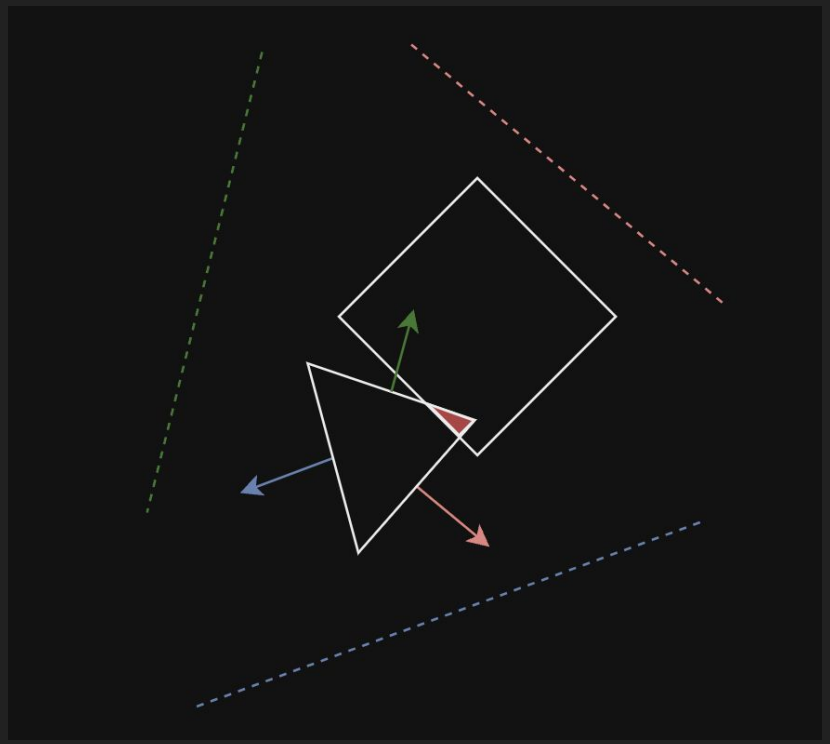


S.A.T. Separated Axis Theorem

Ejemplo de colisión:



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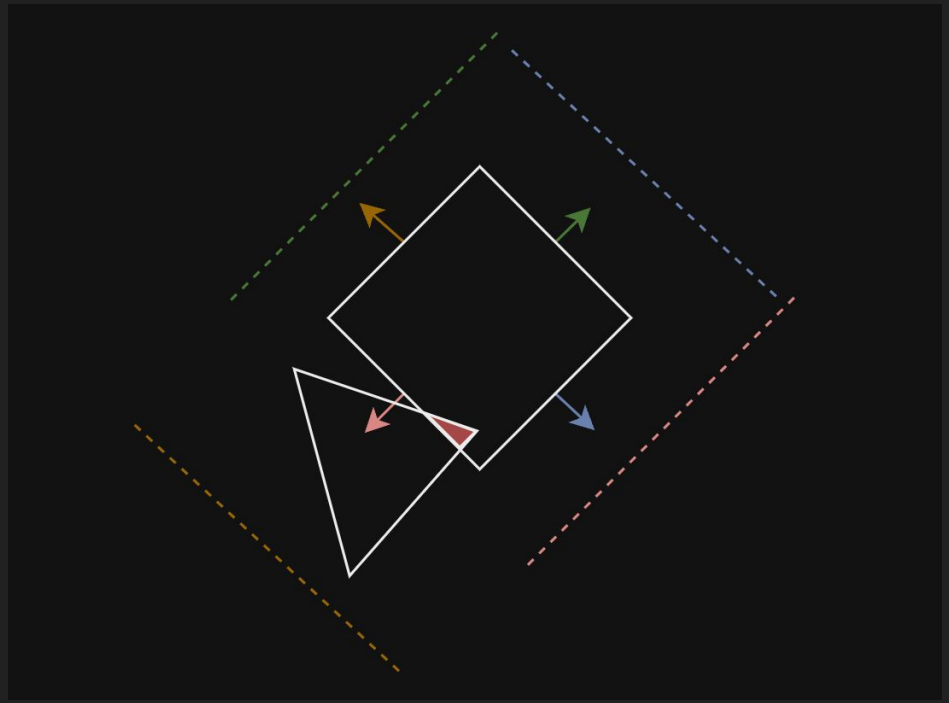
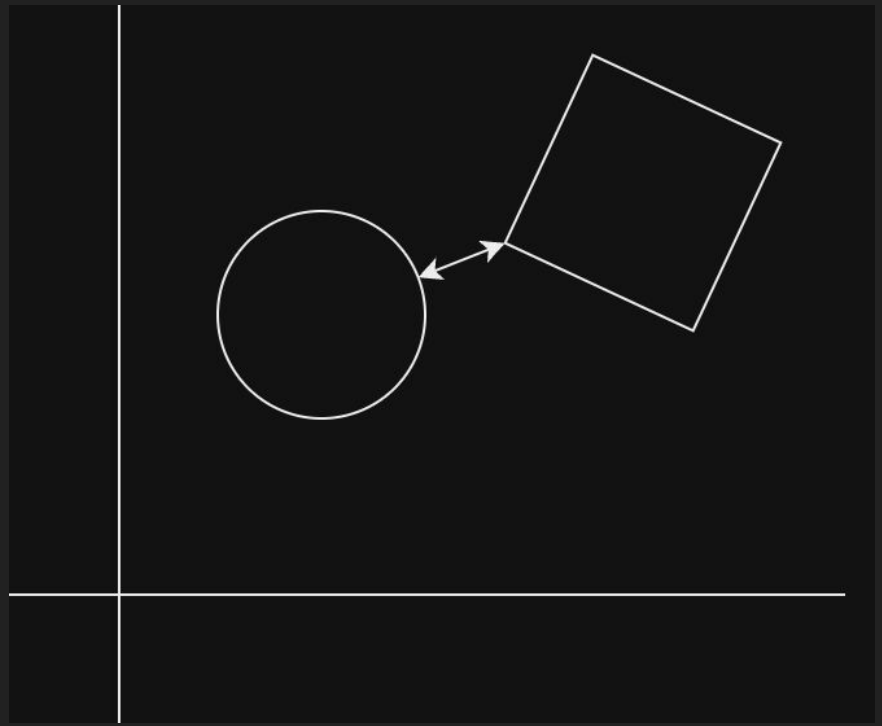


S.A.T. Separated Axis Theorem

Ejemplo de axis con círculo:

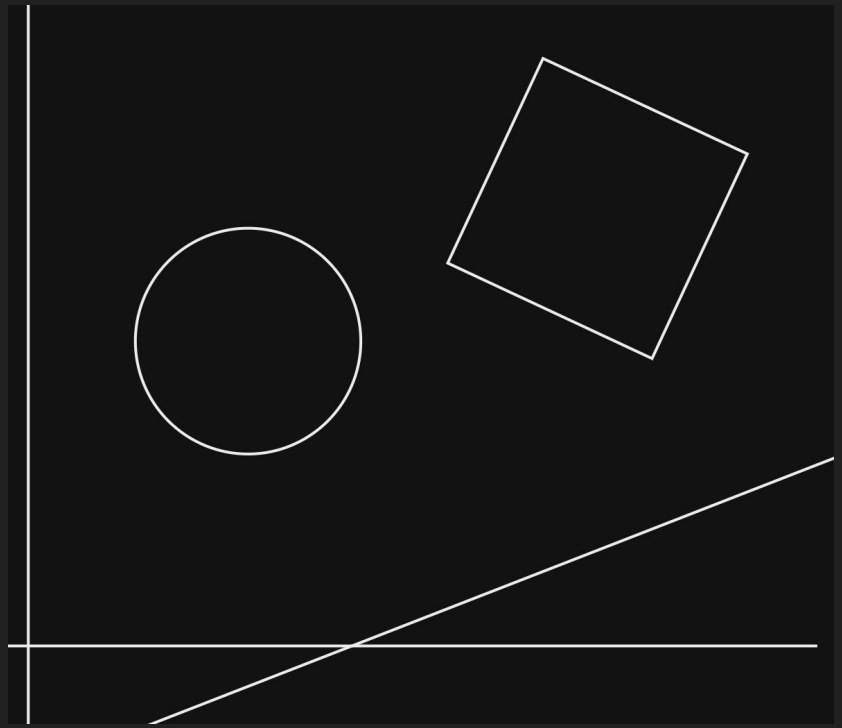


S.A.T. Separated Axis Theorem

```
// Check normal and depth for center
let closest_vertex: Position = find_closest_vertex(center: &circle.position, &polygon.vertices);
axis = Position::sub(a: &closest_vertex, b: &circle.position);
axis.normalize();
```

S.A.T. Separated Axis Theorem

Ejemplo de axis con círculo:



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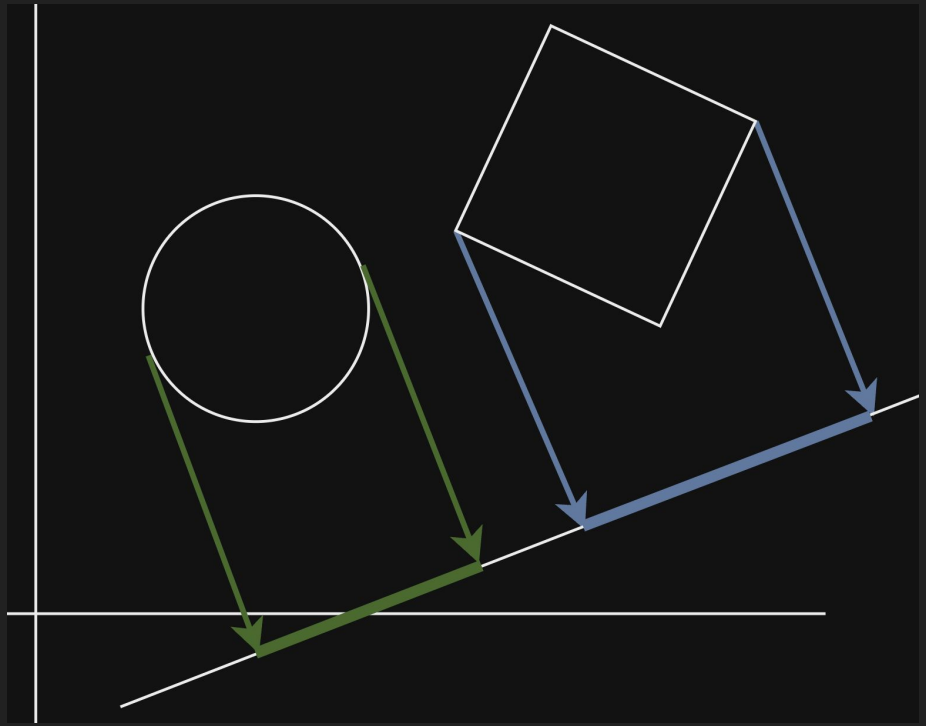

S.A.T. Separated Axis Theorem

Ejemplo de axis con círculo:

```
let (min_polygon_cast_point: f32, max_polygon_cast_point: f32) = project_vertices(&polygon.vertices, axis);
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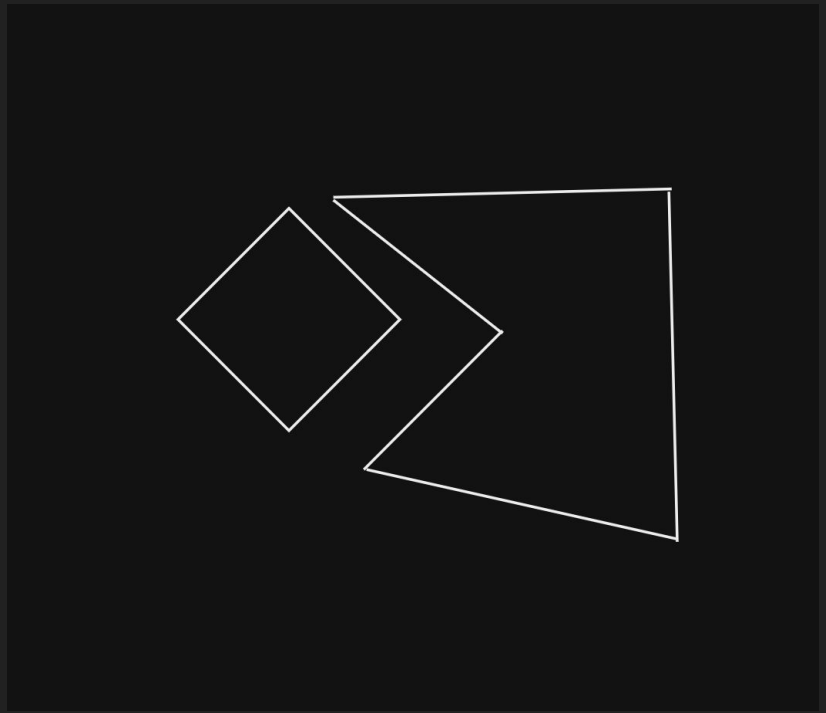
// If there's a gap between the polygon it means they do not collide and we can safely return false
if min_polygon_cast_point ⩾ max_circle_cast_point
    || min_circle_cast_point ⩾ max_polygon_cast_point
{
    return (false, normal, result_depth);
}
```

S.A.T. Separated Axis Theorem

Ejemplo de problema concavidad:



S.A.T. Separated Axis Theorem

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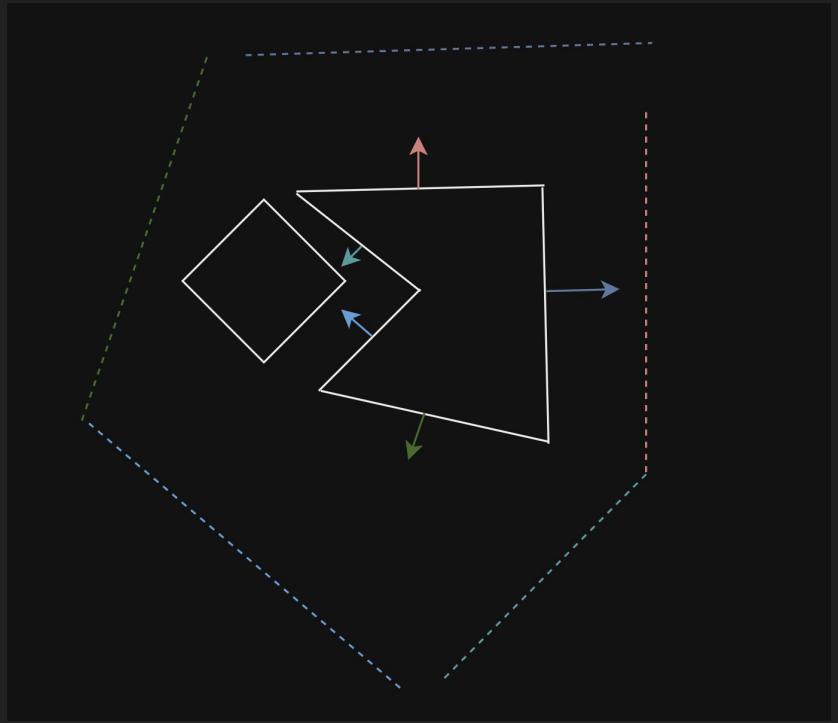

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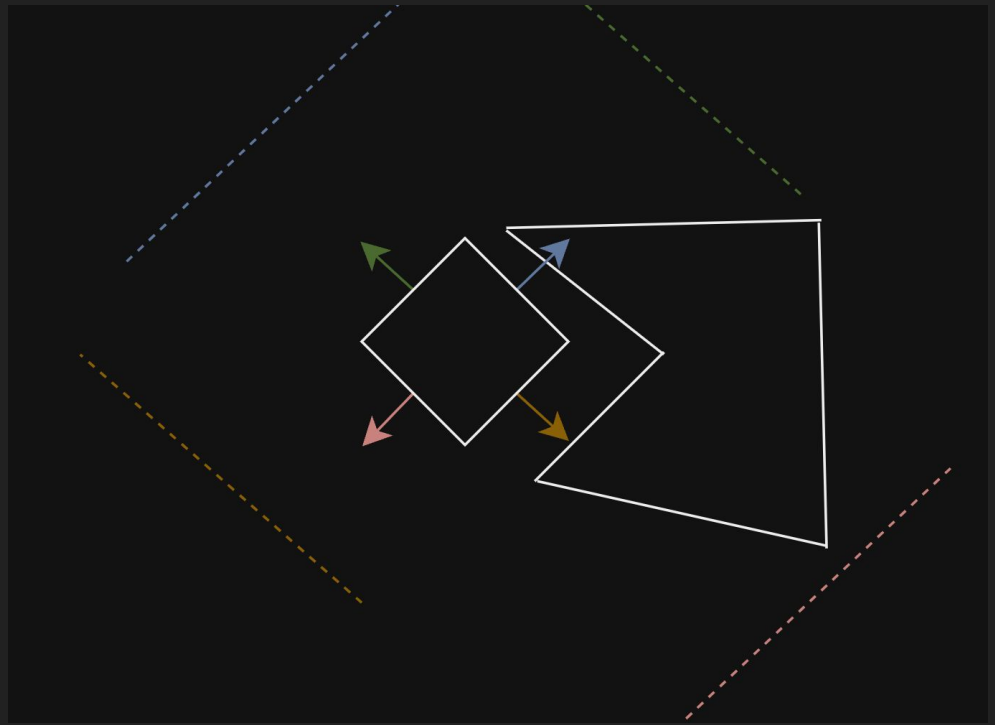

Conclusiones

- Dificultad de implementación
  - Líneas de elixir 3993
  - Líneas de rust 738 en total
    - Algoritmo de jeffrey 193 líneas
    - SAT 224 líneas

- Benchmark de distintos algoritmos
  - jeffrey 20 ms en promedio
  - SAT 9 ms en promedio

Recursos

- Video de youtube sat implementation https://www.youtube.com/watch?v=Zgf1DYrmSnk
- SAT article https://dyn4j.org/2010/01/sat/