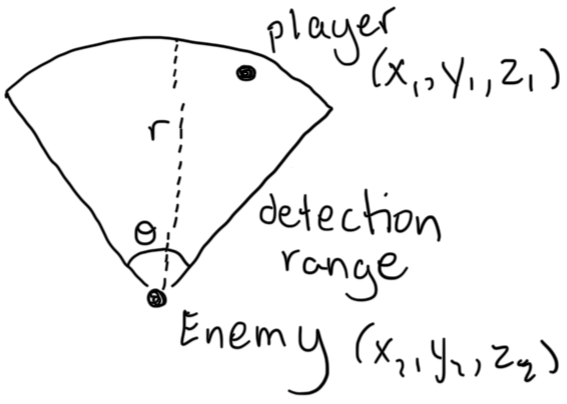
How to determine if the player is in the detection range of an enemy?

Each game object (including all enemies and the player) has a position (x, y, z). We can treat these positions as vectors and use linear algebra to determine if the player is in the detection range of an enemy.

Example

r = detection radius

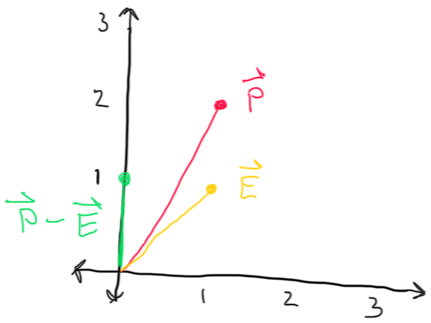
θ = detection angle



player is in range

Find the vector representing the direction/position of the player relative to the enemy.
Let $\vec{P}$ be the player's position and $\vec{E}$ be the enemy's position. Then the desired vector is $\vec{P} - \vec{E}$.

A 2D example

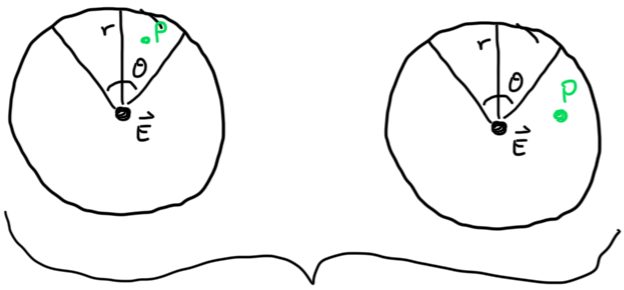


We can see that $\vec{E}+(\vec{p}-\vec{E})$ brings the enemy to the player. Also, the magnitude of $\vec{p}-\vec{E}$,

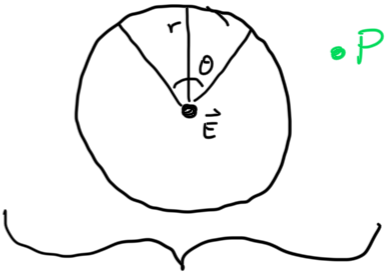
$$\|\vec{p}-\vec{E}\|_2 = \sqrt{x^2+y^2+z^2}$$

is the (straight line) distance the enemy must travel to reach the player.

So, we can first use the magnitude of this vector to determine if the player is in the detection radius of the enemy.

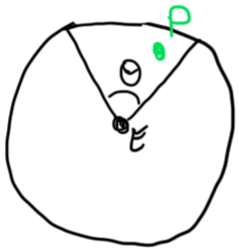


Player is in the detection radius ($\vec{p}-\vec{E} \leq r$)

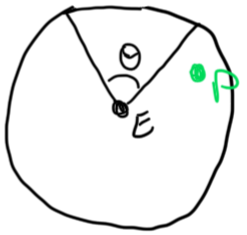


player is NOT in the detection radius ($\vec{p}-\vec{E} > r$)

If the player is in the detection radius, then we check if the player is in the detection angle θ. If the player is in the detection angle, then the player is in the detection range.

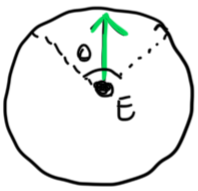


In detection angle (in detection range)



In detection radius but not angle (so not in detection range)

Note, the enemy transform tracks the "forward" vector which is a unit vector in the direction the enemy is facing:



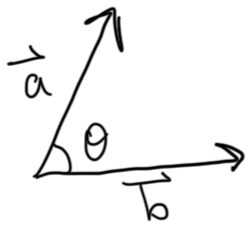
↑ = transform.forward
= unit vector in the enemy's +z direction.

We can use this forward vector and see if the vector from the enemy to player ($\vec{P} - \vec{E}$) is within $\theta/2$ of the forward vector. In that case, the player is in the detection angle.

We'll use the following identity to do this:

$$\vec{a} \cdot \vec{b} = \|a\|_2 \|b\|_2 \cos\theta$$

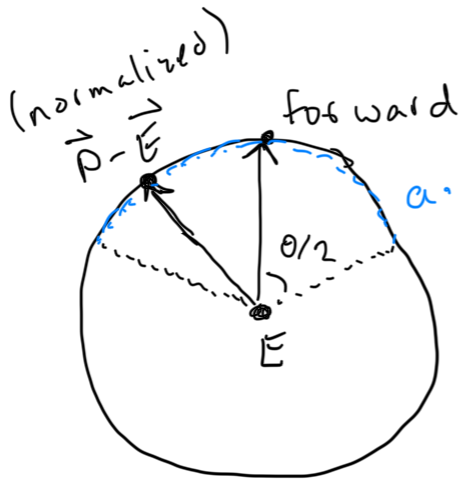
where θ is the angle between $\vec{a}$ and $\vec{b}$:



where we'll let $\vec{a} = \vec{P} - \vec{E}$, $\vec{b}$ = forward vec, and $\theta = \theta/2$

Note that $\|\vec{v}\|_2 = 1$ when $\vec{v}$ is a unit vector. So to simplify this we will normalize $\vec{P} - \vec{E}$ so that $\vec{a} \cdot \vec{b} = \cos\theta$ ($\vec{b}$ is already a unit vector).

Then if $\vec{a} \cdot \vec{b} \geq \cos\theta$ the player is in the detection angle and so is in the detection range.



$a \cdot b = (P-E) \cdot \text{forward} = \cos\frac{\theta}{2}$