Reciprocal Crowdsourcing: Building Cooperative Game Worlds on Blockchain

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***Abstract*—Crowd intelligence has become increasingly popular during recent years, thanks to the exploding global Internet usage. However, most crowd intelligence platforms ceased to operate due to the untrustworthy data or lack of motivated participants. The blockchain technologies propose decentralization as the potential solution to this dilemma. This work introduces reciprocal crowdsourcing, a novel decentralized cooperative crowdsourcing model powered by the blockchain to strengthen trust among crowd intelligence participants, who perform transparent collaborative work in the system thereafter. To validate our proposal, we implemented "Cell Evolution", a blockchain game, in which the players can build cooperative game worlds on the blockchain with reciprocal crowdsourcing.**

***Index Terms*—Crowd Intelligence, Crowdsourcing, Blockchain, Game, Decentralization**

I. Introduction

Playing an increasingly important role in the era of artificial intelligence (AI), the crowd intelligence [1] is a paradigm that attracts, aggregates and manages massive participants to complete challenging tasks in a competitive or cooperative manner. Thanks to the popularization of the Internet, crowd intelligence became a practical solution with the support of online crowdsourcing [2]. In a conventional crowdsourcing system, task initiators increase productivity and reduce labor costs by splitting the project overall goals into tiny tasks and disseminate them to massive participants. Because crowdsourced participants are diverse in terms of backgrounds, the crowdsourced data for crowd intelligence can better represent distinct user groups, thus, enhance the outcome of AI training.

However, most online crowd intelligence platforms cease to operate due to the following issues. First, the participants may not be well motivated in completing the tasks, since the incentive for most tasks is insufficient. However, the increasing reward for the tasks will significantly reduce the cost efficiency of the system. Second, the quality of completed tasks is difficult to be measured. In fact, the state-of-the-art crowdsourcing platforms are still struggling with the authenticity of the submitted data from the participants. Third, the crowdsourcing outcome may not be trustworthy, since it may be manipulated by the task initiators. In fact, existing platforms assume that the task initiators are always honest users in the system, since they are the owners and the users of the crowdsourced data. However, this assumption is not always true in recent emerging scenarios. For example, a public opinion poll is a typical application that massive participants' decisions are submitted and summarized as an overall outcome. However, the poll results are not always accepted by the public, since the task initiator has the intention to tamper the data for their own benefits.

The keys to addressing these issues are the ownership and auditability of the crowdsourced data. Here we define reciprocal crowdsourcing, a special crowdsourcing platform in which the participants are not only the data contributors but also the beneficiaries. In this work, we employ blockchain technologies [3], the promising decentralized infrastructure, to facilitate reciprocal crowdsourcing. With the blockchain's feature of immutable data and transparent smart contract, we envision a decentralized crowd intelligence platform that the participants can retain the ownership of their work and the whole procedure of crowdsourcing can be audited by the participants and third parties.

In order to validate our idea, we designed and implement "Cell Evolution", a game with reciprocal crowdsourcing concept over Nebulas blockchain[1]. Through the gameplay, we collected the individual players' intelligence, represented as cell data, to form the crowd intelligence of the game world.

The remainder of the paper is organized as follows: We first survey the related work in Section II before we present the propose reciprocal crowdsourcing system in Section III. Afterward, we illustrate our design of Cell Evolution, in Section IV and analyze the preliminary results from online players in Section V. Section VI concludes this paper.

II. Related work

A. Blockchain

Blockchain technology becomes the fundamental of the decentralized system [4] since BitCoin was introduced by Satoshi Nakamoto in 2008. As a core mechanism for this type of cryptocurrency, blockchain technology gained extensive attention from the crowds with the success of Bitcoin in recent years. In the process of bitcoin formation, a block is a storage unit that records the transaction information of all the block nodes in a certain period. Each block is linked by the hash algorithm, and the latter block contains the hash value of the previous block. As the information exchange expands, the

[1]https://nebulas.io/

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blocks, one after another are successively connected like a chain, which is called Blockchain. In short, blockchain can be seen as a public ledger, in which all the transaction information is reserved in a chain of blocks [5]. Not only applied in cryptocurrency design, blockchain has other potential applications: Escrow service [6], register of electronic voting [7], recording personal private data [8], game design [9].

B. Crowdsourcing

Crowdsourcing is a process of organizing labor, where firms parcel out work to some form of (normally online) community, offering payment for anyone within the crowd who completes the tasks the firm has set [2]. Through crowdsourcing, crowd intelligence system can be implemented. Today, more and more companies tend to select the crowdsourcing as a way to outsource their tasks or experiments to the crowd, on account of a mass of labors/rich samples that can be obtained via internet [10].

In general, a human intelligence-based crowdsourcing system consists of three basic elements: Operator/initiator, participants/workers, and centralized crowdsourcing program [11]. The Initiator of the crowdsourcing activity will decompose its work to small tasks and post them to the designed centralized crowdsourcing program. The centralized crowdsourcing program will provide affordances to attract potential users into this activity. Then the participants will receive the tasks and resolve it for certain rewards. This type of system is widely applied in data collection. Take the paper published in the Nature magazine in 2018 as an example: researchers outsourced the image-classification task to a mainstream video game (EVE Online) as a mini-game, players would finish the task (mini-game) voluntarily for some bonus [12]. Through that system, 33 million classifications of patterns were gathered from 322,006 players, which was hard to achieve through traditional outsourcing methods.

C. Motivations of Crowdsourcing Activity

Compared with outsourcing way, studies have shown that crowdsourcing costs are lower, the risk is lower, and problems are solved with more quality and alternative methods [13]. Successful crowdsourcing needs an active crowd of participants, so the motivation of the crowdsources is crucial [14]. According to previous research, the motivations and reasons that lead people to participate in the crowdsourcing activities can be classified as two classes–extrinsic and intrinsic [15]. For example, extrinsic motivations through the crowdsourcing activity, participants can get the monetary reward or physical fitness; intrinsic motivations they can get some abilities, feel satisfied or achieve social recognition [16] [17]. Hence, it's necessary for organizers to design an attractive crowdsourcing system that promotes and facilitates the formation of positive motivations towards crowdsourcing tasks and suit to the form of the activity [18]. Google Ingress and Pokemon Go are both successful examples of this domain [19]. This type of game crowdsources players to label the concrete address on the map. After setting some virtual substances around the map, the player will go outside and search for them. After every correct mark, players are rewarded with some unique items, which will be the affordances to get them involved.

III. The Reciprocal Crowdsourcing Platform

Based on the blockchain, we put forward the reciprocal crowdsourcing system. In contrary to conventional centralized crowd intelligence systems, out framework innovates from three perspectives: **1) The permanent ownership:** Through our decentralized framework, participants are more likely to join in the crowd intelligence activity for the permanent ownership of their work. Moreover, their data has the potential to be reused in other crowd intelligence works or help to recruit the veterans. **2) Trust:** Every piece of the information and the operation over the data can be audited through the blockchain by anyone at any time, which makes our obtained data dependable. This feature can bring trust to participants, the operator, and the third party. **3) Cooperation:** the openness of data in the system provides an opportunity for the participants to observe other participants' inputs, thus, encourage potential collaborative work in crowdsourcing.

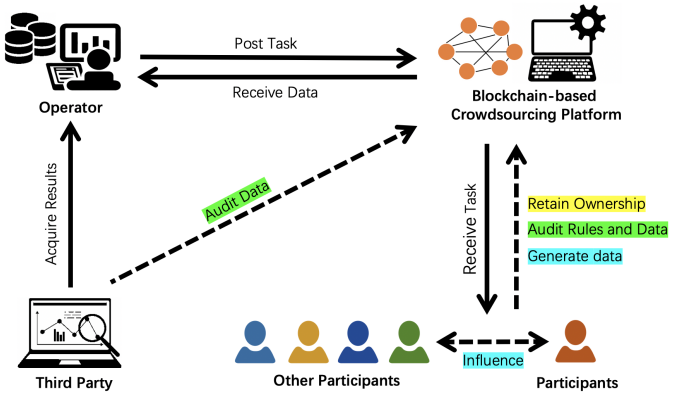

Fig. 1. Conceptual Framework of Reciprocal Crowdsourcing Platform

Fig. 1 depicts the conceptual framework of the proposed reciprocal crowdsourcing platform. Different from existing blockchain-based crowdsourcing systems [11], the participants and third parties have access to the result data sets, which make the above-described features possible.

A. Permanent Ownership

In the existing crowd intelligence program, participants complete the assigned tasks for monetary rewards or virtual prices in certain games. However, the monetary reward is usually set as a very small amount, which may not provide sufficient incentive for task workers. On the other hand, the virtual prices are just a series of virtual assets, which are often limited to the internal circulation of a game or a project. Hence, the task participants may not continue to contribute once they get bored from the particular appliction.

With the blockchain, things can be completely different. Once the virtual assets are written on the blockchain, the workers' accounts, work results, and rewards can all be linked to the

worker's blockchain address. The participants have permanent ownership of the address and the assets underneath it. These data become participants' everlasting owned property rather than temporary itemswhich will increase their engagement.

It is also simple for developers to reuse the assets of other crowd intelligence activity for secondary transformation or cross-program reuse, because the worker owns the unique address with his/her assets forever [20]. For instance, KittyRace [2] is a racing game based on CryptoKitties tokens. The player logs in with his own Ethereum address, and the game will automatically get all the players' CryptoKitties characters for the car racing.

At the same time, there is another benefit. In previous crowd intelligence programs, new projects often need to spend a lot of effort into recruiting new users. In contrast, our system can reduce these promotion costs. For example, the above-mentioned KittyRace can convert the players in CryptoKitties in a short time at a very low price. Similarly, the new crowd intelligence program can get users from the existing one easily through our system.

B. Trust

Most of the time, participants and developers tend to stand in opposition to each other in the crowd intelligence program. One wants to find an imbalance of the activities to earn reputations or rewards as more as possible. The other side adjusts the parameters of the program by changing the program mechanism to extract the value of the user. However, through the blockchain, the relationship between the developer and the worker will change substantially, our system can bring trust to each other. The rule and other information of the crowd intelligence program will be written to the smart contract in the blockchain. Everyone can check them at any time. And participants and developers can neither change it later from one side. Participants can clearly understand the meaning and value of their work. The operator doesn't need to worry about the plug. Transparency information will bring trust to each other. Participants will enjoy the task more naturally.

For the third party, they do not need to worried about the authenticity of second-hand data or the results from the crowdsourcing operator. The operator also doesn't need to think about how to verify their data to the third party. Through our system, the third party can trace every piece of data in the blockchain directly.

C. Cooperation

In the centralized crowd intelligence activity, designers just only design activities in certain areas to attract the crowd to join in. They set affordances for the user, and get what they need in back. The user just goes through the activity progress mechanically and gets positive emotion for himself. For instance, the worker chases the high points or scores just for his psychic gratification. Some affordances like leaderboard or ranking just only provide a way for workers to show their work. No matter how professional a worker is, he has no influence on others. In previous work, the internet is mainly used to connect every worker with the server or transport information of task and feedback between them. However, the Internet should be applied like a net to connect users, instead of just sharing information between two nodes. The possibility that interaction between users can promote engagement and new information is neglected. Studies have shown that collective intentions play a key role in cooperative crowdsourcing [21]. Very few researches study the effects of cooperative crowdsourcing. In our system, we provide a way for participants to interact with each other. Through the decentralized attributes of blockchain, the information that participants upload to the blockchain can change or be part of the program. For instance, the participants may meet their trace in the new round of tasks, even in another activity in the same system. Although there may exist some insubordinate workers, loyal workers will spontaneously maintain the balance of the program, help developers to acquire users, extend the life cycle of the program, and build the entire community. All these can form a small but more real society. We do not need to worry about if the participants are rational, because previous research has helped us to verify that operators are more likely to achieve higher profits in a larger group of workers whose average level of cognition is low [22]. It can attract more participants to join in because workers can cooperate to change the world by their own hands, which is a brand-new experience.

[2]https://kittyrace.com/

IV. The Game Design of Cell Evolution

The key idea behind our approach is to apply blockchain to crowd intelligence design by following our proposed platform. Based on the reciprocal crowdsourcing system, we propose a program named "Cell Evolution", which can be accessed at http://www.cellevo.net:9306/. In this game, we crowdsource the players (individual intelligence) to construct the game world (crowd intelligence) together.

A. Basic Elements

Cell Evolution is built on the Nebulas chain. As shown in Fig. 2, the top panel on the homepage is an information bar, showing the current status of the cell. The survival days represent the number of days your cells have survived within the game. The goal for the player is to survive as long as possible to get a higher score. The cell numbers represent the quantity of cells the player owns, and the target is to cultivate as many cells as possible. The external environment will get harsher along the survival days, and the high-risk environment will threaten the life cycle. Reproductivity determines the cell numbers of each reproduction, while the Adaptability determines the success rate of mutation. Survivability determines the resistance of cells against the external environment. The life cycle determines the cell's survivability. The player can try to go dormant before the end of the life cycle.

The left bottom area is a set of buttons, with which the players cultivate their cells through various methods: Divide, Evolve, Mutate, Sleep.

Fig. 2. Screenshot of Cell Evolution

Divide can increase the number of cells. Evolve and mutate can enhance reproductivity, adaptability, and survivability under particular conditions. There are three modes of mutation. Sleep can restore the life cycle, and the number of recoveries is related to survivability and the external environment. Cell inheritance can get partial world ability at the beginning of the game. Apoptosis can sacrifice itself and donate the main ability of the cell to the world.

Every detail of the world can be displayed to the players by clicking the "World Data" button, as shown in Table. I, so that players can observe the appearance of each world and each cell group data. This feature can better demonstrate social gameplay and more clearly recognize the meaning of coexistence.

TABLE I
WORLD DATA INFORMATION

World Data	number of cells
	final evaluation title
	world adaptability
	world survivability
	world reproductivity
	external environment
	world survival day
	overall score
	world number

Players need to balance the adaptability, reproductivity, and survivability in the game. When the player finished the game, they can choose to do the DNA merging, this function will upload the data into the whole ethnic group. If the whole ethnic group have unbalanced data, the current whole world will be destroyed.

B. Implementation for Key Concepts

Permanent ownership: First of all, we can get the data of cell groups as shown in Fig. 3 from the blockchain, which represents the various attributes - cell group's id, cell creator, number of cells, final evaluation title, adaptability, survivability, reproductivity, external environment, survival day, overall score, world's id - of the cells. Each piece of data will bound to the player's unique address. Users can also get it through the world or cell information buttons on the website, and even query the upload time and player address of a certain fusion from nebulas directly (https://explorer.nebulas.io/#/address/n1gFbEA3c8W6fAHgEhCNYoYBDyN7jCNmG7T), as shown in Fig. 4. All these can also prove that our data is real and trustworthy.

```
|5,n1LAt44u7BMaLjGRZym6UetswpLk1uV34C6,12,
9,3,8,2,21,2054,Little normal Monoplast,0

|6,n1LAt44u7BMaLjGRZym6UetswpLk1uV34C6,76,
24,126,459,3,33,61075,Little normal Archaea,0

|7,n1SPgMzwMPJ485WYWLnhpay7j7VS2sThU5w,6,
13,2,8,1,12,2318,Little normal Monoplast,0
```

Fig. 3. Example of cell group's information in the blockchain

Trust: Cell evolution consists of multiple contracts. The specific rules of the game have been written on the smart contract before the game coming into use, players can check it by themselves on the Nebulas. For example, Fig. 5 shows

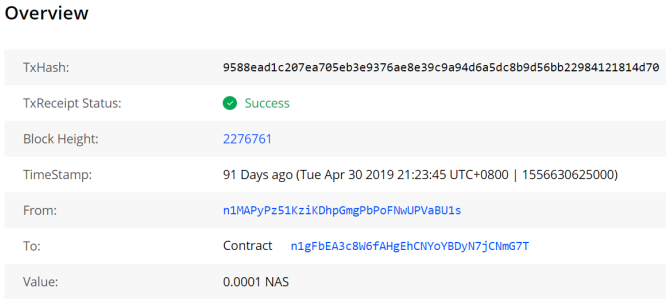

Fig. 4. Screen shot of a cell group's information in the blockchain

the part of the rule of how the world's title is judged. Players can more selectively develop their cells to guide the future way of the world and get the title that they prefer. This can provide trust to the players, and make the systems results more reliable.

```
worldtitlecheck: function() {
    var newcellworld = this.cellhistory.get(this.historyno);

    var inworldno = parseInt(newcellworld.endcellid)
    - parseInt(newcellworld.startcellid);
    if (inworldno > 100) {
        newcellworld.worldtitle = "Highly evolved";
    } else if (inworldno > 50) {
        newcellworld.worldtitle = "Lively";

    } else {
        newcellworld.worldtitle = "Silence";
    }
```

Fig. 5. Part of the smart contract

Cooperation: Players need to use their strategies to develop unique cells as many as possible. Overall thousands of titles for cells can be obtained in the game. Until the end of the game, the player will be asked whether to get cell fusion (upload his cell groups information to the blockchain). After he decides to do so, the world (external environment) will be changed, maybe in a good way or a bad way. Every attribute of the world is the nonlinear combination of the trait of each cell group. The later player of this world will be influenced by his work. Millions of the cells will decide the fate of the world. For instance, some players would like to be world guardians, they will adjust the attribute of cell group carefully to repair and extend the world life; some players would like to be world destroyers, they will upload toxic cells and enjoy the fun of destroying. The function of cell inheritance can best represent this point. The participant can choose to inherit some characteristic of the world that has been changed by other players. The world database is not a scoreboard, every participants' fusion is related to the survival of the entire ecological group. Only balance the inner groups reproductivity, adaptability, and survivability, then the whole group can develop and survive.

V. Result Analysis

According to the data on the Nebulas blockchain, 331 players wrote their cell groups into the blocks by the end of July 2019. The total 1684 cell groups enriched 147 random virtual game worlds. All the data can be traced to the Nebulas blockchain with our game address.

A. Game Difficulties

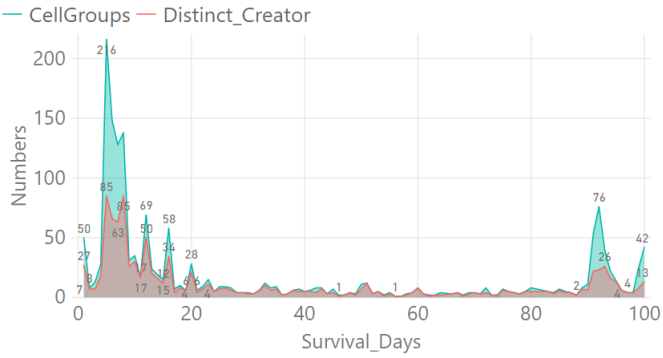

Fig. 6. The number of cell groups and distinct creators over survival days

Fig. 6 depicts the number of cell groups and distinct creators with certain survival days. It can be found that most of the cell groups can not survive for more than 15 days, while there are a small group of elite players who can make their cells live for more than 90 days. Apparently, there exists polarization among the participants. These results can help us to improve the system later to make the difficulty of the game smoother.

B. Returning Players

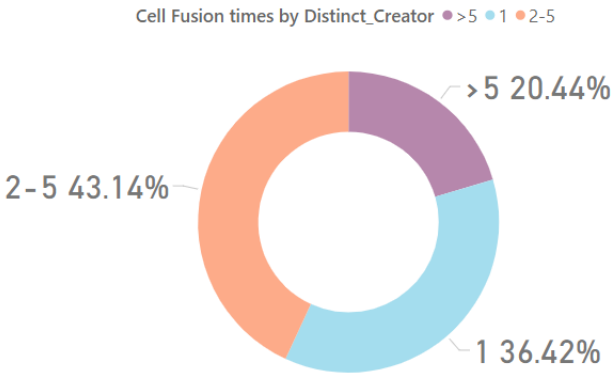

Fig. 7. Cell fusion times of the creators

Fig. 7 plots the proportion of the cell fusion times of the players. We observe that only 36.42% of the players get one fusion. Every fusion consumes the gas in the player's wallet, so repetitive cell fusions mean the player is willing to join that program again for some price. There are nearly 2/3 players (63.58%) who would like to participate in the game one more time. This proves that most of the players are interested in the game and involved in "Cell Evolution".

C. Overview of Cooperative Worlds

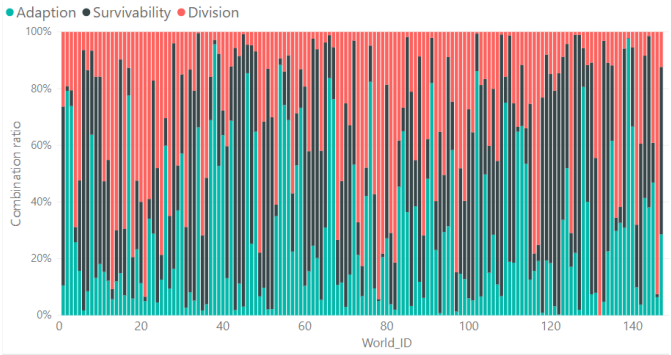

Fig. 8. The proportion of the world's composition

Through the contribution of all the players, we can get 147 unique worlds. Fig. 8 shows 147 worlds with different combinations of the three main attributes - adaption, survivability, and division, which are the nonlinear combination of the fusion cell groups. Compared with the traditional way to generate a game world by the neural network, our model results are closer to the real world, which can be regarded as a small society, so these data can be the template for other game worlds design. And the decentralized attributes of our crowd intelligence systems can guarantee the authenticity of our data because they can check every state and change of every piece of data through the blockchain.

VI. Conclusion

We present a decentralized crowd intelligence system design method - Reciprocal Crowdsourcing - in this work. Based on the decentralized crowd intelligence system, participants can fully control what they own in the program just like their property, which can increase their engagement. Transparent information can be transferred between the program manager and participants, which brings trust to each other. The ability for participants to interact with each other provides a new way for collective innovation, which can also be used to improve the crowd intelligence system itself. If a third party wants to use the results of the crowd intelligence activity, our system can ensure the authenticity and traceability of the data. We implement the approach as a game named "Cell Evolution", and the results show that the method is effective.

One remaining issue of our systems design is that it is hard to measure the motivational effects quantitatively. So we recommend the later research can borrow the idea from philosophy and psychology as a basis to explain what the behavior outcomes can reflect. In future work, we plan to design another crowd intelligence program, in which users can use the information of the cell group in "Cell Evolution".

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