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Mathematical Modeling of Social Games

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***Abstract*—Human computation is a technique that makes use of human abilities for computation to solve problems. Social games use the power of the Internet game players to solve human computation problems. In previous works, many social games were proposed and were quite successful, but no formal framework exists for designing social games in general. A formal framework is important because it lists out the design elements of a social game, the characteristics of a human computation problem, and their relationships. With a formal framework, it simplifies the way to design a social game for a specific problem. In this paper, our contributions are: (1) formulate a formal model on social games, (2) analyze the framework and derive some interesting properties based on model's interactions, (3) illustrate how some current social games can be realized with the proposed formal model, and (4) describe how to design a social game for solving a specific problem with the use of the proposed formal model. This paper presents a set of design guidelines derived from the formal model and demonstrates that the model can help to design a social game for solving a specific problem in a formal and structural way.**

I. Introduction

Human computation is an idea of solving the difficult artificial intelligence (AI) problems through human presence over networks. There exists some AI problems that computers are either unable to or are very poor at solving, but they are easy for human to solve. For example, there is not a general computer system that can quickly recognize and tag objects in an image with high accuracy. Hence, to collect object tagging information manually, it is not enough just to rely on either paid human or unpaid volunteers to annotate these images. Moreover, we cannot guarantee the information they provide is correct as the information can be rather subjective and may be error prone. As the number of online game players is increasing nowadays, social games have been proposed to collect information from players during the game play. Players play social games because they are fun, but as a side effect of their playing, accurate information is collected from them.

To effectively collect information from players through a social game, we have to achieve two important factors.

1) **Guarantee the quality of collected information.** In a social game, the system has to provide an unbiased and fair environment in order to avoid cheating. The game has to encourage players to provide correct information as the goal of the game, check the accuracy of the information provided by the players, and ensure the collected information is in a useful manner or format.
2) **Maintain the enjoyment of players in the game.** Players play games because the games are fun. The objective of a game cannot be achieved if no one plays it. As a result, a game has to provide entertainment value to players with different playing experiences in the game.

The current social games are developed on an ad-hoc basis without a formal framework that provides a systematic approach. To address the above issues, we propose a general formal model for social games. The rest of this paper is organized as follows. Section II gives an overview of preview works related to this paper. Section III describes our proposed model for social games. It describes some of the existing social games as instances of our model. Section IV addresses the common issues of social games by analyzing the properties of our proposed model. Section V presents a set of design guidelines based on the formal model to demonstrate how to design a social game for solving a specific problem in a formal manner. Section VI gives a discussion and conclusion.

II. Related Work

There were a number of high profile projects that tried to solve many difficult AI problems through the use of computational power of computers around the world. Examples for collecting commonsense knowledge are Cyc [7], Open Mind [13] and Mindpixel [1], and an example for solving the maximum clique problem is Wildfire Wally [10]. All these games either relied on contributions from online volunteers or paid engineers to enter information explicitly. Therefore, they were unable to scale up the system due to high cost. Moreover, these systems typically have no validation mechanism to guarantee that the information collected is accurate.

To encourage more Internet users to provide accurate information to solve the difficult AI problems, social games were proposed to provide entertainment to the online game players, but as a side effect of their playing, accurate information can be collected from the players for solving the problems.

ESP game [14], Peekaboom [18], Squigl [2] and Phetch [16] were proposed to collect text information for images. The objective of ESP game [14] is to collect labels for images on Web. In 2006, Google brought a commercialized online version of the ESP game, the Google Image Labeler [3].

[1] http://www.mindpixel.org
[2] http://www.gwap.com/gwap/gamesPreview/squigl/
[3] http://images.google.com/imagelabeler/

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Peekaboom and Squigl aim to label images with all fully annotated information about objects in a given image, where each object is located, and how much of the image is necessary to recognize it. Phetch is to collect explanatory descriptions and sufficient detailed information for images.

Since the commonsense knowledge is so obvious that no one has bothered to record it and the knowledge collected by using search engine may be incorrect and in unstructured format. For this aspect, Verbosity [17] aims to collect common-sense statements or facts related to a given word, while Common Consensus [8] collects and validates common sense knowledge about everyday goals.

Tagatune [6] is an audio-based game that aims to extract subjective descriptions of sounds and music from players. Matchin [4] is a game for collecting players' preference or taste on image aesthetics. Various games of OntoGame [12] apply human computation to ontology alignment and web content annotation for the Semantic Web.

There currently exist many social bookmark sites on the Internet, such as del.icio.us [5]. The Dogear Game [3] is a social game that aims to achieve organizational goals which players can learn about their colleagues' bookmarks. Social Heroes [11] is a pervasive social game in which players trade points by tagging each other using Twitter, and provides an interface for surrounding personal relationships. CyPRESS [5] is being used for e-recruiting which combines self- and e-assessment to improve the short listing process.

Restaurant Game [9] presents a method of learning human behavior patterns through online gaming on creating a salad. In Diplomacy [4], players are required to make deals and plan together with their opponents by creating and dissolving alliances from round to round for ultimate victory.

The Gopher system [1] employs mobile social gaming for geospatial tagging. The Gopher Guessing Game was an early concept prototype that aimed to tag locations in the real world through gameplay, it allows asynchronous matches (so players did not have to be connected at the same time). The Context-Aware Recognition Survey (CARS) system [19] uses ubiquitous sensors to monitor activities in a home. It is a game in which users attempt to correctly guess which activity is happening after seeing a series of symbolic images that represent sensor values generated during the activity.

Existing social games are casual games. Casual games are designed to have simple game play, and are intended for use by a wide player demographic [2]. Since the current social games are developed on an ad-hoc basis without a systematic approach, a formal framework does not exist for designing a social game in general. von Ahn et al. [15] summarized some common properties of current social games and listed out the design principles of current social games. Their study is description-based, but not in a formal framework.

[4]http://www.gwap.com/gwap/gamesPreview/matchin/

[5]http://del.icio.us

III. Social Game Model

A. Definitions

Before proceeding further, we start with the definition of data of all general data types. Then we define the problem domain and also the social game problem. Next, we provide a set of definitions for social game framework.

Definition 1 *A data $\mathcal{D}$ is an object with a data type $\mathcal{T}$ and a set of attributes denotes as $\mathcal{A}$:*

$$\mathcal{T} \in \{text, image, video, sound, URL\}$$

$$\mathcal{A} = (\mathcal{A}_1, \mathcal{A}_2, ..., \mathcal{A}_\mathcal{X})$$

where the date type $\mathcal{T}$ is the media type presented by $\mathcal{D}$; and each attribute $\mathcal{A}_\mathcal{X}$ has a relationship $Rel(\mathcal{A}_\mathcal{X})$ and a set of value $\mathcal{V}(\mathcal{A}_\mathcal{X})$ = $\{\mathcal{V}_1(\mathcal{A}_\mathcal{X}), \mathcal{V}_2(\mathcal{A}_\mathcal{X}), ..., \mathcal{V}_Y(\mathcal{A}_\mathcal{X})\}$; and each value $\mathcal{V}_Y(\mathcal{A}_\mathcal{X})$ is an object with its own data type and contains its set of attributes. $\mathcal{V}_Y(\mathcal{A}_\mathcal{X})$ is also called metadata of $\mathcal{D}$.

Definition 2 *A **social game** is a 4-tuple ($\mathcal{SGPD}$, $\mathcal{GR}$, $\mathcal{GF}$, $\mathcal{ANS}$), where sets:*

1) *$\mathcal{SGPD}$ = $(\mathcal{E}, \mathcal{F}, \mathcal{G}, \mathcal{C})$ is the social game problem domain.*
   a) *$\mathcal{E}$ = $\{e_i|i = 1, ..., x\}$ is a set of problems that we want to solve where the problem e_i is to collect metadata of an input data $\mathcal{D}$.*
   b) *$\mathcal{F}$ = $\{f_i|i = 1, ..., y\}$ is the answer domain. Solutions to any $e_i \in \mathcal{E}$, which f_i is a value of an attribute of $\mathcal{D}$ that we want to collect, can only exist in $\mathcal{F}$.*
   c) *$\mathcal{G} : \mathcal{E} \times \mathcal{F} \rightarrow \Re \in [0..1]$ is a function that determine whether an answer is correct to a problem.*
   d) *$\mathcal{C}$ is a set of constraints in the game that*
      i) *indicating the attribute(s) we want to collect such that $\mathcal{A}_\mathcal{X} \in \mathcal{A}$;*
      ii) *indicating the set of values that we want to collect within $\mathcal{V}(\mathcal{A}_\mathcal{X})$.*
2) *$\mathcal{GR}$ = $(\mathcal{D}, \mathcal{M}, \mathcal{C}, \mathcal{R}, \mathcal{P}, \mathcal{I}, \mathcal{O}, \mathcal{G}, \mathcal{W})$ represents rules of a social game.*
   a) *$\mathcal{D}$ is input data that we want to collect its metadata.*
   b) *$\mathcal{M}$ = $\{m_i|i = 1, ..., x\}$ is a set of metadata which are the values of attributes of $\mathcal{D}$ that we want to collect.*
   c) *$\mathcal{C}$ is a set of constraints in the game that*
      i) *indicating the attribute(s) we want to collect such that $\mathcal{A}_\mathcal{X} \in \mathcal{A}$;*
      ii) *indicating the set of values that we want to collect within $\mathcal{V}(\mathcal{A}_\mathcal{X})$.*
   d) *$\mathcal{R}$ = $\{r_k|k = 1, ..., nR\}$ is the set of roles that players could have during a game.*
   e) *$\mathcal{P}(r_k)$ = $\{p_j^k|j = 1, ..., n\mathcal{P}(r_k)\}$ is the set of players that are assigned to the role r_k during a game.*

f) $\mathcal{I}(p_j^k)$ = $\{i_m^{k,j}|m = 1, ..., n\mathcal{I}(p_j^k)\}$ *is the set of input given to the player p_j^k for solving the problem of input $\mathcal{D}$ during a game.*

g) $\mathcal{O}(p_j^k)$ = $\{o_m^{k,j}|m = 1, ..., n\mathcal{O}(p_j^k)\}$ *is the set of output provided by the player p_j^k for solving the problem of input $\mathcal{D}$ during a game.*

h) *$\mathcal{G}()$ is a procedure that determines whether players have produced outputs that meet specific requirements within a game segment. If so, return a possible answer $f \in \mathcal{F}$.*

i) *$\mathcal{W}(p_j^k)$ is the reward that the player can receive for solving the problem of input $\mathcal{D}$ during a game where $\mathcal{W}(p_j^k) \in \{w_i|i = 1, ..., y\}$. Players will receive a reward when achieving the winning condition of the game.*

3) $\mathcal{GF} = \{pSel, eSel, tMax, pNum, \mathcal{GM}, \mathcal{UI}\}$ *represents the flow of a social game.*

a) *$pSel()$ is a procedure that selects players to play a game and assigns roles to them.*

b) *$eSel()$ is a procedure that picks a problem from the problem set.*

c) *$tMax$ is the maximum duration of a game.*

d) *$pNum$ is the number of players of a game. It may be a single-player game, two-player game or multi-player game.*

e) *$\mathcal{GM} \in$ {collaborative, competitive, hybrid} is the mechanism of a game.*

f) *$\mathcal{UI}$ = $\{ui_j|j = 1, 2, ..., x\}$ is the set of design characteristics of user interface.*

4) *$\mathcal{ANS} = (\xi, \tau)$ represents answer extraction. It defines how answers are generated for each problem based on all the games played.*

a) *ξ is a data structure that supports the following operations:*

i) ***add()** takes $e \in \mathcal{E}$ as input and updates its internal counters.*

ii) ***count()** returns the internal count for a particular $f \in \mathcal{F}$*

b) *τ is a frequency threshold for accepting an answer.*

Definition 3 *An action (AC) is a 2-tuple $(\mathcal{ACT}, \mathcal{ACO})$ where sets:*

1) *$\mathcal{ACT}$ is the type of an action.*
2) *$\mathcal{ACO} = \{aco_i|i = 1, ..., x\}$ is the outcome domain of an action. It specifies the possible output values of the action.*

Definition 4 *A role (R) is a 2-tuple $(\mathcal{KW}, \mathcal{ACS})$ where:*

1) *$\mathcal{KW}$ is the knowledge a role can has.*
2) *$\mathcal{ACS} = \{acs_i|i = 1, ..., x\}$ is the set of actions that can be performed by the role R where acs_i is an action.*

B. Social Game Problem

A social game problem is to collect the values of some specific attributes of an input data. For instance, a picture is an input data of image type. It has two attributes: *label* and *description*; each attribute has a set of values in text format. These values can be called as metadata of the input data. There exist a set of constraints on the metadata to collect, such as what the specific attributes are and what values to be excluded.

C. Social Game Flow

A game is a match played by a set of players inside a social gaming system. The flow of a game is defined as follows.

1) Select players and assign roles to them by $pSel()$.
2) Find a problem from $\mathcal{E}$ to play by $eSel()$.
3) Collect outputs $\mathcal{O}$ from players' actions.
4) If verification $\mathcal{G}()$ is not passed, repeat step 3.
5) If time used time limit $\leq tMax$, repeat step 2.
6) Increase the reward of players by f.

Step 2-3 is called a segment during the game. It corresponds to the period of time when players are working on a particular problem e. While players' actions pass the verification procedure $\mathcal{G}()$, the game proceeds to another segment and players work on the next problem.

D. Answer Extraction Procedure

Answer extraction procedure is responsible for generating answers to each problem based on all the games played in the system. The actual procedure is defined in Table I.

TABLE I
THE ANSWER EXTRACTION PROCEDURE

```
for each e ∈ E do
    for each game segment GS working on problem e do
        if G() = TRUE then
            ξ.add(f)
        end if
    end for
    for each f ∈ F do
        if ξ.count(f) ≥ τ then
            f is regarded as an answer for e
        end if
    end for
end for
```

The procedure counts all the unique answers generated from all game segments for a particular problem e. Answers with frequency lower than threshold τ will be pruned away.

IV. Social Game Properties

A. Type of Information

To design a social game, we first declare whether subjective information or objective information aims to be collected. Assume it is a two-player game and the players aim to provide the common output. For a given problem e, there is a correct answer set $c\mathcal{F} \subset \mathcal{F}$. The correct output given by player p_1 is $\mathcal{O}(p_1) \cap c\mathcal{F}$ and the correct output given by player p_2 is $\mathcal{O}(p_2) \cap c\mathcal{F}$.

Subjective Information: The information presented for the same subject is affected by users because of different choices of vocabularies for the same subject.

- For subjective information, it has lower probability on players' correct outputs being the same because ($\mathcal{O}(p_1) \cap \mathcal{O}(p_2) \cap c\mathcal{F}) \ll ((\mathcal{O}(p_1) \cap c\mathcal{F}) \cup (\mathcal{O}(p_2) \cap c\mathcal{F})$).

Objective Information: The information presented for the same subject is not affected by users because of same choices of vocabularies for the same subject.

- For objective information, it has higher probability on players' correct outputs being the same because ($\mathcal{O}(p_1) \cap \mathcal{O}(p_2) \cap c\mathcal{F}) \approx ((\mathcal{O}(p_1) \cap c\mathcal{F}) \cup (\mathcal{O}(p_2) \cap c\mathcal{F})$).

Table II shows the categorization of social games with examples. The current social games are categorized by game structure, verification method, game mechanism, and player requirement which are described in the following subsections.

B. Game Structure

Game structure defines the key elements of a game including players' input, players' output, the relationship among the input and output of players, and the winning condition.

Output-agreement Game: All players are given the same input and must produce outputs based on the common input.

- $\mathcal{I}(p_1^1) = \mathcal{I}(p_2^1)$, the two players of the same role are given the common input in a game.
- In a two-player game, for a given problem e, there is a correct answer set $c\mathcal{F} \subset \mathcal{F}$, player p_1^1 has a set of potential outputs $\mathcal{O}(p_1^1) \subset \mathcal{F}$ and player p_2^1 has a set of potential outputs $\mathcal{O}(p_2^1) \subset \mathcal{F}$. The probability that players' outputs are accepted within a fixed period depends on $|\mathcal{O}(p_1^1) \cap \mathcal{O}(p_2^1)|$, where $\mathcal{O}(p_1^1) \cap \mathcal{O}(p_2^1)$ is the set of potential outputs shared by players. The larger the $\mathcal{O}(p_1^1) \cap \mathcal{O}(p_2^1)$, the higher the chance that an answer will be accepted with a fixed period.
- *An output-agreement game should be used to collect objective information*, because it has higher probability on players' correct outputs are the same for collecting objective information:($\mathcal{O}(p_1^1) \cap \mathcal{O}(p_2^1) \cap c\mathcal{F}) \approx ((\mathcal{O}(p_1^1) \cap c\mathcal{F}) \cup (\mathcal{O}(p_2^1) \cap c\mathcal{F})$).
- Since the output-agreement game assumes that there is no communications among players, the only information shared by players is the problem itself. Therefore, players who are telling the truth will have a larger $\mathcal{O}(p_1^1) \cap \mathcal{O}(p_2^1)$ and it has a higher chance to get their outputs accepted within a fixed period. It is difficult for players to have their outputs accepted if they are not telling the truth.

Input-agreement Game: All players are given inputs that are known by the game (but not by the players) to be the same or different. The players are instructed to produce outputs describing their input, so their partners are able to assess whether their inputs are the same or different. Players see only each other's outputs.

- $\mathcal{I}(p_1^1)$ and $\mathcal{I}(p_2^1)$ are known by the game (but not by the player p_1^1 and p_2^1 of the same role) to be the same or not.
- In a two-player game, for a given problem e, there is a correct answer set $c\mathcal{F} \subset \mathcal{F}$, player p_1^1 has a set of potential outputs $\mathcal{O}(p_1^1) \subset \mathcal{F}$ and player p_2^1 has a set of potential outputs $\mathcal{O}(p_2^1) \subset \mathcal{F}$. The probability that players can correctly determine the input of players are the same or not within a fixed period depends on $|\mathcal{O}(p_1^1) \cap c\mathcal{F}|$ and $|\mathcal{O}(p_2^1) \cap c\mathcal{F}|$, where $\mathcal{O}(p_1^1) \cap c\mathcal{F}$ and $\mathcal{O}(p_2^1) \cap c\mathcal{F}$ are the set of correct outputs given by player p_1^1 and player p_2^1 respectively. The larger the sets $\mathcal{O}(p_1^1) \cap c\mathcal{F}$ and $\mathcal{O}(p_2^1) \cap c\mathcal{F}$, the more detailed information given by players, the higher the chance that players can correctly make determinations.
- *An input-agreement game should be used to collect subjective information*, because it has higher probability on players having detailed information when collecting subjective information compared with objective one.
- Since there is no communications between the two players, the only information the first player p_1^1 could has are the given input $\mathcal{I}(p_1^1)$ and the hints $\mathcal{O}(p_2^1)$ given by the second player about $\mathcal{I}(p_2^1)$. On the other hand, the only information the second player p_2^1 could has are the given input $\mathcal{I}(p_2^1)$ and the hints $\mathcal{O}(p_1^1)$ given by the first player about $\mathcal{I}(p_1^1)$. Therefore, players who are telling the truth will have a larger $\mathcal{O}(p_1^1) \cap c\mathcal{F}$ and a larger $\mathcal{O}(p_2^1) \cap c\mathcal{F}$ and it has a higher chance that players can correctly determine their inputs are the same or not within a fixed period. In other word, it is very difficult for players to make accurate determination if not telling the truth.

Inversion-problem Game: The first player has access to the whole problem and gives hints to the second player to make a guess. If the second player is able to guess the secret, we assume that the hints given by the first player are correct.

- In a two-player game, $\mathcal{I}(p_1^1)$ is given by the game and $\mathcal{I}(p_1^2)$ is set as the output provided by player p_1^1 (i.e. $\mathcal{I}(p_1^2) = \mathcal{O}(p_1^1)$).
- In the inversion-problem game, every hint given by the first player p_1^1 corresponds to a set of possible guesses which are the outputs of the second player $\mathcal{O}(p_1^2)$. Since there is no communications between the two players, the only information the second player could has are the hints $\mathcal{O}(p_1^1)$ given by the first player. The probability that the second player successfully guesses the secret, the input data $\mathcal{D}$, within a fixed period depends on the size of $\mathcal{O}(p_1^2)$ that is $|\mathcal{O}(p_1^2)|$. The smaller $\mathcal{O}(p_1^2)$, the higher chance the second player can make a correct guess within a fixed period.

Output-optimization Game: All players are given the same input and their outputs are the hints of other players' outputs.

- $\mathcal{I}(p_1^1)$ and $\mathcal{I}(p_1^2)$ are given in a two-player game.
- In the output-optimization game, since players can communicate with each other using their outputs, the output $\mathcal{O}(p_1^1)$ given by the first player affects the output $\mathcal{O}(p_1^2)$ given by the second player, while the output $\mathcal{O}(p_1^2)$ given by the second player affects the output $\mathcal{O}(p_1^1)$ given by the first player. It aims to collect their output patterns.
- *An output-optimization game should be used to collect subjective information*, because the output pattern of players reflects outputs of players are strongly affected by others' outputs. It is subjective.

TABLE II
CATEGORIZATION OF SOCIAL GAMES WITH EXAMPLES

Game Structure	Verification Method	Game Mechanism	Player Requirement		Examples
			Num of Player	Game Play	
Output-agreement	Symmetric	Collaborative	2	Synchronous	ESP, Matchi, Squigl, OntoGame
		Hybrid	Multi-players	Synchronous	Common Consensus, Social Heroes
		Hybrid	Multi-players	Asynchronous	Gopher Game
Input-agreement	Symmetric	Collaborative	2	Synchronous	TagATune
		Hybrid	N/A	N/A	N/A
Inversion-problem	Asymmetric	Collaborative	1 or 2	Synchronous	Peekaboom, Verbosity
		Competitive	2	Asynchronous	Dogear, CyPRESS, CARS
		Hybrid	1 or Multi-players	Synchronous	Phetch
Output-optimization	Symmetric	Collaborative	2	Synchronous	Restaurant Game
		Competitive	N/A	N/A	N/A
		Hybrid	Multi-players	Synchronous	Diplomacy

C. Verification Method

Verification method of a game defines the method to check the output accuracy of players by asking players to do the same task or different tasks.

Symmetric Verification Game: *Either an output-agreement game or an input-agreement game is symmetric verification.*

- $\mathcal{R} = \{r_k \mid k = 1\}$, all players in a game could be assigned to the only one role to do the same task.

Asymmetric Verification Game: *An inversion-problem game is asymmetric verification.*

- $\mathcal{R} = \{r_k \mid k \geq 2\}$, players in a game could be assigned to one of the roles to do different tasks.

D. Game Mechanism

Game mechanism defines the relationship of all players in the game in order to achieve the winning condition.

Collaborative Game: It determines the *winning condition of all players*.

- For a two-player collaborative game, when both players (i.e. p_1^1 and p_2^1) complete their assigned tasks which is helping each other to complete his tasks, both players (i.e. p_1^1 and p_2^1) achieve the winning condition and receive rewards (i.e. $\mathcal{W}(p_1^1)$ and $\mathcal{W}(p_2^1)$). *The accuracy of output is guaranteed by collaboration of all players.*

Competitive Game: It determines the *winning condition of a player*. *Neither an output-agreement game nor an input-agreement game can be a competitive game.*

- For a two-player competitive game which determines the precise accuracy of the player's guess based on the information stored in the database, when player p_1^1 can make a guess correctly, player p_1^1 achieve the winning condition and receive a reward, i.e. $\mathcal{W}(p_1^1)$. *Output accuracy is guaranteed by information stored in a database. Players' enjoyment in the game can be increase in competition.*

Hybrid Game: To achieve the *winning condition of some players*, players have to complete their assigned tasks which are helping other players to complete their tasks. After that, the achievements of all players are compared with other players' achievements or their history of game records or information stored in a database.

- *The accuracy of output is guaranteed by collaboration of the winning two players. Players' enjoyment in the game can be increase in competition.*

E. Player Requirement

Player requirement defines the rules on accessing the game of all players.

Synchronous Game: Players have to give real-time response to other players' action.

- All players in a game (i.e. $\forall p \in \mathcal{P}$) are accessing the game during the maximum duration of a game, $tMax$.

Asynchronous Game: Players do not have to give real-time response to other players' action. The information collected from one player is stored in a database and will be used to determine the correctness of other players' output.

- Not all players in a game (i.e. $\exists p \in \mathcal{P}$) is accessing the game during the maximum duration of a game, $tMax$.

Single-player Game: It allows one player to play and the other's moves can be simulated from the prerecorded game. *Only inversion-problem game can be a single-player game.*

Two-player Game: It allows two players to play together.

Multi-player Game: It allows multiple players to play together. *Only hybrid game can be a multi-player game.*

V. DESIGN GUIDELINE

Guidelines are necessary to help designers to design a social game for solving a problem in general based on the characteristics of the problem. Table III shows the guidelines based on the properties of our proposed model.

Given our task is to locate objects in the labels of images. The input object of the game is an *image*, and the attribute *label* is our concern. The data of attribute *label* is of *text* type. Since labels are objective and obvious information, we may design an output-agreement or an inversion-problem game.

To design an output-agreement game for locating objects in the labels of images, we have only 2 players in the game and it is the Squigl game. However, if we choose to have more than 2 players in the game, then it is a hybrid game. For example, there are 3 players in the game. Each player is given the same input image and is asked to locate objects in

TABLE III
THE DESIGN GUIDELINES ON SOCIAL GAMES

if $data.attr.value$ = $objective$ **then**
  $struct$ = (**output-agreement or inversion-problem**)
else if ($data.attr.value$ = $subjective$ **and**
$data.attr.value.data\text{-}type$ = $output\text{-}pattern$) **then**
  $struct$ = **output-optimization**
else if ($data.attr.value$ = $subjective$ **and**
$data.attr.value.data\text{-}type \neq output\text{-}pattern$) **then**
  $struct$ = (**input-agreement or inversion-problem**)
end if
if $struct$ = (**output-agreement or input-agreement**) **then**
  if $no\text{-}of\text{-}players > 2$ **then**
    $mechanism$ = $hybrid$
  else if $no\text{-}of\text{-}players = 2$ **then**
    $mechanism$ = $collaborative$
  end if
end if
if $struct$ = **inversion-problem then**
  if $no\text{-}of\text{-}players > 2$ **then**
    $mechanism$ = $hybrid$
  else if $no\text{-}of\text{-}players = 2$ **then**
    if *ans verification based on outputs of players* **then**
      $mechanism$ = $collaborative$
    else if *ans verification based on info stored in DB* **then**
      ($mechanism$ = $competitive$ **and** $time$ = $async$)
    end if
  else if $no\text{-}of\text{-}players = 1$ **then**
    ($mechanism$ = ($collaborative$ **or** $hybrid$) **and**
    moves simulated from the prerecorded game)
  end if
end if
if $struct$ = **output-optimization then**
  if $no\text{-}of\text{-}players > 2$ **then**
    $mechanism$ = $hybrid$
  else if $no\text{-}of\text{-}players = 2$ **then**
    $mechanism$ = ($collaborative$ **or** $competitive$)
  end if
end if

labels of the image. The location of object in an image for a label provided by a player is assumed to be correct when two players drag the same area for the object. The first two players complete the dragging of the area of an object related to a label and the overlapping area is higher than a threshold will gain marks. It encourages the players to drag the object as fast as possible and locate the object correctly in order to have higher probability to match other players' output. Besides, all players in the game are competing against each other.

To design an inversion-problem game for solving labeling images problem, we have only 2 players in the game, it is the Peekaboom game. However, if we choose to have more than 2 players in the game, then it is a hybrid game and it may be similar to Phetch. There are 3 players in the game. One of the players is given an input image and the player provides labels to all other players, while other players have to guess which one is the input image from a set of images. The player guessing the correct image in the shortest time and the describer of the image will gain marks.

VI. CONCLUSION

In this work, we have formulated a formal model on social games and illustrated how current social games can be realized with the proposed formalism. We then present a set of design guidelines based on the formal model for solving a variety of problems in a formal and structural way. In the future, we plan to consider using the model to design social games for solving a set of inter-related problems and are able to handle different data types under different environmental context.

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