diep.io Physics

Ponyomediately

1. Introduction

diep.io is a multiplayer online 2D game developed by Brazilian developer, Matheus Valadares, also known as Matheus28, M28, or Zeach. I was a player of the game actually, but one day has become an analyzer. Surprisingly, there are many people like that in the world. They use social networking services, create a community, collect and share information.

To begin with, a document that summarizes a physical information in the game has already existed. Nevertheless, the reason for writing it is that I wanted to collect information to help in my project about the duplication of this game. In other words, I just wanted to write it for myself. It's more forgivable than living a boring life, but considering that I've spent about 5% of my life working on this game, it's a bit pathetic. So I won't write anything about it. (LOL)

2. Entity

An entity is a conceptual object that exists in the game. It is designed from the smallest unit of some entities called an "elementary entity". Currently, 11 have been found and used by a game connection. Basic (B), Cannon (C), Collidable (CA), Destroyable (DA), Map information (MI), Nameable (NA), Player information (PI), Position (P), Renderable (RA), Tank (T) and Team information (TI). For example, Here is an algebraic representation of the structure of a player entity (P′) using elementary entities :

$$P' = CA + DA + NA + PI + P + RA + T$$

In addition, most of them cannot exist independently.

2. 1 Cannon Entity

A cannon entity (C) can generate bullet entities. Here is the structure of a bullet entity (Bu) :

$$Bu = B + C + CA + DA + P + RA$$

2. 1. 1 Generating Time

A timing for generating (t) them is defined by reloading and delaying; the amount of "reload" points (S_7) is more, the smaller the timing. Here is a timing formula found by a WebSocket communication :

$$t = \frac{\dfrac{1000}{T} \cdot 0.6 \cdot R_m}{\left(\dfrac{500}{457}\right)^{S_7}}$$

Note that the constant T is a tick rate, which indicates a value how many times per second a server is updated. In this game, the value is 40. And, R_m is a reloading multiplier based on the "Basic" Tank as 1.0 . Also, 0.6 is a correction factor for the tick rate. Based on these facts, it can be rewritten as follows :

$$t = \frac{15 \cdot R_m}{\left(\dfrac{500}{457}\right)^{S_7}}$$

Now, the rate (δ) of change of the value due to a change in the amount of "reload" points ($S_7 \rightarrow S_7'$) can be obtained by using the denominator of the above equations.

$$\delta = \frac{\left(\dfrac{500}{457}\right)^{S_7'}}{\left(\dfrac{500}{457}\right)^{S_7}} \qquad (S_7' \geqq S_7 \geqq 0)$$

For example, if the reload points are allocated from 0 to 7, the value is about 188% smaller.

2. 2 Collidable Entity

A collidable entity (CA) will be executed a process on physical movement when entities partially overlap each other. Also, this process in the game is called "Collision".

The method of detecting collision depends on the shape drawn by the client. Specifically, if the shape will be drawn is a rectangle, the decision algorithm is based on a "Rectangle". If it's a regular polygon or a circle, the decision algorithm is based on a "Circle". This method is in order to reduce the processing load on the server as much as possible. In addition, the overall collision detector process is used quadtree decomposition.

2. 2. 2 Size

Size is a necessary step in detecting collisions. In this game, it is defined as the distance (r) from the center. For a player entity, it will be adjusted by its level (l) . Here is a size formula found for

a player entity by the communication :

$$r = 50 \cdot 1.01^{l-1}$$

For the other entities, the values are constant, so the following table shows them :

Table 1. The value of r for a given entity

Name	r
Crasher (Small)	$17.5\sqrt{2}$
Square, Triangle, Crasher (Large)	$27.5\sqrt{2}$
Pentagon	$37.5\sqrt{2}$
The Guardian of the Pentagons, Summoner, Defender	$67.5\sqrt{2}$
Alpha Pentagons, Fallen Booster, Fallen Overlord	$100\sqrt{2}$
Dominator	150
Mothership(?), Arena Closer	200

2. 2. 3 Damage by Collision

Prepared two entities (Entity A and B) in an arena and examined for damage in the case of a collision. Let d be a maximum amount of damage that can inflicted on the collision target called "Partner". It has known that this value will be changed by depending on the situation. Here is the formula for the relationship considering by using a multiplier (m) :

$$d = d_0 \cdot m$$

Note that d_0 is a natural amount of damage to a collision partner, and m is a multiplier caused by the combination of types of entities in each other's collision. About d values, for a player (tank) entity, let S_3 be the amount of "Body Damage" points. Then the formula will be

$$d_0 = 6 \cdot S_3 + 20$$

For a bullet entity, let S_6 be the amount of "Bullet Damage" points, then the formula will be

$$d_0 = D_m(7 + 3 \cdot S_6)$$

Note that D_m is a damage multiplier of a bullet entity based on a cannon of the "Basic" Tank as 1.0 . For the other entities, the following table shows them :

Table 2. The value of d_0 for a given entity

Name	d_0
Pentagon	12
Alpha Pentagon	20
Crasher (Large)	4.0
The Guardian of the Pentagons, Summoner, Defender, Fallen Booster, Fallen Overlord	?
Dominator, Mothership	?
(Others)	8.0

Also, about m values, the following table shows them :

Table 3. The value of m for a given combination

Combination	m
Both are tanks	1.50
The partner is a bullet	0.25 (?)
Both are bullets (?)	0.50 (?)

Next, consider a damage system in the event of a collision. Let d' be the amount of damage that will give to the partner, assuming that the damage can be handled until its health (h') is reduced to 0. Then, the formula must be

$$d' = \begin{cases} h' & \text{if } h' - d < 0 \\ d & otherwise \end{cases}$$

And the formula for the wasted damage rate inflicted on the partner (w) will be

$$w = 1 - \frac{d'}{d} \qquad (0 \leq w \leq 1)$$

From these facts, the formulas for the amount of damage that they actually inflict on each other in the event of a collision are

$$d_{AB} = d_A - d'_A \cdot w_B$$
$$d_{BA} = d_B - d'_B \cdot w_A$$

The reason why damage process is not a simple subtraction process is to execute, no matter how few the health is.

2. 2. 4 Knockback by Collision

Finally, examined for knockback in the case of a collision. Parsing the communication has revealed the amount of knockback given to the partner (k_0) and the rate inflicted on its own knockback (m). So the formula will be

$$k = k_0 \cdot m$$

Table 4. The value of k_0 for a given entity

Name	k_0
Wall	2.0
Drones	4.0
Pentagon, Alpha Pentagon	11
Crasher (Small), Crasher (Large)	12
(Others)	8.0

About m values, for a bullet entity, let K_m be a knockback multiplier of a bullet entity based on a cannon of the "Basic" Tank as 1.0, then the formula will be

$$m = K_m$$

For the other entities, the following table shows them :

Table 5. The value of m for a given entity

Name	m
Crasher (Small)	2.00
Pentagon	0.50
Crasher (Large)	0.10
Alpha Pentagon	0.05
The Guardian of the Pentagons, Summoner, Defender, Fallen Booster, Fallen Overlord, Mothership	0.01
Dominator, Arena Closer	0
(Others)	1.00

2. 3 Destroyable Entity

A destroyable entity (DA) is an entity that has the concept of health. Let h_{max} be max health and h be current health, and the relationship must be

$$0 \leqq h \leqq h_{max}$$

The entity will be removed from a server when its h is reduced to 0. Also, this process in the game is called "Destruction". About h_{max} values, for a player entity, let l be its level and S_2 be the amount of "Max Health" points. Then here is the formula found by the communication :

$$h_{max} = 50 + 2l + 20 \cdot S_1$$

For a bullet entity, let S_5 be the amount of "Bullet Penetration" points and P_m be a penetration multiplier of a bullet entity based on a cannon of the "Basic" Tank as 1.0, the found formula is

$$h_{max} = (2 + 1.5 \cdot S_5) \cdot P_m$$

For the other entities, the values are constant, so the following table shows them :

Table 6. The value of h_{max} for a given entity

Name	h_{max}
Square, Crasher (Small)	10
Triangle, Crasher (Large)	30
Pentagon	100
Alpha Pentagon, The Guardian of the Pentagons, Summoner, Defender, Fallen Booster, Fallen Overlord	3000
Dominator	6000
Mothership	7000
Arena Closer	10000

Surprisingly, Arena Closer has a defined maximum health even though its damage applied is disabled.

2. 3. 5 Durability

Now, from the information about collidable and destroyable entity, the durability will be calculated. If the durability is greater than the collision partner's, the main can always kill it. If it is less, the main will always be killed, and if both are the same, both will be killed (a draw). Let d be a maximum amount of damage that can inflicted on the collision partner.

$$D = h \cdot d$$

In particular, the maximum value (D_{max}) will be

$$D_{max} = h_{max} \cdot d$$

For example, for a player entity, the maximum durability will be

$$\begin{aligned}
D_{max} &= h_{max} \cdot d_0 \\
&= (50 + 2l + 20 \cdot S_1)(6 \cdot S_2 + 20) \\
&= 4(25 + l + 10 \cdot S_1)(3 \cdot S_2 + 10)
\end{aligned}$$

Assuming its level is 45,

$$\begin{aligned}
D_{max} &= 4(25 + 45 + 10 \cdot S_1)(3 \cdot S_2 + 10) \\
&= 4(70 + 10 \cdot S_1)(3 \cdot S_2 + 10)
\end{aligned}$$

$0 \leq S_1 \leq 10$,$0 \leq S_2 \leq 10$ について，次のようにな

Table 7. The maximum durability of a player entity

S_1 / S_2	0	1	2	3	4	5	6	7	8	9	10
0	28.0	32.0	36.0	40.0	44.0	48.0	52.0	56.0	60.0	64.0	68.0
1	36.4	41.6	46.8	52.0	57.2	62.4	67.6	72.8	78.0	83.2	88.4
2	44.8	51.2	57.6	64.0	70.4	76.8	83.2	89.6	96.0	102.4	108.8
3	53.2	60.8	68.4	76.0	83.6	91.2	98.8	106.4	114.0	121.6	129.2
4	61.6	70.4	79.2	88.0	96.8	105.6	114.4	123.2	132.0	140.8	149.6
5	70.0	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0	160.0	170.0
6	78.4	89.6	100.8	112.0	123.2	134.4	145.6	156.8	168.0	179.2	190.4
7	86.8	99.2	111.6	124.0	136.4	148.8	161.2	173.6	186.0	198.4	210.8
8	95.2	108.8	122.4	136.0	149.6	163.2	176.8	190.4	204.0	217.6	231.2
9	103.6	118.4	133.2	148.0	162.8	177.6	192.4	207.2	222.0	236.8	251.6
10	112.0	128.0	144.0	160.0	176.0	192.0	208.0	224.0	240.0	256.0	272.0

3. References

- http://spade-squad.com/physics.html 【SAPDE-SQUAD.COM】
- https://github.com/ABCxFF/diepindepth/blob/main/physics/README.txt 【diepindepth】