A Peek at Metaverse Society from Web 3.0 Games: A Preliminary Case Study of Dark Forest

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***Abstract*—The notion of metaverse powered by blockchain technology has been buzzing in recent years, raising expectations for an advanced social vision of Web 3.0. Thus far, online multiplayer games are considered to be the sole counterparts of the full-state metaverse, and their in-game group behavior becomes a microscopic sample for estimating social dynamics in metaverse. In this paper, we select massive data from Dark Forest relating to players' behavior to explore how and to what extent the web 3.0 game simulates the social system. By analyzing and clustering the time series of players' behavior, We reveal the consistency of behavioral habits both inside and outside of the simulated gaming system; suggest that games based on blockchain technology have the advantage of digitally representing reality, and therefore constitute a key venue for future social practice.**

***Index Terms*—Metaverse, Blockchain, Web 3.0, Game, Social Study**

I. Introduction

With the support of blockchain technologies, the metaverse [1] has become the hottest topic in the Web 3.0 community all over the world. Many researchers in both industry and academia have been attracted by this new decentralized digital society. On the other hand, digital games, especially massive multiplayer online (MMO) games, have been widely studied from the cultural and social perspectives. Its influence on players, and the influence of players on games has been confirmed by many literature. The players' behavior in different game genres may diverse from each other due to distinct player groups and game rules. These characteristics, in turn, can reflect, to some extent, the social systems that arise in the context of the game's regulations. Therefore, Web 3.0 games, a.k.a blockchain games [2], becomes a perfect subject for metaverse social study, given the metaverse is yet to be constructed. Built on smart contracts hosted by blockchain, Web 3.0 games support cryptocurrencies and Non-Fungible Tokens (NFTs) that belongs to players, while the game rules are decentralized, trusted, and transparent. To this end, the player groups in traditional MMO and Web 3.0 games do not seem to have a high degree of overlap at present, which may lead to different network ecology. In this work, we leverage Web 3.0 games to conduct preliminary studies on the future society in metaverse.

In this work, we select Dark Forest[1] (DF), a Web 3.0 Real-Time Strategy (RTS) game, as the study subject. DF is a space-conquest MMO built on Gnosis Chain[2], a Ethereum[3]-compatible sidechain, with zero-knowledge cryptography. Players start with a home planet and expand territory by capturing new planets. For the connection between video games and the social environment, Jasper Juul's [3]research has identified three frameworks: the game as goal orientation, the game as experience, and the game as a social event. Under this approach, we focus on the game's goal setting, the player's positive experience, and the player's winning strategy. we collect In-game data that visualizes player behavior under specific game rules, summarizing the sorts of player activity, phase transitions, and tactical considerations within linear time periods. Based on an understanding of game dynamics through data analysis, we propose a dual social interpretation of DF game design and player behavior.

The main contribution of this paper is to leverage Web 3.0 games to illustrate, through behavioral analysis, how individuals balance resources between long-term goals and short-term development at different stages of development in the environment simulated by the game, and the strategies adopted in the direction of individual development. We conclude that human behavior has convergences across environments. The remainder of this paper is organized as follows: We first survey related work in Section II and introduce the DF game in Section III. Afterward, we present the data processing methodology in Section IV. We perform result analysis in Section V. Section VI concludes this paper.

II. Related Work

A. Social Studies on Online Games

Increased academic attention to video games has led to the discussion of MMO games as a micro model for social studies [4] [5]. The relationships between the gaming world and the real world, both from the inside outward in the form of effective action and from the outside inward in the form of realistic representation, effectively engaged players in social and cultural issues [6]. MMO games like the Second Life were

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[1]https://zkga.me
[2]https://www.gnosischain.com/
[3]https://ethereum.org

viewed as the new frontier of human life, including issues of gender, race, sex, money, conflict and antisocial behavior, the construction of place and time, and the interplay of self and group [7]. A series of studies of MMO games shows how elements of gameplay may extend beyond the realm of the game, bringing a better understanding of human dynamics. For example, Woods argues that social-system simulation games combine roles, rules, and other elements of gameplay effectively to replicate existing social systems, placing the participant "within" the experience in order to facilitate a greater understanding of the dynamic forces that shape society [8]. Ross et al. combine Williams mapping principle and a modern theoretical account of human decision-making to explore how a theory about individual interactions in well-defined contexts (games) can explain collective behavior [9]. Guitton points out how the immersive virtual settings function as new "spaces of life" [10]. Chen et al. conduct a social organization study by viewing game worlds as ecosystems consisting of evolving guilds and proving how guild life cycles reflect game world characteristics [11]. Current literature demonstrated a particularly valuable area of investigation. However, most of the sample games were web2 products, and we are facing the emergence of Web 3 social innovation in the post-pandemic era. With the rise of blockchain technology, the underlying design of Web3 games has changed, and it's natural to question how and to what extent a game connects with its broader technocultural subjectivities.

B. Web 3.0 Games and zk-SNARK

Web 3.0 games are collective games built as decentralized applications on the blockchain [12]. Blockchain games have been developing since the debut of CryptoKitties[4] in 2017. Most developers and researchers of blockchain games prioritize the economy and rewards within the game, thus, digital assets such as cryptocurrencies and NFTs has become the major interest in Web 3.0 games. This has likewise led to the majority of blockchain games being based on the Play-to-Earn (P2E) economic model [13]. Unfortunately, the state-of-the-art P2E games are all ponzi games. Also, there is few research work on analyzing blockchain game player behavior from a sociological perspective.

An important techniques to facilitate Web 3.0 games is Zero-Knowledge Succinct Non-Interactive Argument of Knowledge (zk-SNARK) [14]. It is a cryptographic proof that allows one party to prove it possesses certain information without revealing that information. In Web 3.0 games, zk-SNARK become important since we don't want to rely on any centralized 3rd party to make judgement and smart contract is transparent to the public. The DF game builds a zk-SNARKs system that is efficient enough for MMO games to use—making the fog of war gameplay possible, which identifies the DF game from other blockchain games.

[4]https://www.cryptokitties.co/

III. Introduction to Dark Forest

The concept of dark forest was proposed in *The Three-Body Problem* by Cixin Liu. In the book, dark forest refers to the universe, where "Every civilization is a hunter carrying shotgun." [15].When players enter the universe for the first time, they will be placed randomly on a different planet with similar initial conditions. Players could start performing different function calls, such as withdrawing artifacts and occupying the planet. Players could further explore the universe, but before that, they need to place cursors to open a new map. The exploration speed is dependent on the computational power of the CPU. Exploring allow the player to capture new planets, which could lead to more resource production. In the DF game, the resource produced by planets is silver and energy. The speed of resource production varies between different planets. Therefore players will need to fight their way toward high-efficiency planets. During the game round, players' performances are recorded and ranked. Top ranking players will be awarded planet NFT when the round ends. Scores could be earned by extracting silver, finding artifacts, and capturing planets. DF featured new gameplay compared to other traditional cryptography games, the "fog of war". This means players can't have information on all parts of the map. They can only see the explored area. This is widely used gameplay in traditional games such as StarCraft and Sid Meier's Civilization game series. However, it is not easy to implement this gameplay in a cryptography game since all the block data are open for reading on the blockchain. The game achieved this through the zero-proofing method zkSNARKs[2]. With zkSNARKs, the client could hold part of the data private while still allowing others to verify the credibility of the data. In this case, the planet's locations are kept secret from other players.

DF is open-sourced for any player who is interested in developing plugins. All the players in the game are real human beings. So far, the game has hosted eight official rounds with slightly different game rules and winning conditions. Here we take v0.6 round 5 as our main focus of the investigation.

IV. Data Processing

This section describes our specific process of data collection, preprocessing, and feature extraction. It also covers how to apply K-means, an unsupervised clustering algorithm, to capture groups of players with similar patterns.

A. Data Collection and Preprocessing

All the data used to collect players' behavior are collected from the gnosis blockchain RFC endpoints. By sending requests to the endpoint block by block, the endpoint will return the data of that block on the gnosis chain. Since the Dark Forest game is not the only one using the Gnosis chain, there are many transactions and blocks that we do not need. We reject them by trying to decode the data using the game data structure. If the decoding process fails, then the current block is not a valid Dark Forest block. Because of the network instabilities, we specify a range of block addresses (250) to fetch at a time.


```
{
    "to": "0x5da117b8aB8b739346F5EdC166789E5aFb1a7145",
    "from": "0x0C6B6A25f2bf0d15fB9CfF9BE80d28F69964655E",
    "time": 1645243375,
    "name": "transferOwnership",
    "params": [
        {
            "name": "_newOwner",
            "value": "0x5d99805ca2867f22a318c4e6b0dc5c0eac4
                57386",
            "type": "address"
        }
    ],
    "blockNumber": 20713470,
    "type": 2,
    "value": {
        "type": "BigNumber",
        "hex": "0x00"
    },
    "gasPrice": {
        "type": "BigNumber",
        "hex": "0x77359400"
    },
    "gasUsed": {
        "type": "BigNumber",
        "hex": "0x038359"
    }
}
```


The data fetched from the Gnosis Chain is extracted into a JSON structure, "to" field represents the receiver address of the current transaction, "from" field represents the sender address of the current transaction, "time" field represents the timestamp of the current transaction, "name" field represented the operation performed by current transaction, "param", "type" and "value" field represented some additional information attached to the performed operation, "blockNumber" field represented the block height of the block containing the current transaction, "gasPrice" and "gasUsed" are the gas price and gas used in the current transaction.

We preprocess the data from the time dimension to analyze it from a macro perspective in two directions: the overall trend of the whole season and the player behavior of subgroups. In order to construct the time series, we need to preprocess and clean the extracted data. From the blockchain, we get the functions called at a certain address at a certain time and their parameters, and afterward, we write them to the dictionary according to each operation. We get a data structure like: player address: "time, name of function called, function-related parameters".

B. Feature Extraction

First, we extract the address of each person's function call from the contract and rearrange it in the form of a time series to construct a time series. For example, the address 0x000...7A called initializePlayer at t0 for initialization and move for one move, and another move at t1. We record the operations at this address using the new format:0x00...cF7A: [initializePlayer 1, move 1], [move 1]. Here each time period (t1, t2, t3...) will be divided into a day, an hour, and a half-hour as needed. And on top of this, we will perform two orientations, the time series orientation, and the player cluster orientation. In the time series orientation, the number of operations in each time period will be extracted as needed. In the player cluster orientation, in addition to keeping the previous data processing results, the data on all corresponding positions of a single player will be accumulated. We cluster the parameters of some functions separately. For example, there are three types of upgrades, address 0x000...7A occurs five calls, which means that there is data for five kinds of parameters of upgrade. The kinds 0, 1, and 2 were called 0, 0, and 1 time respectively in time period 1, and 2, 1, and 1 time respectively in time period 2. Then the data will be processed as: 0x00...cF7A: [0,0,1],[2,1,1]. On this basis, similarly, the data are processed towards two orientations. In the time series orientation, the data of the corresponding positions of all players will be accumulated and finally obtained in the form of [[kind 0 in t1, kind 1 in t1, kind 2 in t1], [kind 0 in t2, kind 1 in t2, kind 2 in t2], [...], ...] of the data structure. In the player cluster orientation, the data on all corresponding positions of a single player are accumulated to obtain the data structure shaped as 0x00...cF7A: [number of kinds 0, number of kinds 1, number of kinds 2].

C. Clustering

We performed a varying number of clusters in each clustering using the K-means algorithm [16] and iterate over the number of iterations and the number of clusters. elbow method and contour coefficients are used in combination to determine the k values, with different parameters taking the best values in different data divisions.

V. Result Analysis

A. Player Function Call Frequency

It is more accurate to depict the portrait of player by using the function call, which records all of the player's actions in the game. As Fig. 1 shown, we categorized eight function calls with the highest amounts into three graphs. The first one is *move*, the second one is planet-related function calls, and the last one is artifact-related function calls. The amount of function *move* called is much larger than any other function calls. Especially at the beginning of the round, this is because it is the most important function of all. It is responsible for all logistics-related actions, such as moving silver and transferring other resources. Occupying a planet also requires the player to move to it. However, a strong correlation between function *move* and function *upgradePlanet* could be observed. Correlations could also be found between *invadePlanet* and *capturePlanet*, *withdrawArtifact* and *activateArtifact*.

To simplify the analysis, we collected 8 most representative player behaviors and categorized them into 3 graphs. The top one plots the amount of *move* function called every day during the round, it is separated into an individual graph because it has a much larger calling frequency than all other function calls combined (pie chart) as Fig. 1 shows. The second graph shows player's behaviors towards planets, and the third one is about player's behaviors towards artifacts.

We divided the round mainly into 3 stages. **Stage 1**: 2022-02-19 to 2022-02-21, this is the first two days of round 5.

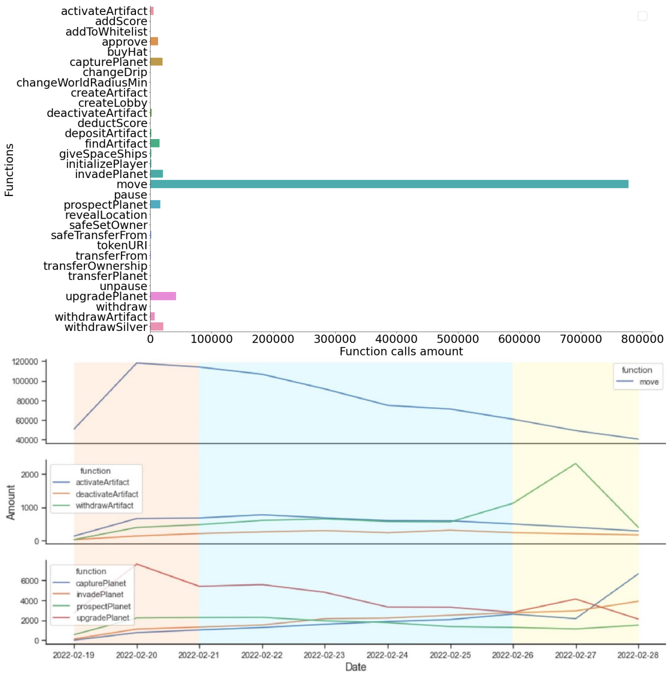

Fig. 1. Amount of Functions Called

Players are all busy exploring the surrounding environment. However, since removing the fog of war requires the CPU to mine a block, players' gameplay options are limited. We can see a significant peak of *upgradePlanet*. There is also a minor peak in *prospectPlanet*. **Stage 2**: 2022-02-22 to 2022-02-26, in this stage, the amount of *move* and *upgradePlanet* function call started to decrease in a steady rate, while *capturePlanet* and *invadePlanet* gradually increase. A more violence universe start to emerge. **Stage 3**: 2022-02-26 to 2022-02-28, in the last 2 days of the round, *capturePlanet* behavior dramatically increased to it's peak point. Accompanied by the lowest point of *prospectPlanet* and *upgradePlanet*. We could deduce that due to the planet's limited resource production rate, players are forced to fight with each other instead of keep on upgrading owned planets in order to gain more points. Since capturing planets now award the highest points among three ways of getting points.These observations match some of the ideas of the dark forest theory. Since no communication could be established between players, and furthermore, there are no rules that promote corporation between players. The only option left is to invade other players' planets and get more points.

According to players' activity portrait, the main factor propelling the development of the DF game is the expansion of space. This process is very similar to capital expansion in the early days of liberal capitalism: capital constantly plunders resources from the outside for its own development. A timeworn *Western Rationality* theme has been updated for the web 3.0 era in the DF space expedition plan. We can see the shadow of *Robinson Crusoe*, but the design of DF does not praise the greatness of expansion while highlights the survival dilemma of late capitalist society. In DF, players must actively colonize the vast starry sky because if they don't, they will be sucked up. The unknown starry sky waiting to be conquered is neither dreamy nor promising. DF mirrors the present social reality based on the degree of game goal orientation displayed by player's activities.

B. Winning Strategies

Typically, winning moments in games are associated with positive experiences. In this subsection, we explore the types of behaviors that make up a positive experience in DF by analyzing players' winning strategies. In the game, a player's power level and goals are quantified as scores, so we record the number of calls per hour to three functions, which directly related to obtaining scores, forming a time series to analyze the strategies adopted by players in terms of how they score, and how the strategies change over time. For the substance of function, *prospectPlanet* is the act of attacking others, *invadePlanet* is the act of probabilistic treasure hunting, and *withdrawSilver* consumes base resources. The first two functions need to consume energy and can indirectly improve the efficiency of accumulating resources. The third one requires the consumption of silver, which can be used to enhance player attributes and thus improve the efficiency of resource acquisition.

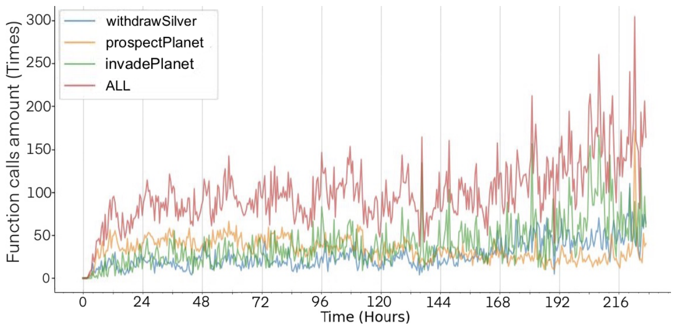

Fig. 2. Time Series of Three Operations

As shown in the Fig. 2, the curves of the four types above correspond to: *withdrawSilver*, *prospectPlanet*, *invadePlanet*, and the sum of the three. From an overall perspective, the number of operations related to obtaining scores is low in **Stage 1** and gradually increases. From the perspective of a single function, the number of *withdraw silver* is small in the early stages, increasing slowly over time, and growing rapidly in the last stage. *ProspectPlanet* tends to be flat and decreasing slowly over time, accounting for a higher percentage of the early stages than the other two, with an abrupt increase at the end. *InvadePlanet* is low at first, increasing slightly faster over time than *withdrawSilver*. The *invadePlanet* is low in the early stage, increases over time at a slightly faster rate than *withdrawSilver*, and significantly in the late stage but decreases at last. The data reveals a typical in-game battle cycle. In the early stages, the player's resources are mainly used for development. Player prefer peaceful expansion rather than consuming resources to engage in offensive and defensive battles with others. *ProspectPlanet*, as a probable byproduct of expansion, occurs more frequently than the other two, but most players do not focus on this in the early stages with the goal of scoring directly. As players develop, they also begin to have a surplus of resources and begin to clash with each other, and the benefits of winning battles are greater than maintaining Peace. In this case, players start to score points by consuming resources and invading others. When players' development reaches the limit, and the number of artifacts they can acquire decreases, players engage in large-scale battles. When the group faces the decision to rank or even survive or not based on resource reserves, there will be a lot of fighting in the later stages as the time point approaches. At the end, all parties will stop depleting each other's resource reserves and turn all available resources into real benefits. Furthermore, we can see that between directly consuming resources to gain points and indirectly consuming resources to improve one's score and resources, most people choose the latter. This will be demonstrated in the next section.

C. Individual Enhancement Strategies

For survival and development, players need to adopt strategies for strength enhancement. In this subsection, we analyze the strategies adopted by players to enhance their attributes.

1) Two Types of Enhancements: There are two ways for players to enhance themselves: activating artifacts and upgrading planets. The former is probabilistic and random, the latter is easy and controllable. Here we select *activateArtifact* and *upgradePlanet* for preliminary analysis.

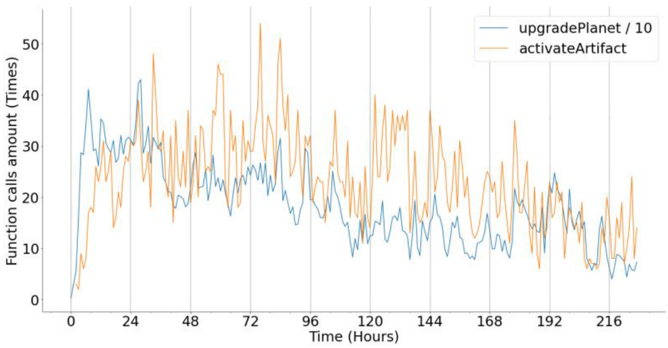

Fig. 3. Time Series of Ways to Enhance

As shown in Fig. 3, the number of activated artifacts is much smaller than the number of upgrades given to planets. For the individual functions, *activateAartifact* has a tendency to rise and then fall, with an overall more moderate. The number of *upgradePlanet*, on the other hand, increases rapidly at the beginning and then decreases slowly. Obviously, acquiring artifacts is much harder than planet upgrades. In this case, players naturally tend to choose a more reliable and simple way rather than a gambling strategy. At the same time, even if artifact is found, players cannot protect it in the absence of power. In addition, higher attributes leads to more efficient the player can find artifacts. In **Stage 1**, everyone starts from 0 and needs to accumulate resources. In **Stage 2**, after obtaining enough resources, most players choose to upgrade planet while some players discover artifacts and equip them. After a period of time, the resources needed to upgrade planets increase, and with limited resources, it is necessary to make trade-offs and upgrade planets with stronger attributes. At the same time, as players continue to develop, the total number of times a planet can be upgraded decreases. Thus, we can summarize the player's enhancement strategies. Players naturally tend to develop in a steady and simple way rather than adopting a gambling style strategy. They choose to boost when they have sufficient resources and high investment returns or low investment costs, and start making trade-offs when they have limited resources or high investment costs or relatively low returns. In order to further examine the player's investment strategy, we will analyze the simple and controllable investment method, that is, the call to *upgradePlanet*.

2) Upgrade Planet: Players have three directions to choose from when calling *upgradePlanet*:*defence*, *range*, and *speed*. *Defence* reduces the power of the attack received, *range* represents the range at which the planet emits energy, and *speed* affects how fast the planet sends energy. In Fig. 4, the four sequences are the time series curves of *defence*, *range*, *speed*, and the accumulation of the three.

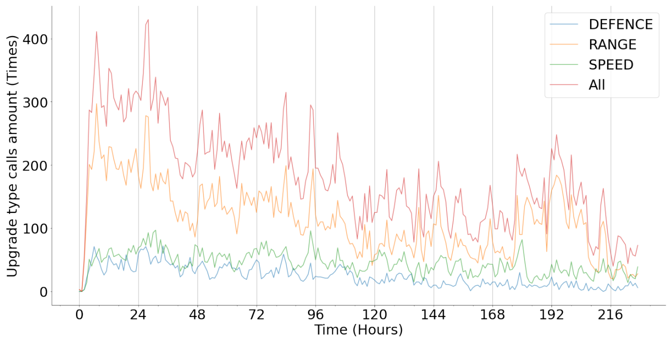

Fig. 4. Time Series of Three Kinds of Upgrading

In terms of total number, the number of *range* is much larger than the other two, and the count ratio of the three upgrades is 1:5:2 in the whole game. From the perspective of time division, in **Stage 1**, after a short accumulation of resources at the beginning, players massively perform *range* upgrades, and the number of upgrades decreases over time. In **Stage 2**, the total number of upgrades is much less than in stage1 and continues to decline, but the trend of decreasing *speed* and *defence* is much less pronounced than *range*. At the intersection of **Stage 2** and **Stage 3**, there is a clear pickup in *range* and then a decline. *Defence* and *speed* follow a similar pattern, but level off. Data trends suggest that in the early expansions, there are few crossfires between players and players, and most are in independent zones when reaching new planet is more important for development. After a period of time, resources were diverted to the development of *dedenxe* and *speed*. In the late stages, players focus on planet range which has strategic significance. Finally, all upgrades are reduced because the silver used for upgrades is also consumed for scores. Most people have completed their strategic development, and it does not make sense to upgrade more planets. More data allow us to zoom in and observe the strategy choices of individual. Fig. 5 shows the clustering of players' upgrade directions in three-dimensional space. Each point in the graph represents a player, and the coordinates of the x, y, and z axes represent the number of player upgrades in *defense*, *range*, and *speed*, respectively. The distribution of the three types of players in *range* is similar, the number of *defence* and *speed* of one type of players is similar, and this type of players accounts for the most; in the other two clusters, one type focuses on *defence* and one type focuses on *speed*. the number of players focusing on *defence* is more than the other type, but fewer players in the other category have upgrades on *speed*.

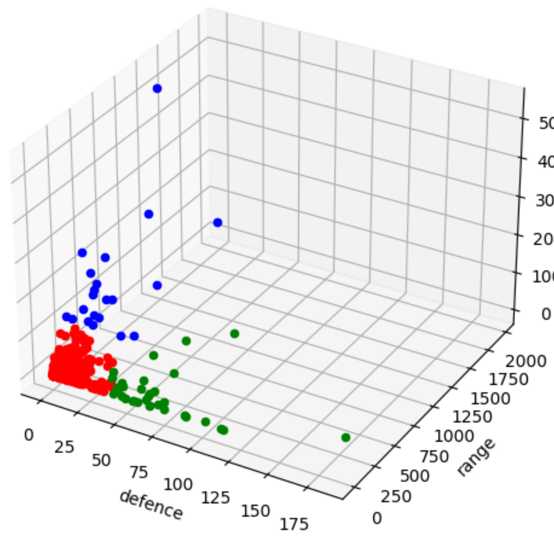

Fig. 5. Clustering of Three Kinds of Upgrading

The above two aspects of the analysis of players' enhancement strategies suggest: **1)** The range that power energy can reach is the most important in strategic decisions: when developing, range determines the speed and breadth of expansion; when generating rivalries, range determines the distance between attack and defense. **2)** Defensive power is more generally welcomed as a passive ability that takes effect immediately, as opposed to speed, which is more aggressive and prone to armament competition. **3)** Players' overall decisions change over time and as the situation changes: in the early expansion, players are generally weak, there are fewer conflicts, more overall upgrades, and more range upgrades; after the firefight other attributes increase in importance, the total number of upgrades and range upgrades decrease; in large-scale long-distance combat and resource transfers, the number of upgrades and range upgrades again The number of upgrades and range upgrades are again increased when large-scale long-range combat and resource transfer are in progress; when the priority of final realization is the highest, there is no value in spending on combat ability upgrading.

VI. Conclusion

In this paper, we examine the social connection between DF and its technocultural subjectivities. Data analysis shows that most players in DF tend to develop peacefully in the early stage, fight for resources in the middle stage, and focus on converting game assets into monetary gains in the final stage. In the DF game, the layout of the environment mimics the growth of capitalism and the profit-related behaviors demonstrate how the blockchain game is more realistically based.

VII. Acknowledgments

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