

2GD11 Alex Stukalovs' PPGA project's technical report

Formulas used

- **Transformations** (for controls and collision resolution):

$$R * T * X * (R * T)^{-1},$$

$$R, T - motors,$$

$$X \in n - vector, n \in [1, 3]$$

- **Distance acquisition** (for collision detection):

$$d_1 = |A_n \vee B_m|,$$

$$n, m \in [1, 3]$$

- **Angle determination**(for player character and enemy rotation):

$$\cos(\alpha) = a \cdot b / (|a| + |b|),$$

$$|\sin(\alpha)| = |a \wedge b| / (|a| + |b|),$$

$$\alpha = \text{atan2}(\sin(\alpha), \cos(\alpha)),$$

$$n, m - bivectors, \alpha - \angle(n, m)$$

- **Direction plane* between 2 points**(for sphere-sphere collision)

$$p = (P(A) \wedge P(B)) \vee e_{123}$$

* Direction plane is such p., normal of which is collinear with $A \vee B$.

NOTE: Not using join in the left operand, because its formula involves application of inverse dual, which is unneded in this case.

Specific applications

Camera and character

The project involves 3rd person camera, which gives an ability rotate around the character when motionless.

When moving, the character rotates to face the same direction as the camera does.

Collisions

Camera uses sphere collisions, and character - capsule collisions to realistically interact with the environment.

Sphere-plane collisions(for camera)

Given:

$$\hat{O}^{(3)} = O - \text{sphere's center(normalized)},$$

$$r^{(0)} = r - \text{sphere's radius},$$

$$\hat{P}^{(1)} = P - \text{collision plane(normalized)}$$

Find:

$$O_1^{(3)} = O_1 - \text{sphere's center after collision}$$

Solution:

1) Getting distance from sphere's origin to the plane

$$d = |O \vee P| = H^{-1}(H(O) \wedge H(P))$$

2) $d < r \Rightarrow \text{Sphere}(O, r) \cap P$:

2.1) Retrieving the translation motor:

$$T = 1 - \frac{1}{2}t(-e_0),$$

$$t = (d - r)\hat{P}^{(1)}$$

NOTE : The e_0 coefficient of P is irrelevant, because it turns into void regardless.

NOTE : See rationale behind translation by $(d - r)$ in the Figure 1.

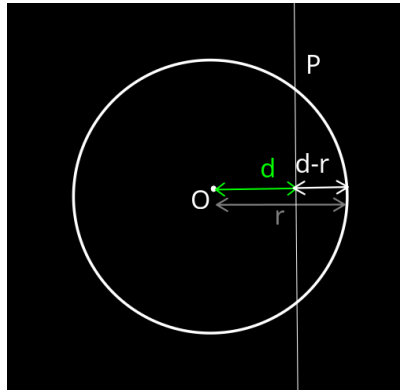


Figure 1. Sphere – plane collision resolution

2.2) Translating the sphere's origin:

$$O_1^{(3)} = \langle T O T \rangle_3 \text{ (gep) } - \text{solution}$$

Capsule-plane collisions(for character)

Given:

$$h^0 - \text{capsule's height}$$

$$r^0 - \text{capsule's radius}$$

$$\hat{O}^3 = O = O_x e_{021} + O_y e_{013} + O_z e_{032} + O_w e_{123} - \text{capsule's origin}$$

Find:

$$O_1^{(3)} = O_1 - \text{capsules center after collision}$$

Solution:

1) Finding A^3 and B^3 . See Figure 2 for reference

$$A^3 = A = O_x e_{032} + (\mathbf{h}-\mathbf{r}) O_y e_{012} + O_z e_{013} + O_w e_{123}$$

$$B^3 = B = O_x e_{032} + \mathbf{r} O_y e_{012} + O_z e_{013} + O_w e_{123}$$

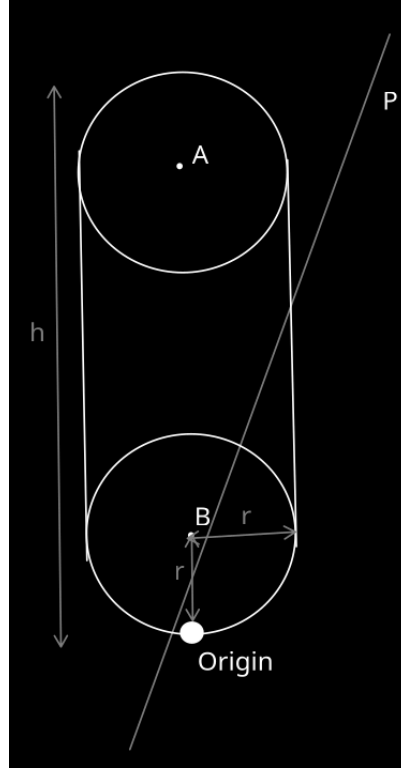


Figure 2. Capsule – plane collision

2) Retrieving the closest sphere

$$d_A = |A \vee P|, d_B = |B \vee P|$$

$$|d_A| < |d_B| \Rightarrow A \text{ is closer and vice versa}$$

3) Performing collision handling on the closest sphere.

See [Sphere-plane collisions\(for camera\)](#).

NOTE : Instead of applying translation to sphere's origin, it should get applied to the capsule's

Sphere-sphere collisions(between enemies and character)

NOTE: Since there's no vertical movement present, it is sufficient to always test against only bottom spheres.

Given:

$$\hat{E}^{(3)} = E - \text{enemy's origin(normalized)},$$

$$\hat{C}^{(3)} = C - \text{character's origin(normalized)},$$

$$r_E, r_C - \text{radii}$$

Find:

C' – character's origin after collision

E' – enemy's origin after collision

NOTE: Both actors are moved by the same distance for simplicity.

Solution:

1) Finding distance and proceed if it's larger than sum of radii

$$dist = |E \vee C|,$$

$$dist > r_E + r_C \Rightarrow \text{proceed}$$

2) Determining translation vectors

$$dir_B = \text{normalize}(P(E) \wedge P(C) \vee e_{123}),$$

$$translationDist = dist - (r_E + r_C),$$

$$translation_B = dir_B \text{ translationDist}$$

$$translation_A = -translation_B,$$

3) Calculating translation motors

$$T_A = 1 - \frac{1}{2}translation_A(-e_0),$$

$$T_B = 1 - \frac{1}{2}translation_B(-e_0) - \text{solution}$$

Enemy rotation

Logic for rotating enemies towards the player.

Given :

$$\hat{E}^{(3)} = E - \text{enemy's origin(normalized)},$$

$$\hat{C}^{(3)} = C - \text{character's origin(normalized)},$$

NOTE : The e_{012} (vertical) component is irrelevant, because only yaw is affected.

$$\hat{V}^{(2)} = V - \text{enemy's initial view direction(normalized)},$$

Find :

R – rotation motor to apply to B to direct it towards C

Solution :

1) Calculating final enemy's view direction

$$V' = C \vee E / (|C| \cdot |E|) - \text{enemy's final view direction(normalized)}$$

2) Calculating $\cos(\alpha)$

$$\cos(\alpha) = V \cdot V'$$

NOTE: No division by norms since the bivectors are normalized.

3) *Calculating the sign of $\sin(\alpha)$*

$$\begin{aligned}\hat{w}^2 = w &= V \wedge V' / (|a| \cdot |b|) = \\ &w_1 e_{23} + w_2 e_{31} + w_3 e_{12}, \\ s &= w_1 \cdot w_2 \cdot w_3 / |w_1 \cdot w_2 \cdot w_3| - \text{sign}, \\ s &\in \{-1, 1\}\end{aligned}$$

NOTE: If $w_n = 0, n \in R$, then it must be removed from equation (or set equal to 1).

3.1) *Calculating $\sin(\alpha)$*

$$\sin(\alpha) = s \cdot |w|$$

4) *Calculating the angle*

$$\alpha = \text{atan2}(\sin(\alpha), \cos(\alpha)) - \text{solution}$$