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Safety Lead Curve and Entertainment in Games

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Abstract

This paper is concerned with the safety lead curve and entertainment in games, where the safety lead curve is that once information of the game outcome goes above it, the advantageous team will win the game with 100% certainty. The safety lead curves have been derived by using a series of approximate solutions of the flow between two parallel flat walls, one of which is at rest; the other is suddenly accelerated from the rest to a constant velocity. The safety lead curve is critical for neutral observer(s) to assess entertainment in games, for when the information of game outcome is below it, the game is interesting, while the information is above it, the game is boring. The power balance between the two teams (players) results in that the information of game outcome follows along the safety lead curve so as not to lose entertainment in game. The safety lead curve can be a critical edge of game, at which two different things, viz. interesting game and boring game, happen, and thus we feel a particular emotion while the game proceeds along it. The four Japan games in 2010 FIFA World Cup are under the safety lead curve, respectively, and thus are interesting for neutral observer(s).

Keywords: Safety Lead Curve, Entertainment, Game Advantage, Information of Game Outcome, Soccer, Fluid Mechanics.

1. Introduction

Nothing perhaps is more intriguing in game than to know game progress patterns or how information of game outcome varies with the game length or time, where information of game outcome is the data that are the certainty of game outcome.

Information of game outcome and its development are therefore topics that have attracted many researchers (e.g. Iida et al 2011a, 2011b), but much remains to be done before a satisfactory understanding is obtained and real prediction is possible.

Game information dynamic models (Iida et al 2011a) makes it possible to treat and identify game progress patterns. The two models are expressed, respectively, by

Model 1: $\xi=\eta^n$, (1)

and

Model 2: $\xi=[\sin(\pi/2\cdot\eta)]^n$, (2)

where ξ is the non-dimensional information of game outcome, η the non-dimensional game length or time, and n the positive real number parameter depending on fairness of the game, strength of the two teams(players), and strength difference between the two teams (players).

It has been confirmed that game information dynamic models are quite useful for understanding and explaining game progress patterns in Base Ball (Iida et al 2011a), Soccer, Chess, Shogi and others. However, effect of the safety lead on game progress patterns has not been taken into account in these models, where the safety lead is that once the lead exceeds to its value, the leading team will win the game with 100% certainty. The safety lead is sometimes a critical factor in game entertainment, for if one team(player) gets the safety lead against the other team(player) the game becomes immediately boring, but if not it is kept to be interesting. Thus, the safety lead curve, which is that once the information of game outcome goes above it, the team having advantage will win the game with 100% certainty, plays a part as a game information dynamic model(see Appendix), along which the game proceeds under certain conditions, as to be shown.

It is evident that winner(s), loser(s) and neutral observer(s) have different feeling, or emotion during the game from each other, where winner(s) is winning player(s) and winner-sided supporter(s), and loser(s) is losing player(s) and loser-sided supporter(s). Thus, in this study concerning entertainment for the sake of clarity we will only inquire whether neutral observer(s) feels interested or bored during the game. However, how one feels emotion during the game essentially belongs to each personal, so that the present discussion on entertainment is based on authors' subjective views.

The main purpose of the present study is to propose two novel information dynamic models representing safety lead or uncertainty of game outcome, and to clarify the role of the safety lead curve and its relation to entertainment in games.

2. Safety Lead Curve and Entertainment in Game

In any game, it is realized that there exists a safety lead curve, which is defined in such a way that once the information of game outcome goes above it, the advantageous team will win the game with 100% certainty. The safety lead curves have been derived as a series of approximate solutions of the flow between two parallel flat walls, one of which is at rest, the other is suddenly accelerated from the rest to a constant velocity (see Appendix), and it is expressed by

$\xi=(1-\eta)^q$ for $0 \le \eta \le 1$, (3)

where ξ is the non-dimensional current safety lead of game, η the non-dimensional current game length, and q the positive real number parameter. The safety lead curve depends on characteristics of the game, strength of the two teams (players) and strength difference between the two teams (players). To know the relation between the safety lead curve and entertainment in game, the three artificial elemental game progress patterns are introduced, viz., "balanced game", seesaw game" and "one-sided game" , as listed in Table 1(Iida et al 2011c).

Table 1: Time history of goals during three artificial Soccer games between team A and team B

Game	Result*	Goal time** (minutes)
Balanced game	0 − 0	
seesaw game	5 − 4	9(A), 18(B), 27(B), 36(A), 45(A), 54(B), 63(B), 72(A), 81(A)
One-sided game	50 − 0	From 1 to 50 minutes, one goal in every 1 minute.

* In the column "Result", the left value is the goal sum for team A after the game, while the right value is the goal sum for team B.

* In the column "Goal time", characters A and B in brackets denote team A and team B, respectively.

The non-dimensional information ξ_S in Soccer is here defined as follows: When the total goal(s) of the two teams at the end of game $G_T \neq 0$,

$$\xi_S = |G_A(\eta) - G_B(\eta)| / G_T \quad \text{for } 0 \leq \eta < 1,\ 1 \text{ for } \eta=1, \quad (4)$$

where $G_A(\eta)$ is the current goal sum for the team A(winner), and $G_B(\eta)$ is the current goal sum for the team B(loser). At $\eta=1$, ξ_S is assigned the value of 1, for at the end of game the information must reach the total value. On the other hand, when $G_T=0$,

$$\xi_S = 0 \quad \text{for } 0 \leq \eta < 1,\ 1 \text{ for } \eta=1. \quad (5)$$

Note that in a draw case ξ_S may also take the value of 0 other than 1 at$\eta=1$, depending on the game rules: In case of tournament match, $\xi_S=1$ at $\eta=1$, while in case of league match, $\xi_S=0$ at $\eta=1$.

The game length is defined as the current time (minutes), and it is normalized by the total game length or the total time to obtain the non-dimensional value η. The total game length of Soccer is normally 90 minutes, but in case of extended games it becomes 120 minutes.

Figure 1 show the relation between non-dimensional information $\xi$and non-dimensional game length η for three artificial Soccer games, viz. “balanced game”, “seesaw game”, and “one-sided game. In this figure, two safety lead curves are concurrently plotted for reference: The safety lead curve 1 is $\xi=(1-\eta)^2$, while safety lead curve 2 is$\xi=(1-\eta)^{0.4}$.

Firstly, let us discuss the entertainment of the game, by assuming the safety lead curve 1. In case of “balanced game”, the information is always under the safety lead curve 1 trough the game except for the value at $\eta=1$. In case of “seesaw game”, the information exceeds to the safety lead at $\eta \simeq 0.69$, so that the game is solved at this game length.. In case of “one-sided game”, the information is under the safety lead curve 1 until crossing each other, but after that the information is above the safety lead curve 1. This means that before the crossing point this game is interesting, but after the cross point it becomes boring for neutral observers.

Secondly, let us discuss the entertainment of the game, by assuming the safety lead curve 2. In both cases of “balanced game” and “seesaw game”, the information is below the safety lead curve 2 through the game except for the value at $\eta=1$.This means that the entertainment in these games is maintained through the total game length except at the end. In case of “one-sided game”, the information is under the safety lead curve 2 until crossing each other, but after that the information is above the safety lead curve. This means that before the crossing point this game is interesting, but after the cross point it becomes boring. Note that when the safety lead curve changes from the curve 1 to 2, the interesting game length becomes longer or boring game length becomes shorter. It may be instructive to consider the two extreme cases, viz. the parameter q=0 and ∞. When q=0, the safety lead curve become ξ=1 for 0≤η<1, but ξ=0 for η=1. In this case, every game is interesting. On the other hand, when q=∞, the safety lead curve ξ≈0 for 0<η≤1, but ξ=1 for η=0 approximately coincide with "balanced game" except for the value at η=0. Thus, in this case, only "balanced game" is interesting, and the rest games are boring.

It is suggested that we normally try to design a game in such a way that it proceeds so as to keep the information under the safety lead curve. This is because when the information is under the curve game is interesting, while when the information is above the curve it is boring. The safety lead curve is, therefore, critical to assess entertainment in game. In Soccer, while one team is behind goal(s), the players make their efforts to avoid the safety lead of the other team. On the other hand, while one team leads goal(s), the players try to secure their safety lead against the other team. This power balance between the two teams may result in that the information of game outcome follows along the safety lead curve. In another words, Soccer players in one team severely struggle with those in the other team to avoid the safety lead of the other team, for as far as the opponent's lead is within the limit, it is quite possible to revert the game later. The situation is similar in Marathon race: A strong runner often is willing to take rear position in keeping the distance within the safety lead of the front runner, for this provides her or him the highest probability to win the race. This again results in that Marathon proceeds in such a way that the distance between the two competing runners is kept to be the safety lead of the front runner approximately, so that the information of race outcome follows along the safety lead curve. Thus, the safety lead curve can be a critical edge of the game, at which two different things happen (Iida 2007). This is because we feel a particular emotion at the edge, or the safety lead curve.

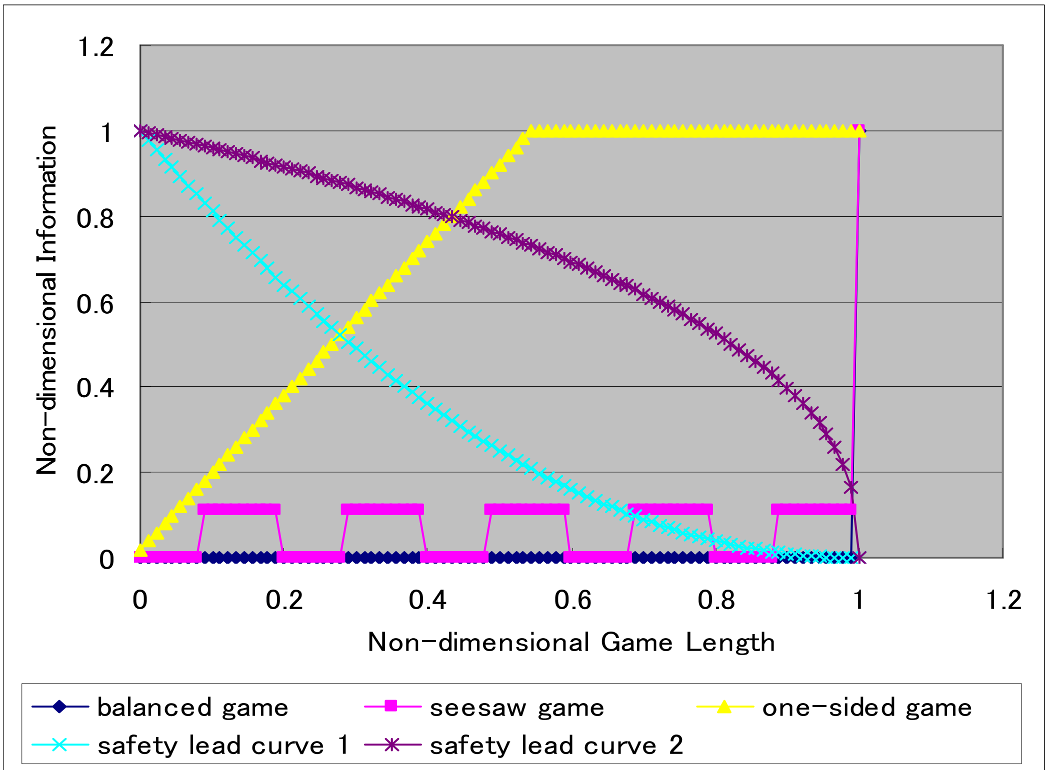

Figure 1: Non-dimensional information ξ against non-dimensional game length η for artificial Soccer games, viz. "balanced game", "seesaw game", and "one-sided game

3. Data Analyses

Four Japan games in 2010 FIFA World Cup South Africa have been considered and the data analyses have been done, where Soccer is a form of football in which the use of the hands and arms either for playing the ball or for interfering with an opponent is prohibited. Some of the relevant information is summarized in Table 1.

Table 1: Four Japan Games in 2010 FIFA World Cup South Africa

Game	Result	Goal time (minutes)	Total Game Length (minutes)	
Group E 1st game	1 – 0 0 – 0 ------------- Japan 1−0 Cameroon	39(Japan)	90	June 14 , Bloemfontein
Group E 2nd game	0−0 1−0 -------------- Holland 1−0 Japan	53(Holland)	90	June 19, Durban
Group E 3rd game	2−0 1−1 ------------ Japan 3−1 Denmark	17(Japan) 30(Japan) 81(Denmark) 87(Japan)	90	June 24, Rustenburg
Round of 16	0−0 0−0 0ex0 0ex0 ------------ Japan 3PK5 Paraguay		120	June 29, Pretoria

Figure 2 shows the relation between non-dimensional game information ξ_S and the non-dimensional game length η for the four Japan games in 2010 FIFA World Cup South Africa.

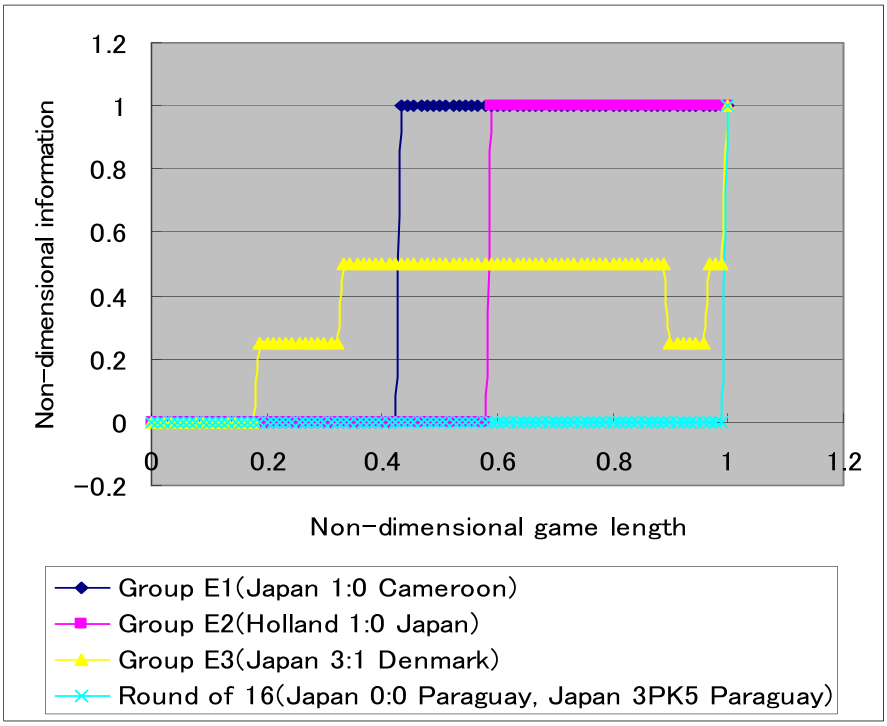

Figure 2: Non-dimensional game information ξ_S against the non-dimensional game length η for the four Japan games in 2010 FIFA World Cup South Africa

Group E 1st game: Japan vs. Cameroon

Figure 2 indicates that ξ_S is kept to 0 until $\eta \simeq 0.433$, but it jumps to 1 at $\eta=0.433$ and is kept to be the same value until the end of game. In this game, there are two intervals, where ξ_S is constant: In the earlier interval, $\xi_S = 0$, while in the later interval $\xi_S = 1$. Thus, although this game represents a typical information curve as one-sided game, it is interesting in fact: During the earlier interval $\xi_S = 0$, the game may proceed, experiencing alternate changes from offense to defense by the two teams many times. On the other hand, during the later interval$\xi_S = 1$, in addition to the alternate changes from offense to defense by the two teams many times, the game is still pending state, for if Cameroon gets one goal during this interval, the game immediately reverts to the balanced state again.

Group E 2nd game: Holland vs. Japan

Figure 2 indicates that ξ_S is kept to 0 until $\eta \simeq 0.589$, but it jumps to 1 at $\eta \simeq 0.589$ and is kept to be the same value until the end of game. In this game, there are two intervals, where ξ_S is constant: In the earlier interval $\xi_S = 0$, while in the later interval $\xi_S = 1$. Thus, similarly to Group E 1st game although this game represents a typical information curve as "one-sided game", it is interesting in fact: During the earlier interval $\xi_S = 0$, the game may proceed experiencing alternate changes from offense to defense by the two teams many times. On the other hand, during the later interval $\xi_S = 1$, in addition to the alternate changes from offense to defense by the two teams many times, the game is still a pending state, for if Japan gets one goal during this interval, the game will immediately reverts to the balanced state again.

Group E 3rd game: Japan vs. Denmark

Figure 2 shows that ξ_S is kept to be 0 until $\eta \simeq 0.189$, but it jumps to 0.25 at $\eta \simeq 0.189$ due to the Japan's first goal and is kept to be the same value until $\eta \simeq 0.333$. At $\eta \simeq 0.333$, ξ_S jumps to 0.5 due to the Japan's second goal and is kept to be the same value until $\eta \simeq 0.9$. At $\eta \simeq 0.9$, ξ_S decreases suddenly to 0.25 due to the Denmark's first goal and is kept to be the same value until $\eta \simeq 0.967$. However, at $\eta \simeq 0.967$, ξ_S jumps to 0.5 due to the Japan's third goal and is kept to be the same value until$\eta \simeq 0.989$. Then, ξ_S becomes 1 at the end of game.

Round of 16: Japan vs. Paraguay

Figure 2 shows that ξ_S is kept to be 0 until $\eta \simeq 0.992$, but it jumps to 1 at $\eta=1$. This game is a draw case, so that the winner is determined by the penalty match, where five kickers for each team participate. During the penalty match, Paraguay gets 5 goals, while Japan gets 3 goals, so that Paraguay wins the game.

This game is a typical " balanced-game", in which both teams cannot get any goal but they repeat from offense to defense by the two teams many times, and thus it is interesting. This is because strength of the both teams is quite high and strength difference between the two teams is very small: During the game offensive and defensive battles between the two teams are so severe that no team can get any goal for 120 minutes.

It may be worth noting that all of balanced-games are not always interesting: For example, when strength of the both teams is very low, both teams may not get any goal due to the luck of their skill. Moreover, when one team intentionally tries to make a game draw against the other team, the game may not be interesting.

4. Discussion

This section discusses the relation between the game progress pattern, which is how the non-dimensional information ξ varies with non-dimensional game length η, and information dynamic models.

Figure 3 shows the relation between the non-dimensional information ξ and non-dimensional game length η for Group E1, Group E2 and Model 2. Group E1 is roughly accounted for by Model 2 at n=1.5, while Group E2 is roughly accounted for by Model 2 at n=3. This denotes that the maximum information velocity (increase rate) of Group E2 is greater than that of Group E1. In another words, Group E2 is more interesting and exciting than Group E1.

In Group E1 and Group E2, the strength difference between the two teams is extremely small, so that in safety lead curve $\xi=(1-\eta)^q$, $q\simeq 0$: This denotes that the safety lead curve becomes $\xi\simeq 1$ for $0 \le \eta < 1$, but $\xi=0$ for $\eta=1$. In these games, before the winning goal is gotten by either Japan or Holland, they are balanced, and after that they follow the safety lead curve $\xi\simeq 1$. Hence, it is considered that these games are exciting through the total game length, even though they may look like one-sided game at a first glance.

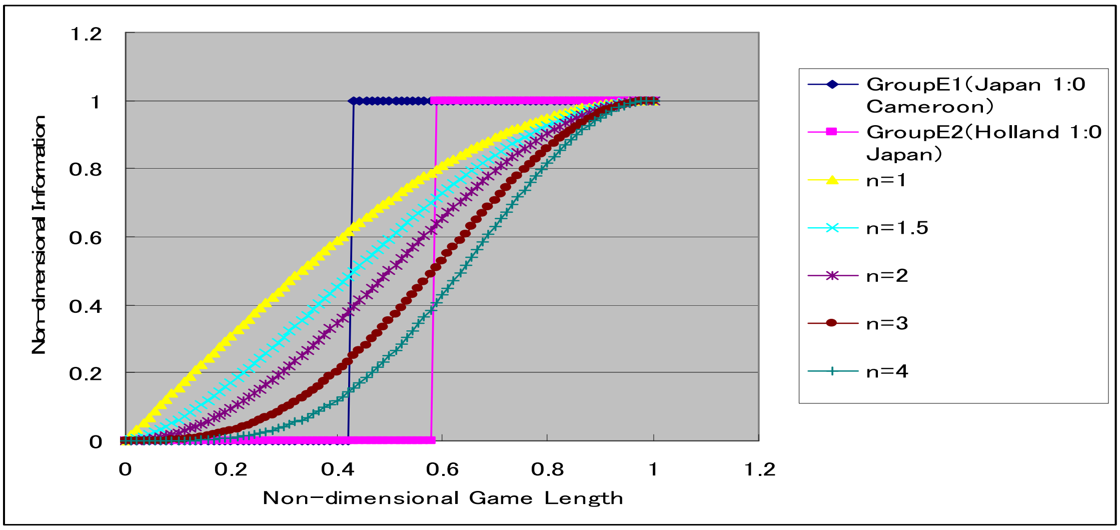

Figure 3: Non-dimensional information ξ against non-dimensional game length η for Group E1, Group E2 and Model 2

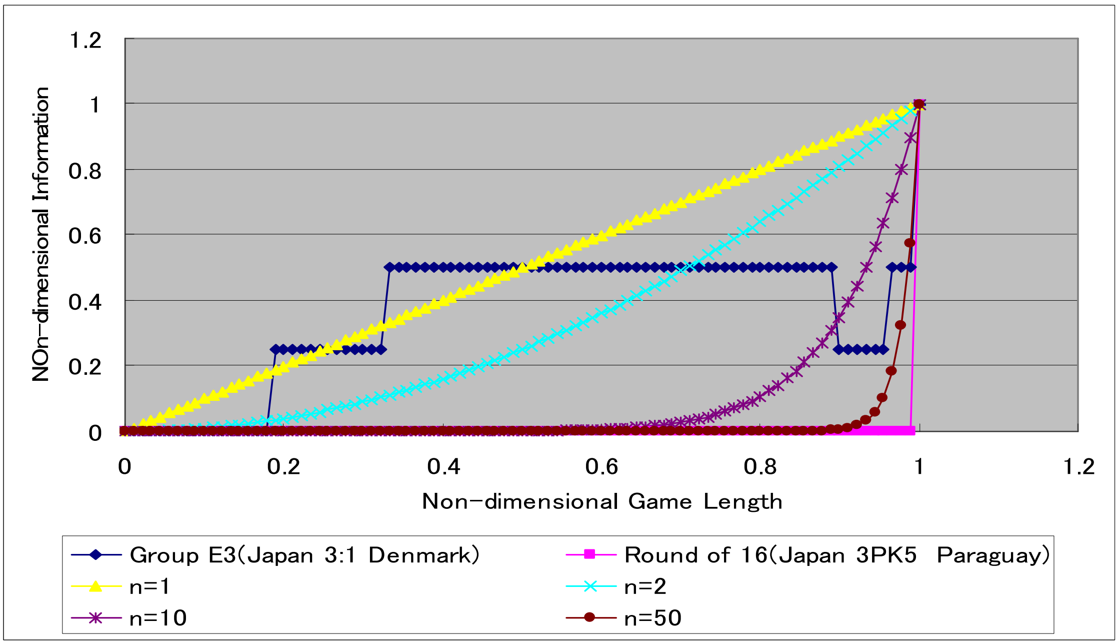

Figure 4: Non-dimensional information ξ against non-dimensional game length η for Group E3, Round of 16 and Model 1

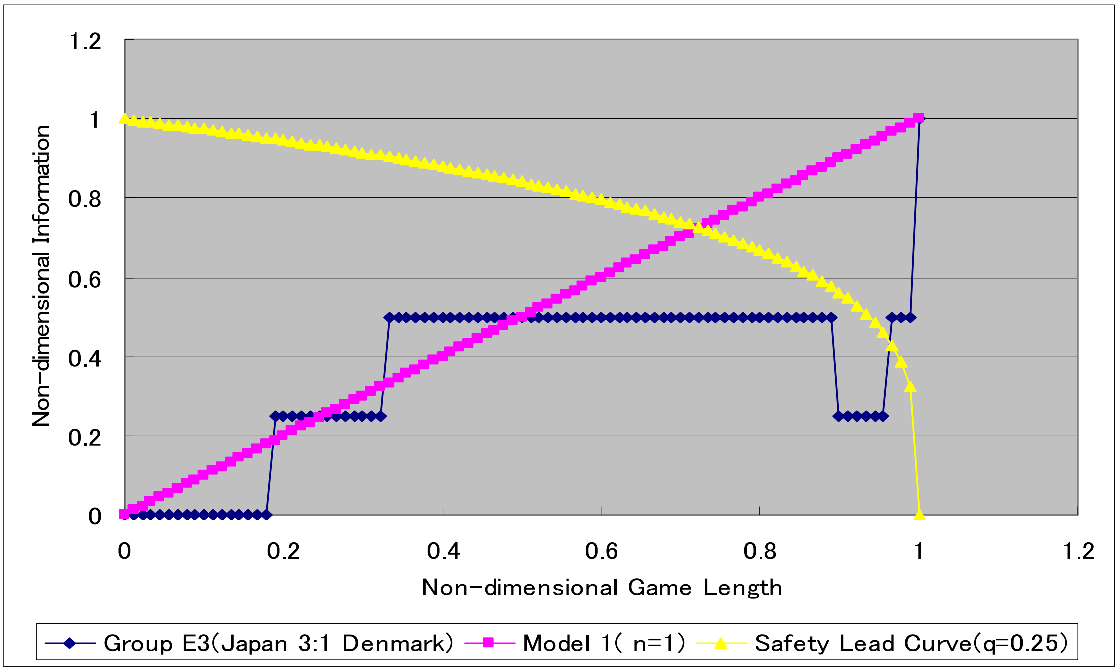

Figure 5: Non-dimensional information ξ against non-dimensional game length η for Group E3, Model 1 and Safety lead curve

Figure 4 shows the relation between the non-dimensional information ξ and non-dimensional game length η for Group E3, Round 16 and Model 1. Group E3 cannot be accounted for by Model 1 with any value of n, while Round 16 is roughly accounted for by Model 1 at n=50. In Round of 16, the strength difference between the two teams is also extremely small, so that the safety lead curve becomes $\xi \simeq 1$ for $0 \leq \eta < 1$, but $\xi=0$ for $\eta=1$ as in Group E1 and Group E2. Hence, it is considered that this game is interesting through the total game length.

Figure 5 illustrates a possible interpretation of Group E3. This game follows Model 1 $\xi=\eta$ until crossing the safety lead curve $\xi=(1-\eta)^{0.25}$, and then it bifurcates into two branches at the cross point(referred to "bifurcation point", here after): One branch is Model 1 $\xi=\eta$ and the other branch is the safety lead curve $\xi=(1-\eta)^{0.25}$: Information of Group E 3 follows Model 1 $\xi=\eta$ until the bifurcation point, then it switches to the safety lead curve $\xi=(1-\eta)^{0.25}$ and follows the curve until just before the end. Then, information of Group E3 jumps and joins to Model 1 $\xi=\eta$ at the end $\eta=1$.

This game progress pattern can be expressed analytically, by introducing the unit step function,

$u(\eta)=0$ for $\eta < 0$, $u(\eta) = 1$ for $\eta > 0$.

Then, the analytical expression of this game progress pattern becomes

$$\xi= \eta[u(\eta)-u(\eta-a)]+(1-\eta)^{0.25}[u(\eta-a) - u(\eta-1)] \quad \text{for } 0 \leq \eta < 1, \; 1 \quad \text{for } \eta=1, \tag{6}$$

where $a \simeq 0.72$. The coordinate (ξ, η) at the bifurcation point is (0.71, 0.71) approximately.

This finding is critical in view of entertainment in games, for if information of Group E3 follows Model 1 $\xi=\eta$ after the bifurcation point, the game becomes boring because the information is above the current safety lead curve $\xi=(1-\eta)^{0.25}$ or (6). On the other hand, as far as information of Group E3 is kept under the safety lead curve $\xi=(1-\eta)^{0.25}$ or (6), Group E3 is interesting, for the winner and loser are still uncertain. This result reflects the nature of game when the strength difference between the two teams is fairly small: In Group E3, Japan gets two consecutive goals first, so that Denmark fights very severely against Japan to avoid Japan's third goal, for this may result in providing Japan safety lead.

5. Conclusion

The new knowledge and insights obtained through the present investigation are summarized as follows.

Proposed are the safety lead curves of game. The safety lead curves have been derived by using a series of approximate solutions of the flow between two parallel flat walls, one of which is at rest, the other is suddenly accelerated from the rest to a constant velocity, and are expressed by

$$\xi=(1-\eta)^q \quad \text{for } 0 \leq \eta \leq 1$$

where ξ is the non-dimensional safety lead of game, η the non-dimensional game length, and q the positive real number parameter. It is realized that the proposed model of the safety lead also represents the uncertainty of game outcome.

The safety lead curve is critical for neutral observers to assess entertainment in game, for when the certainty of game outcome is below it, the game is exciting, while when the certainty is above it, the game is boring. It is suggested that any game is designed in such a way that it proceeds so as to keep the certainty of game outcome under the safety lead curve.

The power balance between the two teams (players) results in that the certainty of game outcome follows along the safety lead curve so as not to lose entertainment in game.

The safety lead curve can be a critical edge of game, at which two different things, viz. interesting game and boring game, happen, and thus one feels a particular emotion while the game proceeds along it.

The four Japan games in 2010 FIFA World Cup are under the safety lead curve , respectively, and thus they were interesting for neutral observers: In Group E1, Group E2, and Round of 16, the safety lead curve is common, and the safety lead ξ takes approximately value of 1 through the game except at the end, where $\xi=0$. In Group E3, the certainty of game outcome follows the information dynamic model $\xi=\eta$ until crossing with the safety lead curve $\xi=(1-\eta)^{0.25}$, and then it bifurcates into the two branches, follows the safety lead curve, and takes value of 1 at the end.

6. Recommendation for Future Work

It is realized that the analytical functions $\xi=(1-\eta)^q$ represents the safety lead of game and/or the uncertainty of game outcome, which is data that are uncertainty of game outcome(see Appendix). This function represents how uncertainty of game outcome depends on the game length. Májek & Iida(2004) have calculated how uncertainty of game outcome for Chess or Soccer changes with increasing the game length during the game. Thus, a direct comparison the information dynamic model$\xi=(1-\eta)^q$ and the calculated uncertainty of game outcome by Májek & Iida(2004) is strongly encouraged and recommended, for this provides us some clue to discover the relation between the present approach(Iida et al 2011a, 2011b) and Shannon's approach(Shannon 1948, 1951) on information.

Appendix: Derivation of Safety Lead Curve

The modeling procedure of information dynamics based on fluid mechanics has been established by Iida et al (2011a). An information dynamics model for a series of approximate solutions of the flow between two parallel flat walls, one of which is at rest, the other is suddenly accelerated from the rest to a constant velocity U_0, Figure A1, will be constructed by following the procedure step by step.

As a similar flow near a flat plate which is suddenly accelerated from rest and moves in its own plane with a constant velocity is solved by Stokes(1851, 1901). For a brief sketch of the solution, see Schlichting (1968).

(a) Let us assume the flow between two parallel flat walls, one of which is at rest, the other is suddenly accelerated from the rest to a constant velocity U_0. Figure A1.

Note that the walls are two-dimensional, horizontal and infinitely long.

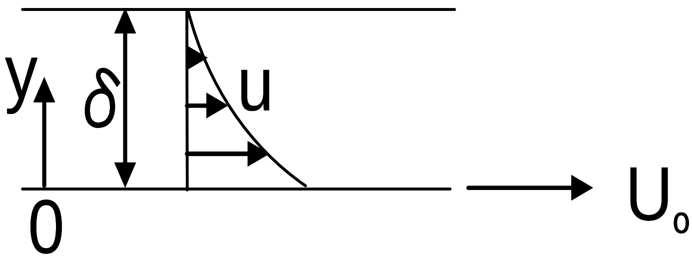

Figure A1: A definition sketch of flow between two parallel flat walls, one of which is at rest, the other is suddenly accelerated from the rest to a constant velocity U_0.

Since the system under consideration has no preferred length in the horizontal direction, it is reasonable to suppose that the velocity profile are independent of the horizontal x-direction, which means that the velocity profile u(y) for varying distance x can be made identical by selecting suitable scale factors for u and y. The scale factors for u and y appear quite naturally as the lower wall velocity U_0 and gap length between the two walls δ. Hence, the velocity profile after the time $t > 0$ can be written as the function of f in the following way.

$$u/U_0 = f(y/\delta). \quad \text{(A-1)}$$

(b) Get the solutions.

The velocity profile is here accounted for by assuming that function f depends on y/δ only, and contains no additional free parameter. Since the fluid particles are fixed on the surface of two walls due to the viscous effect, the function must take the value of 1 on the lower wall(y=0) and the value of 0 on the upper wall(y=δ) , because owing to the viscous effect the fluid particles are fixed on the walls. The boundary conditions are:

$t \le 0$: $u/U_0=0$ for $0 \le y/\delta \le 1$,
$t > 0$: $u/U_0=1$ for $y/\delta=0$; $u/U_0=0$ for $y/\delta=1$.

When writing down an approximate solution of the present flow, it is necessary to satisfy the above boundary conditions for u/U_0. It is evident that the following velocity profiles satisfy all of the boundary conditions.

$$u/U_0 = (1 - y/\delta)^q, \quad \text{(A-2)}$$

in the range $0 \le y/\delta \le 1$, where q is positive real number parameter. Equation (A-2) is considered as the approximate solutions on the flow between two parallel flat walls, one of which is at rest, the other is suddenly accelerated from the rest to a constant velocity U_0, where each solution takes an unique value of q. The value of q must be determined by the boundary conditions and the Reynolds number $R_e= U_0 \bullet \delta/\nu$, where ν is the kinematic viscosity of the fluid.

It is known that the transition from laminar to turbulent flow in the boundary layer is governed by the Reynolds number $R_e= U_\infty \bullet d/\nu$, where U_∞ is the free stream velocity, d the boundary layer thickness. The critical Reynolds number $R_{e\ crit.}$, at which the transition is initiated, is of 2,800 approximately (e.g. Hansen 1928, Schlichting 1968).

In case of the present flow, as shown in Figure A1, at 1 atmospheric pressure and temperature at 20°C, water has the kinematic viscosity ν=1.004x10^{-2} cm^2/s. When water is chosen as the fluid, and the constant velocity U_0 = 10 cm/s and the gap distance between the two walls δ=10 cm are set, we obtain the Reynolds number $R_e \simeq 10^4$. The result of this calculation clearly illustrates how the flow is liable to be turbulent under an ordinary conditions.

The solutions (A-2) are smooth analytical functions and thus they are only valid for laminar flow. For turbulent flow, no solution is known yet, but there is some hope to obtain it, by following Tsugé's statistical theory of turbulence (Tsugé 1974, Nakagawa 2008).

The fundamental governing equations for fluid mechanics are the Navier-Stokes equation(e.g, Nakagawa & Chanson 2002, 2006). This inherently nonlinear set of partial differential equations has no general solution, only a few exact solutions have been found(Wang 1991). All of these exact solutions are for laminar flows, and no turbulent flow solution is available yet. However, it is considered that each of the laminar solutions in (A-2) represents an approximate turbulent solution. In this regard, we consider that the solutions (A-2) are only applicable for laminar flow.

(c) Let us examine whether this solution is game information or not.

The non-dimensional velocity u/U_0 varies from 1 to 0 with increasing non-dimensional distance y/δ in many ways with changing the parameter q. It can be considered that u/U_0 represents the non-dimensional safety lead of game. This is why the non-dimensional safety lead of game takes the value of 1 at start, and it decreases with increasing the game length and becomes the value of 0 at the end of game.

(d) Visualize the assumed flow with some means.

Imagine that the assumed flow is visualized with neutral buoyant particles. Motion of the visualized particles is detected by the eye almost instantaneously through light and is mapped on our retina(Solso 1994), so that during these processes, motion of the "fluid particles" is transformed into that of the "information particles" by light carrying the images of fluid particles. This is why motion of the fluid particles is intact in the physical space, but only the reflected lights, or electromagnetic waves consisting of photons can reach the retina. Photons are then converted to electrochemical particles and are passed along the visual cortex for further processing in parts of the cerebral cortex(Solso 1994). Photons and /or electrochemical particles are considered to be information particles. It is, therefore, natural to expect that the flow in the physical world is faithfully transformed to that in the information world, or brain including eye, which is referred to "informatical world" here after. During this transformation, the flow solution in the physical world changes into the information in the informatical world.

(e) Proposed are correspondences between the flow and game information, which are listed in Table A1.

Table A1: Correspondences between flow and game information

Physical world(flow)	Informatical world(game)
u: flow velocity	I: current safety lead
U_0: lower plate velocity	I_0: initial safety lead
y: vertical distance	L: current game length, or time
δ:gap between two walls	L_0: total game length

(f) Obtain the analytical expression of information.

Considering the correspondences in Table A1, (A-2) can be rewritten as

$I/I_0 = (1-L/L_0)^q$. (A-3)

Introducing the following non-dimensional variables in (A-4),

$\xi = I/I_0$ and $\eta = L/L_0$,

we finally obtain the analytical function of the non-dimensional safety lead of game as

$\xi = (1-\eta)^q$ for $0 \le \eta \le 1$, (A-4)

where ξ is the no-dimensional current safety lead of game, η the non-dimensional current game length, and q the positive real number parameter. We expect that the greater the value of q is, the greater the strength difference between the two teams (or players) in a game is, and vice versa.

It is realized that the analytical functions, (A-4) represents the non-dimensional uncertainty of game outcome.

Figure A2 illustrates how non-dimensional safety lead and/or non-dimensional uncertainty of game outcome ξ due to (A-4) changes with increasing non-dimensional game length η.

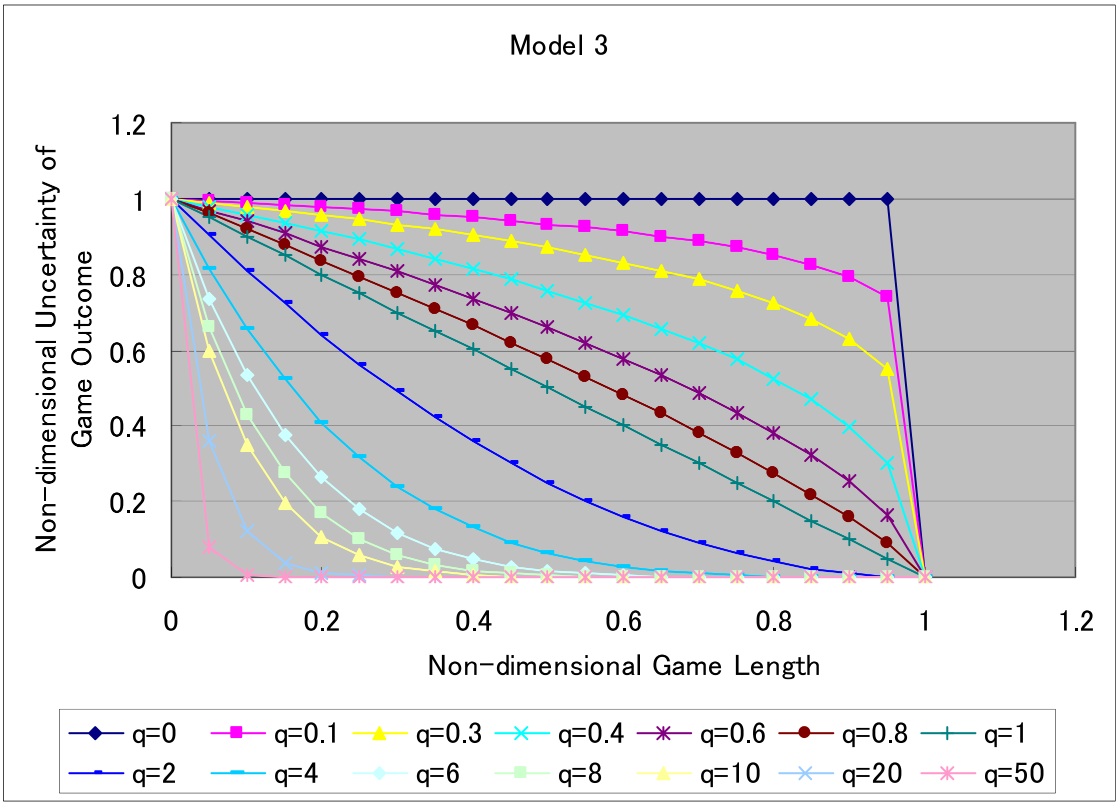

Figure A2: Non-dimensional safety lead and/or uncertainty of game outcome ξ against non-dimensional game length η

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