ICONIP 2009 Intelligent Liar Competition:
Liar Dice (Individual Hand)

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1 Introduction

Liar dice games are popular bar (drinking) games that can be dated back to many centuries ago [5]. The challenge of Liar Dice games is that a player can bluff (lie). Variants forms of Liar Dice have evolved. In this competition, we base on one simplest form called Individual Hand. Moreover, we limit the number of players to 2 (i.e. a two-person game).

In this simple form, a cup and five dices are provided for the players. (Detail of the rule-of-game will be presented in the later section.) In the starting of the game, one player (say John) rolls the dices (without letting the other player know what the actual numbers rolled) and then makes a call similar to So-Hand in Poker Game. Suppose John makes a call 2 pairs 4 and 5. The other player (say Mary) needs to decide either (i) trusts the call and then call up or (ii) makes a Liar announcement and then checks if the call is a bluff. Mary wins if she has made a Liar announcement and the cup does not consist of 4455$x$ (here $x$ is any other number). Otherwise, John wins if the cup consists of 4455$x$.

Now, we assume that Mary trusts the call. She opens the cup and finds that the actual pattern is 34552. It is not possible for her to call up based on these numbers. What Mary can do is to re-roll (once) some of those dices and see if she can get better pattern. As she can re-roll once, she needs to determine carefully which dice(s) should be taken out for re-roll, in order to let her make a call beating 4455$x$. For 34552, one possibility is to re-roll dices 2, 3 and 4 and leave 55 fixed. In such case, there is more than 0.5 probability to get one more 5 and make a call 555$xx$.

After Mary has made a call, it comes to John to make decision. The game terminates once a player has lost. Of course, we do not intend to promote alcohol or gambling. We would like to seek for any computational intelligence technique that can be applied to beat human players, or any technique that can make a computer being a professional Liar.
<table>
<thead>
<tr>
<th>E.G.</th>
<th>Level</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>16543</td>
<td>0</td>
<td>Nothing</td>
</tr>
<tr>
<td>11654</td>
<td>1</td>
<td>One Pair</td>
</tr>
<tr>
<td>11665</td>
<td>2</td>
<td>Two Pairs</td>
</tr>
<tr>
<td>11165</td>
<td>3</td>
<td>Three of a kind</td>
</tr>
<tr>
<td>11166</td>
<td>4</td>
<td>Full house</td>
</tr>
<tr>
<td>11116</td>
<td>5</td>
<td>Four of a kind</td>
</tr>
<tr>
<td>11111</td>
<td>6</td>
<td>Five of a kind</td>
</tr>
</tbody>
</table>

Number Rank: 1 > 6 > 5 > 4 > 3 > 2

Table 1: Level rank of dice pattern and number rank.

The content of this briefing is extracted from a paper presented in ICMLC2003 [4]. One can also download a software from FastEddie [2] for a program with beautiful graphical interface design or a prototype developed by Jan Chan [1] based on Visual Basic language to experience the funny part of this game.

## 2 Notations

The notations defined in this section are for presentation clarification. Let us define a few notations that will be used in the rest of the paper. First, let us denote the set of all the possible dice pattern be $D$, i.e.

$$D = \{X = x_1x_2x_3x_4x_5| x_i \in \{1, 2, 3, 4, 5, 6\}\forall i = 1, 2, 3, 4, 5\}.$$  

Suppose $X$ and $Y$ are two dice patterns, i.e. $X, Y \in D$, the level of $X$, $L(X)$ can be defined by Table 2 and the ranking between two dice patterns can be defined by the following definition.

**Definition 1 (Rank)** The dice pattern $X$ is higher rank than the dice pattern $Y$, denoted $X \succ Y$, if (i) $L(X) > L(Y)$ or (ii) $L(X) = L(Y)$ and there exists $k \in \{1, 2, 3, 4, 5\}$ such that $x_{\pi_k} > y_{\pi_k}$ and $x_{\pi_i} = y_{\pi_i}$ for all $i < k$.

Here $x_{\pi_k}$ is the $k^{th}$ largest number in $X$, i.e.

$$x_{\pi_1} \geq x_{\pi_2} \geq x_{\pi_3} \geq x_{\pi_4} \geq x_{\pi_5}.$$  

For illustration, let us have a few examples.

- $22234 \succ 11665$ because $L(22234) > L(11665)$.
- $55223 \succ 44331$ because $L(55223) = L(44331)$ but $55 > 44$.
- $55643 \succ 55432$ because $L(55643) = L(55432)$ but $6 > 4$.
- $12345 \succ 23456$ because $L(12345) = L(23456)$ but $1 > 6$. 
Definition 2 (Sub-pattern) A dice pattern $S$ is a sub-pattern of dice pattern $X$ iff $C \cap X = C$.

Suppose $S^1 = \{223\}$ and $S^2 = \{322\}$ are two dice patterns. They are sub-patterns of $X = \{11232\}$ since $S^1 \cap X = S^1$ and $S^2 \cap X = S^2$.

Definition 3 (Truthful call) A call, $C$, is a truthful call if the call pattern is a sub-pattern of the actual dice pattern.

Suppose the actual dice pattern is $X$, $C$ is a truthful call iff $C \cap X = C$. For instance, the call three of a kind of number 6 means that the dice pattern consists at least three number 6, such as 22666, 26666, 15666 or 66666. If the actual dice pattern is 22366 or 23111, the call will be not a truthful call.

3 Rule of game

Without loss of generality, we assume that there are only two players A and B. The rule of game can be summarized as follows:

- Player A first covers all the dice with a cup and then rolls.
- Player A reveals the dice pattern without letting B know the actual pattern, $X^a$.
- Player A makes a call (also coined as a bid or a claim), $C^a$, to Player B.
- Player B makes an announcement based on Player A’s call.
  - If Player B does not trust the call, he/she has to announce Liar. B wins if the call is not true. Otherwise B loses.
  - If Player B trusts the call, he/she has to announce Trust. Then Player B is allowed to re-roll the dice and make a new higher call, $C^b$.
- After Player B has made a call $C^b$, it takes turn to Player A to make an announcement.

As each player has to make a higher call, the game stops whenever a player loses. Figure 1 and Figure 2 show two exemplar games how the players select the dices to re-roll and how they make the call.

3.1 Strategy for re-roll

To increase the chance to get a dice pattern of higher rank, Player B is free to select any dice to re-roll. For instance, if the dice pattern passed by Player A is 55443 and Player A calls two pairs 55 and 44. Player B can simply select the dices ‘4’, ‘4’ and ‘3’ to re-roll. In such case, Player B can have more than 1/2 probability to get higher ranked pattern, including three of a kind (555), two pairs (5566 and 5511), flush (55xxx and (555xx), four of a kind (5555), and five of a kind (55555).
### 3.2 Challenges of the game

The challenges of this game are three folds: (1) **when to make a trust announcement**; (2) **which dice have to be re-rolled**; and (3) **what call has to be made after re-roll**.

#### 3.2.1 1st challenge

The first decision depends solely on how much a player know about the playing behavior of the opponent. Player who is a frequent liar might always make false alarm, i.e. $C \cap X \neq C$. An honest player will usually make a truthful call, i.e. $C \cap X = C$. This decision is purely based on heuristic. No solid mathematical analysis can help.

#### 3.2.2 2nd challenge

The second challenge is easier. A tactic for which a player can be based has been suggested by Freeman in [3]. The idea is described as that. Once a player has made a trust announcement and lifted up the cup, what he can do is to determine which dice has to be re-rolled. This decision can be expressed as follows:

$$S_0 = \arg \max_S P_{CU}(Y \in D(S) \text{ and } Y \succ C^a | S \in X^a),$$

(1)

where $D(S) = \{Y | S \cap Y = S\}$, i.e. all the dice patterns that consists of $S$ as a sub-patterns. The subscript LP stands for larger pattern.

#### 3.2.3 3rd challenge

The third decision is also a difficult decision. Suppose B has re-rolled the dice and get a pattern larger than the previous A call, B can simply make a truthful
call. However, it will give a chance for A to re-roll a much larger dice pattern since player A might announce a trust call. It might diminish the chance that B can win in return.

For illustration, let us consider the example shown in Figure 2. Suppose Player A has rolled 55632 and called a pair of 5. Since the chance of rolling such pattern is high (≈ 0.2) and the chance to get a larger dice pattern is high even the call might not be true (> 0.2), B should trust the call. Considering that

$$P_{CU}(Y \in D(55) \text{ and } Y \succ "55xxx" | "55" \in "55632")$$

equals to 1, B can thus hold the pair of 5 and re-roll the remaining 632.

Suppose B gets 164 after re-roll. Together with the dice being hold, the pattern is 55164. Player B has several options to call, such as a pair of 5 and a dice of 1 and a pair of 5 and a dice of 4 if B does not want to lie. But he prefers to lie and calls three of a kind of 5.

Since the probability that getting at least one dice 5 out of three is approximately 0.42, it is a reasonable lie. Normally A will trust the call as it is too risky to say no. Certainly, Player A will find that B is a liar. What A can do is to re-roll the dice and hope that the re-roll dice pattern can be larger than three of a kind of 5. A rational choice is to hold the pair of dice 5 since the probability of getting larger dice pattern, i.e.

$$P_{LP}(Y \in D(S) \text{ and } Y \succ "555xx" | S \in "55164")$$,

is the largest when $$S = 55$$. The dice 164 are re-rolled. As you can see, the dice pattern after re-roll is still lower rank than B's call, Player A must lie. Suppose B does not trust A and announce "do not trust", Player B wins the game.

4 Tournament

Tentatively, the Intelligent Liar Competition is conducted in a single-elimination fashion, see Figure 3. There is no specify requirement on the software interface. Contestant can refer to FastEddie's Liar Dice for a program with beautiful graphical interface design or a prototype developed by Jan Chan [1] based on Visual Basic language.

5 Submission

Each contestant (or contestant team) has to send expression of interest (together with an abstract describing the algorithm and the software developed if any) to John Sum (pfsum@nchu.edu.tw) no later than July 28, 2009.

In accordance with the algorithm proposed, organizer will short-list some (or all) of them for the final competition to be held in ICONIP. Notification of short-list will be announced at August 15, 2009. Each contestant has to formally register for the participation of the conference on or before October 1, 2009 (for early-bird September 6, 2009).
Each contestant could also submit a full paper (LNCS format camera ready) to the ICONIP paper submission system no later than July 28 for regular review and possible inclusion in the ICONIP conference proceeding.

Software, together with source code and executable file, has to be submitted on or before November 1, 2009, to John Sum. Those programs will be upload to a public domain for download. A homepage will be ready for this collection of Liar Dice (Individual Hand) programs.

**Deadlines**

- **Expression of interest:** July 28, 2009.
- **Paper submission:** July 28, 2009.
- **Acceptance Notification:** August 15, 2009.
- **Conference Registration:** October 1, 2009.
- **Full Paper/Early bird registration:** September 6, 2009.
- **Submission of Software:** November 1, 2009.
- **Competition/Special Session:** December 1-5, 2009.

**References**
