

Japan Judo Championship 2019

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Abstract

This paper is concerned with the case studies on Final and Semi-final in All Japan Judo Championship 2019, and is analyzing the relevant data in terms of the information dynamic model. The Final is a typical balanced game, which is finished by the Golden Score, while the Semi-final is classified as one-sided game. In the Semi-final, it has been shown that the winner gets the safety lead against the loser at the normalized time $\eta \approx 0.8$, which means that outcome of this match becomes definite at the stage, 80% of the total game length. It is inferred that in the All Japan Judo Championship, the sudden death of both players will occur, but drawn game cannot be expected anymore, as far as the current refereeing rules are sustained. It is realized that the present approach is promising to predict the history and outcome of any game before it starts, so that it is useful for preparing the tactics or strategy for future games.

Keywords: Judo, Golden Score, Advantage, Certainty of Game Outcome, Gambling, Serious Game

1. Introduction

Any event can be viewed as a single game as far as there is the start, play and end. Of course, life, an annual ring of a tree, construction work of dam or building, judo[1], baseball [2] , the effect of medicine[3], soccer or shogi [4] are not the exception. It is, therefore, crucial to examine how each the game varies with time. Since 2010, a new information dynamic model for the game has been researched extensively and developed by several authors [1,2] in terms of the boundary layer theory in fluid mechanics. This model incorporates notion of time in the game analyses for the first time, and thus makes it possible to discuss how advantage, or certainty of game outcome change with time before, during and after the game. In principle, we could not only reflect the game after it is over, but predict the game before it starts, if necessary and sufficient information regarding to players or teams, is provided. Obvious candidates of natural phenomena and games, to be considered in the future, are typhoon (cyclone), earthquake, flood, tsunami, climate, business fluctuations, horse race, bicycle race, motorboat race, and gambling. As far as the author is aware, no previous model has been able to predict the history and outcome of the game before it starts. For example, von Neumann's game theory [5] is concerned with only a few outcomes obtained by each player, but is not discussing about the history of the game.

Main purpose of the present study is to conduct case studies for Final and Semi-final in All Japan Judo Championship 2019, in order to understand details of these matches and obtain new knowledge and insights being useful for the further development of judo.



Method of Analyses

2.1 Elemental Procedure

For clarity, elemental procedure for obtaining the advantage α , certainty of game outcome ξ , and uncertainty of game outcome ς will be explained by using soccer game between teams A and B, where only goal is assumed to be the evaluation function score, which may be defined as critical factor(s) for the game outcome.

The advantage α is defined as follows: When the total score(s) of the two teams at the end of game $S_T \neq 0$,

$$\alpha = [S_A(\eta) - S_B(\eta)]/S_T \text{ for } 0 \leq \eta \leq 1, \quad (1)$$

Where $S_A(\eta)$ is the current score sum for team A(winner), and $S_B(\eta)$ is the current score sum for team B(loser). This means that when $\alpha > 0$, team A (winner) gets the advantage against team B (loser) in the game, while when $\alpha < 0$, team B (loser) gets the advantage against team A(winner). It is certain that when $\alpha = 0$ the game is balanced. It is worth noting that goal is merely one of the evaluation function scores in soccer, but shoot, penalty kick, free kick or corner kick maybe the other candidates of the evaluation function score(s). It is critical how assessor(s) chooses and assesses the evaluation function scores during the game. When the total score(s) of the two teams at the end of game $S_T = 0$, $\alpha = 0$ for $0 \leq \eta \leq 1$.

The certainty of game outcome ξ during the game is defined as follows: When the total score(s) of the two teams at the end of game $S_T \neq 0$,

$$\begin{aligned} \xi &= |S_A(\eta) - S_B(\eta)|/S_T \text{ for } 0 \leq \eta < 1 \\ &= 1 \text{ (completed game) or } 0 \text{ (drawn game) at } \eta = 1. \end{aligned} \quad (2)$$

At $\eta = 1$, ξ is assigned to the value of 1, for at the end of a completed game, the information on the game outcome must be full. The reason why we take the absolute value of the advantage α to get the certainty of game outcome ξ for $0 \leq \eta < 1$ is that ξ is independent of the sign of α . This may be reasonable if one consider meaning of the certainty of game outcome: As far as the absolute value of the advantage α increases (decreases), the certainty of game outcome ξ must increase (decrease). However in case of a drawn game, ξ may be assigned to the value of 0 at the end of game $\eta = 1$, the game is back when it starts. When the total score(s) of the two teams at the end of game $S_T = 0$, $\xi = 0$ for $0 \leq \eta \leq 1$.

The uncertainty of game outcome ς during the game is defined as follows,

$$\varsigma = 1 - \xi. \quad (3)$$

This equation denotes that the current uncertainty of game outcome ς can be obtained by subtracting the current certainty of game outcome ξ from value of 1.

The game length is the current length (or time) from the start of the game, and is normalized by the total game

length (or total time) to obtain the normalized game length η .

2.2 Data Analyses

Keeping in mind the forgoing elemental procedure to obtain the advantage α , certainty of game outcome ξ , and uncertainty of game outcome ζ , it may be straight forward to apply them to actual judo matches. That is, in soccer we consider that goal(s) is no more than evaluation function score, assessed by the referee. Similarly to soccer, in judo, score(s) assessed by the referee has been adopted as the evaluation function score(s), for it is the most reliable and critical information regarding to the game outcome.

In All Japan Judo Championship, Kodokan Judo Refereeing Rules [7], which are published by All Japan Judo Federation, and are different essentially from International Judo Federation Refereeing Rules [8], which are published by International Judo Federation, have been adopted. Main points of Kodokan Judo Refereeing Rules[7] are summarized as follows:

There is no class divided by weight or open-weight. This may be the most unique rule in this championship for determining the best *judoka* in Japan. Duration of the regular match is of 4 minutes.

Evaluation of the scores in *tachi-waza*: (1) There will be *ippon*, *waza-ari* and *yuko*. (2) *Ippon* will be given when one *judoka* throws his opponent on the back, applying a technique or countering his opponent's attacking technique, with considerable ability with maximum momentum and skillfulness. (3) Criteria for *ippon* are speed, force, on the back, and skillfully control until the end of the landing. (4) Rolling can be considered *ippon* only if there is no brake during landing. (5) *Waza-ari* will be given when the four *ippon* criteria are not fully achieved. (6) *Yuko* will be given when one *judoka* throws his opponent with control, and as the result, the opponent falls on the side of the upper body. (7) Two *waza-aris* are the equivalent of *ippon* (*waza-ari-awasete-ippon*) and the match will be finished, but because the value of three (or more) *yukos* is even less than that of *ippon*, the regular match will not be finished by any number of *yuko* before the regular time is run out. Bridge: All situations of voluntarily landing in the style of bridge, will be given *hansoku-make*. Head defense: Voluntary use of the head for defense to avoid landing in escaping from a score will be given *hansoku-make*. Evaluation of the scores in immobilizations (*osaekomi*): *Waza-ari* is for 25 seconds, and *ippon* is for 30 seconds.

Technical score: (1) During the regular time of 4 minutes, a match can only be won by technical score(s)(*yuko*, *waza-ari* or *ippon*). (2) A penalty (or penalties) will not decide the winner or loser, except for *hansoku-make* (direct or by accumulative three *shidos*). (3) A penalty is not a score. (4) Two *shidos* are already given to one *judoka* and then her (or his) third *shido* results in the *hansoku-make*.

Shido: Given are in various cases, for examples (1) Breaking the grip of the opponent with two hands, (2) Blocking the opponent's hand(s), (3) Help with legs to break grip of the opponent, (4) Intentional action to lose the time, (5) Continuing to negative judo without fighting.

Judogi: (1) For a better efficiency and to have a good grip it is necessary for the jacket to be well fitted in the belt,

with the belt tied neatly, (2) To reinforce that, each the *judoka* shall arrange her(or his) *judogi* and belt quickly between *Mate!* and *Hajime!* announced by the referee. (3) If a *judoka* intentionally loses time arranging her (or his) jacket and belt, she (or he) will receive *shido*.

Golden Score: When both players' technical scores are equal within the regular time of 4 minutes, the game shall be continued a regardless number of *shido*(s) given. (1) Any existing technical score(s) and *shido*(s) given during the regular time shall be carried into the Golden Score period and thus will remain on the score board. (2) Golden Score can only be won either by a technical score (*yuko*, *waza-ari* or *ippon*) or *hansoku-make* (direct or by accumulative three *shidos*). (3) A penalty is not a score. (4) There is no time limit for the Golden Score period.

On the basis of the above referee rules [7], standard of the present evaluation function scores has been proposed as listed in Table 1. The score of *ippon* is assigned to 1, and that of *waza-ari* is assigned to 0.5, for two *waza-aris* are equivalent of *ippon*. Accumulative three *shidos* become *hansoku-make*, and thus score of *shido* is assigned to -0.33, and that of *hansoku-make* is assigned to -1. Finally, score of *yuko* is assigned to 0.25 tentatively, for the value must be between 0 and 0.5, and smaller than 1/3. This is because even three (or more) *yukos* are not worth of *ippon*. Note that during the two case studies, to be discussed in the next section, no *yuko* appears.

Table 1 Standard of the present evaluation function scores

Name	Score
<i>ippon</i>	1
<i>waza-ari</i>	0.5
<i>yuko</i>	0.25
<i>shido</i>	-0.33
<i>hansoku-make</i>	-1

2. Two Case Studies

In this section, two games have been investigated. One is the Final, H. Kato vs. W. Aaron, and the other is the Semi-final, Y. Ogawa vs. W. Aaron in All Japan Judo Championship, held on April 2019 at Nippon Budo-kan, Tokyo Japan.

3.1 Final

Table 2 summarizes results of data analyses together with the evaluation function scores, where $t_0=329$ seconds is the total game time, $\eta=t/t_0$ is the normalized time, t is the time, α is the advantage, $A_T=\sum_{i=1}^3 |A_{il}|=1.16$ is total

of the evaluation function scores, $a_i = A_i/A_T$ is each of the normalized evaluation function scores, and A_i is each of the evaluation function scores.

Table 2 Game records of Final, Hirotake Kato vs. Wolf Aaron

Time	Normalized Time	Advantage	Evaluation Function Score $A_i(a_i)$	
t (s)	η	α	H. Kato	W. Aaron
0	0	0		
94	0.286	0	-0.33(-0.28)	-0.33(-0.28)
240*	0.729	0		
329	1	0.43	0.5(0.43)	

*At this moment, the regular match is over, and is extended until W. Aaron gets the Golden Score.

Brief history of the game:

Soon after the match starts, Kato and Alon grapple with each other tightly, and are trying to make a grab at the good part of the opponent's jacket without any success.

At $t=94$ seconds, *shido* is given to the both players, respectively, at the same time, for they have not attacked seriously with each other since the start. The match is restarted, but the situation does not change, they only fight with fingers by trying to grab the opponent's jacket. This continues to $t=240$ seconds, when the main match is over. The match is immediately extended to Golden Score stage, and the similar battle is continued by the both players during this period. However, at $t=329$ seconds, Aaron throws Kato by *sasae-tsurikomi-ashi* with his left foot. At this moment, the referee declares *waza-ari* by raising his right hand horizontally. Aaron wins the match by taking the technical score, *waza-ari*. This match continues to be balanced until the moment just before Aaron gets the Golden Score, so that this match may be classified as so-called balanced game [6].

3.2 Semi-final

Table 3 summarizes results of data analyses together with the evaluation function scores, where $t_0=208$ seconds is the total game time, $\eta=t/t_0$ is the normalized time, t is the time, α is the advantage, $A_T=\sum_{i=1}^4 |A_i|=1.99$ is total of the evaluation function scores, $a_i = A_i/A_T$ is each of the normalized evaluation function scores, and A_i is each of the evaluation function scores.

Table 3 Game records of Semi-final, Yusei Ogawa vs. Wolf Aaron

Time t (s)	Normalized time η	Advantage α	Evaluation Function Score $A_i(a_i)$ Y. Ogawa	W. Aaron
0	0	0		
67	0.322	0.17	-0.33(-0.17)	
161	0.774	0.34	-0.33(-0.17)	
193	0.927	0.17		-0.33(-0.17)
208	1	0.67		1(0.5)

Brief history of the game:

From the start, Aaron attacks to Ogawa by *Ouchi-gari*, and repeats *waza* several times, while Ogawa is defending Aaron's attack mainly. Thus, at $t=67$ seconds the referee declares the first *shido* to Ogawa. Aaron maintains his attack on Ogawa, and throws him so as to fall backward on his rear end. Though no score is added to Aaron by these attacks, at $t=161$ seconds the referee declares the second *shido* to Ogawa. Then, Ogawa begins his attacks to Aaron by grabbing the *oku-eri* without gaining any score, but at $t=193$ seconds the referee declares the first *shido* to Aaron. After that, the offensive and defensive battles by the both players are repeated in several times, and at $t=208$ seconds Aaron makes Ogawa fall down on his back by *Ouchi-gari*, and the referee declares *ippon* by raising his right hand vertically. Aaron wins the match. Figure 1 shows the relation between the advantage α and the normalized time η for the match, Ogawa vs. Aaron. It is evident from this figure that Aaron (winner) keeps his advantageous position against Ogawa (loser) throughout the match, though Aaron is declared *Shido* at $\eta=0.927$ (193 second).

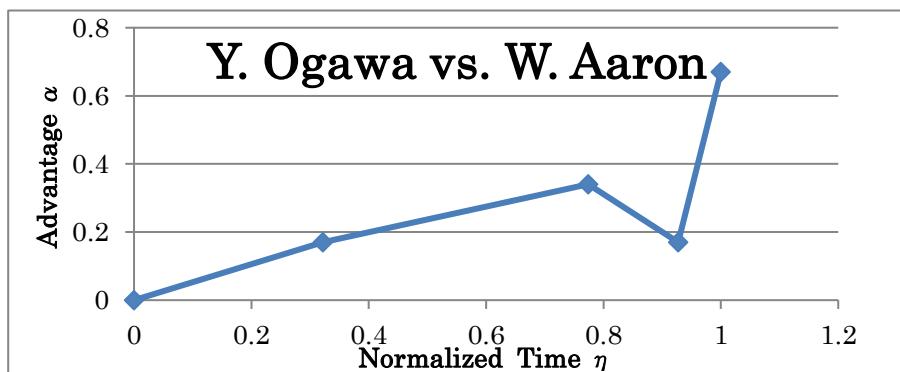
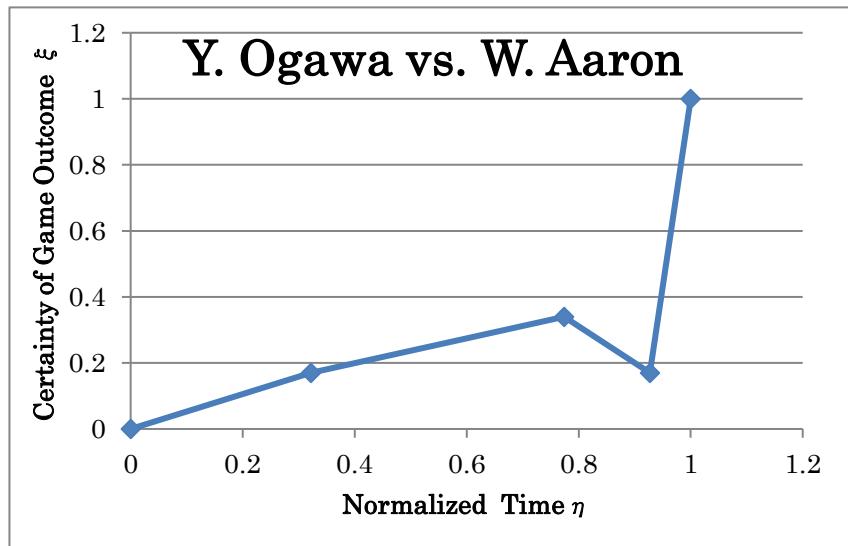


Figure 1 Advantage α against the normalized time η

Figure 2 shows the relation between the certainty of game outcome ξ and the normalized time η for the match, Ogawa vs. Aaron. This indicates that certainty of game outcome ξ gradually increases with increasing normalized time η except at $\eta=0.927(t=193\text{second})$, so that it is considered that this match is classified as a so-called one-sided game [4].

**Figure 2 Certainty of game outcome ξ against the normalized time η**

4 Discussion

In any completed game, there must be game point, which is defined in such a way that once certainty of game outcome exceeds over the point (or uncertainty of game outcome goes below the point), the advantageous player gets the safety lead against the disadvantageous player. The game point is no more than the cross point of the two curves, certainty of game outcome ξ and uncertainty of game outcome ζ .

Let us discuss the game point in the match, Ogawa vs. Aaron in terms of information dynamic model,

$$\xi = \eta^m, \quad (4)$$

where ξ is certainty of the game outcome, η is the normalized time, and m is a positive real number. In Figure 3, plotted are the curves of the certainty of game outcome ξ due to the evaluation function scores(or data) and three information dynamic models $\xi = \eta^2$, $\xi = \eta^3$, and $\xi = \eta^5$ concurrently. For the full account of the information dynamic model, refer to Appendix.

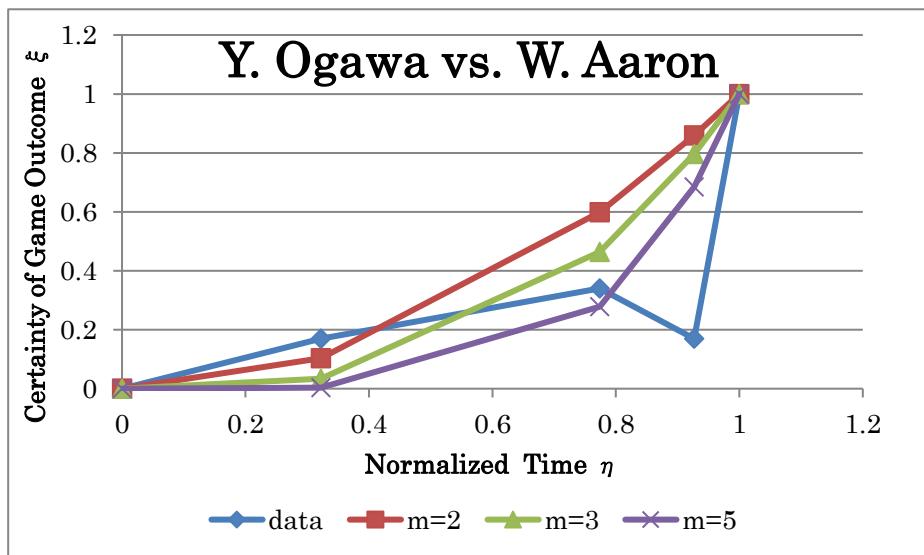


Figure 3 Certainty of game outcome ξ against normalized time η

It may be evident that the best fit information dynamic model with the game data of Ogawa vs. Aaron is

$$\xi = \eta^3. \quad (5)$$

Using (3) and (5), we have the uncertainty of game outcome as

$$\zeta = 1 - \eta^3 \quad (6)$$

Figure 4 shows the relation between the information of game outcome and the normalized time η , where certainty of game outcome ξ and uncertainty of game outcome ζ are plotted concurrently. The game point (or cross point) is found by using (5) and (6), as $\xi = \zeta = 0.5$, $\eta \approx 0.8$. It is, therefore, considered that Aaron gets the safety lead against Ogawa at the normalized time $\eta \approx 0.8$.

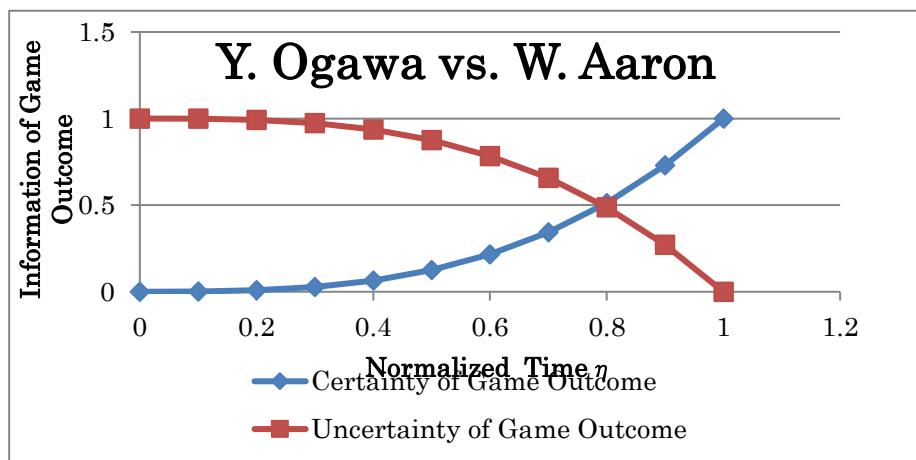


Figure 4 Information of game outcome against normalized time η

During the championship, there appears unusual match, Kazunari Sato vs. Yusuke Kumashiro, both of whom are

declared the third *Shido* at the same time, and thus the game ends without any winner. When Sato and Kumashiro are given the second *shido*, respectively, by stopping the match, the referee notices that the third *shido* results in *hansoku-make* or the loss of the match. None the less, they cannot still fight offensively in the match, so that the sudden death of the both players happens during the Golden Score period. On this regard, after the match, the chairman of referees makes supporting comments on the referee's judge.

In the history of All Japan Judo Championship, another unusual game, Takahiko Ishikawa vs. Masahiko Kimura has been reported: The Final, in the Second All Japan Judo Championship 1949, Ishikawa fought desperately with Kimura using *tachi-waza* and *ne-waza*, until the end of the third extended matches. As the result, according to the rule at that time, both Ishikawa and Kimura became the champion. It is considered that this is reflecting the Kodokan Judo Refereeing Rules [7] at that time, which put weight to decide the victory or defeat by *waza* or technical scores(*ippon*, or *waza-ari*).

In 2017, International Judo Federation Refereeing Rules [8] are revised extensively. Although class divisions in weight are maintained, as *waza*, *waza-ari*, and *Ippon*, while as penalties, *shido* and *hansoku-make* become the main objects to be judged by the referee: *Waza-ari* and *Ippon* are counted as technical scores, and the two *waza-aris* are equivalent of *ippon* (*waza-ari-awasete-ippon*). On one hand, *shido* is not counted as minus technical score, but the three *shidos* result in *hansoku-make*.

In addition, introduction of the Golden Score to the Kodokan Judo Refereeing Rules [7] has enhanced to promote positive judo, for one *judoka* can become winner only by the technical scores without time limit. The International Judo Federation Refereeing Rules [8] regarding to *shido*, *hansokumake*, and Golden Score have been introduced into the current Kodokan Judo Refereeing Rules [7] without any change. It may be evident that these cause the unusual game Kato vs. Kumashiro, which is the sudden death of the both players, but contribute to avoiding the drawn game in judo. It is, therefore, suggested that in the All Japan Judo Championship, sudden death of both players will occur, but drawn game cannot be expected any more in the future, as far as the current refereeing rules are maintained.

It may be worth pointing out that the information dynamic model possesses the potential to predict the history and outcome of game. Using initial conditions such as player's ranking, and/or record, value of the parameter' in the analytical expression of the model in eq. (4) may be obtained before a match starts. It is clear that once this value is given, the match will proceed along one of the model curves as plotted in Figure 6 from start to end. The information dynamic model is applicable to predict future trends in GDP (Gross Domestic Product), population, temperature, and many others.

5 Conclusions

In this section, new knowledge and insights obtained through the present study have been summarized.

- The Final, Kato vs. Aaron is a typical balanced game, which is finished by Aaron's Golden Score due to *sasae-tsurikomi-ashi*.

- In the Semi-final, Aeron keeps his advantageous position against Ogawa throughout the match, which is classified as one-sided game. It has been demonstrated by the data analyses that Aaron gets the safety lead against Ogawa at the normalized time $\eta \approx 0.8$, which is corresponding to the stage, at 80 % of the total game length.
- It is inferred that in All Japan Judo Championship, sudden death of both players as the match, Sato vs. Kumashiro will occur, but drawn game as the game, Ishikawa vs. Kimura in the second championship 1949, cannot be expected anymore, as far as the current refereeing rules are sustained [7].
- It is realized that the present approach is promising to predict the history and outcome of any game before it starts, so that it is useful for preparing tactics or strategy for future judo matches.

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Appendix: Information Dynamic Model

Currently, information dynamic model only make it possible to treat and identify game progress patterns depending the game length (or time). In this model, information of game outcome is expressed as a simple analytical function depending on the game length, where information of game outcome is certainty of the game outcome. In this Appendix, the information dynamic model has been introduced.

Modelling Procedure

The modeling procedure of information dynamics based on fluid mechanics is summarized as follows:

- (a) Assume a flow as the information dynamic model and solve it.
- (b) Get the solutions, depending on the position (or time).
- (c) Examine whether any solution of the flow can correspond to game information.
- (d) If so, visualize the assumed flow with some means. If not, return the first step.
- (e) Determine the correspondence between the flow solution and game information.
- (f) Obtain the analytical expression of the information dynamic model.

The information dynamic model will be constructed by following the above procedure step by step.

- (a) Let us assume flow past a flat plate at incident angle of zero as the information dynamic model (Figure 5).

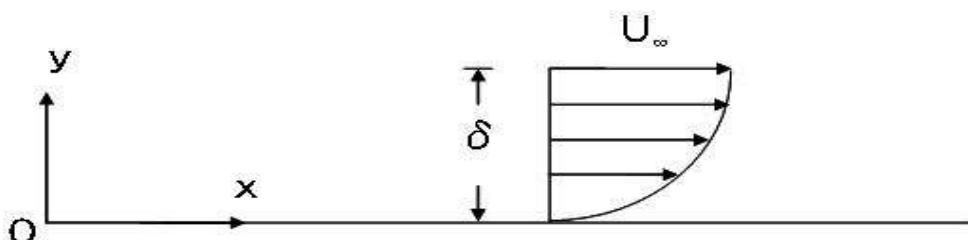


Figure 5 Definition sketch of flow past a flat plate at incident angle of zero

An example of the application of the boundary-layer equations, which is the simplified version of Navier-Stokes equations [9], is afforded by the flow along a very thin flat plate at incident angle of zero. Historically this is the first example illustrating the application of Prandtl's boundary layer theory [10]; this has been solved by Blasius [11] in his doctoral thesis at Göttingen. Let the leading edge of the plate be at $x=0$, the plate being parallel to the x -axis and infinitely long downstream, as depicted in Figure 5. We shall consider steady flow with a free-stream velocity U_∞ , which is parallel to the x -axis. The boundary-layer equations [9,10] are expressed by

$$u \cdot \partial u / \partial x + v \cdot \partial u / \partial y = -1/\rho \cdot dp / dx + \nu \partial^2 u / \partial y^2, \quad (7)$$

$$\partial u / \partial x + \partial v / \partial y = 0, \quad (8)$$

$$y = 0 : u = v = 0; \quad y = \delta : u = U_\infty, v = 0, \quad (9)$$

where u and v are velocity components in the x - and y - directions, respectively, ρ the density, p the pressure and ν the kinematic viscosity of the fluid. In the free stream,

$$U_\infty \cdot dU_\infty / dx = -1/\rho \cdot dp / dx. \quad (10)$$

The free-stream velocity U_∞ is constant in this case, so that $dp/dx=0$, and evidently $dp/dy=0$. Since the system under consideration has no preferred length it is reasonable to suppose that the velocity profiles at varying distances from the leading edge are similar to each other, which means that the velocity curves $u(y)$ for varying distances x can be made identical by selecting suitable scale factors for u and y , respectively. The scale factors for u and y appear quite naturally as the free-stream velocity, U_∞ and the boundary-layer thickness, $\delta(x)$, respectively. Hence, the velocity profiles in the boundary-layer can be written as

$$u/U_\infty = f(y/\delta). \quad (11)$$

Blasius [9] has obtained the solution in the form of a series expansion around $y/\delta=0$ and an asymptotic expansion for y/δ being very large, and then the two forms being matched at a suitable value of y/δ .

(b) The similarity of the velocity profile is here accounted by assuming that function f depends on y/δ only, and contains no additional free parameter for each profile. The function f must vanish at the wall ($y = 0$) and tend to the value of 1 at the outer edge of the boundary-layer ($y = \delta$).

When using the approximate method, it is expedient to place the point at a finite distance from the wall, or in other words, to assume a finite boundary-layer thickness $\delta(x)$, in spite of the fact that all exact solutions of boundary-layer equations tend asymptotically to the free-stream associated with the particular problem. 'Approximate method' here means that all the procedures are to find approximate solutions to the exact solution. When writing down an approximate solution of the present flow, it is necessary to satisfy certain

boundary condition for $u(y)$. At least the no-slip condition $u = 0$ at $y = 0$ and the condition of the continuity when passing from the boundary-layer profile to the free-stream velocity, so that $u = U_\infty$ at $y = \delta$, must be satisfied.

It is evident that the following velocity profile satisfies all of the boundary conditions for the assumed flow past a flat plate at incident angle of zero,

$$u/U_\infty = (y/\delta)^m, \quad (12)$$

where m is positive real number. Eq. (12) is heuristically derived, and represents a series of the approximate solutions for the assumed flow, taking each the different values of m . In the case of $m=1$, (12) reduces to an exact solution for the boundary-layer equations, but the rest solutions are considered as the approximate solutions to the other exact solutions, respectively. Note that only several exact solutions are known so far [8].

(c) Let us examine whether these solutions are game information or not. Such an examination immediately provides us that the non-dimensional velocity u/U_∞ changes from 0 to 1 with increasing the non-dimensional vertical distance y/δ in many ways as the non-dimensional information varies from 0 to 1 with increasing the non-dimensional time, so that these solutions can be game information. However, the validity of this conjecture will be confirmed by the relevant data.

(d) Imagine that the assumed flow is visualized with neutral buoyant particles. Motion of the visualized particles is detected by the eye almost instantaneously through the lights and is mapped on our retina first[12], so that during these processes, motion of 'fluid particles' is transformed into that of the 'information particles' by the 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 at the retina. The photons are then converted to electrochemical particles and are passed along the visual cortex for further processing in parts of the cerebral cortex [12]. The photons and/or electrochemical particles are considered to be information particles. It is, therefore, natural to expect that the flow in the physical space is faithfully transformed to that in the information space, or brain including the eye. During this transformation, the flow solution in the physical space changes into the information solution in the information space.

(e) Proposed are correspondences between the flow and game information, which are listed in Table 4.

Table 4: Correspondences between flow and game information

Flow	Game
u : flow velocity	I : current information
U_∞ : free stream velocity	I_0 : total information

y: vertical co-ordinate

t: current game length

 δ : boundary layer thickness t_0 : total game length

f) Considering the correspondences in Table 4, (12) can be rewritten as

$$I/I_0 = (t/t_0)^m \quad (13)$$

Introducing the following normalized variables in (13),

$$\xi = I/I_0 \text{ and } \eta = t/t_0,$$

we finally obtain the analytical expression of the information dynamic model as

$$\xi = \eta^m \quad (14)$$

where ξ is the certainty of the game outcome, η the normalized game length, and m is a positive real number.

Figure 6 illustrates the relation between certainty of game outcome ξ and normalized game length η (or time), where a total of 10 model curves have been plotted concurrently. This figure suggests the versatility of this model (14), for each of the curve, is considered to represent a game. Thus, this model can represent any game in principle, for the parameter 'm' can take any positive real number. The smaller the strength difference between both players (or teams) is, the greater the value of m , and vice versa. This means that each the game takes a unique value of m , and thus experiences its own history from start to end.

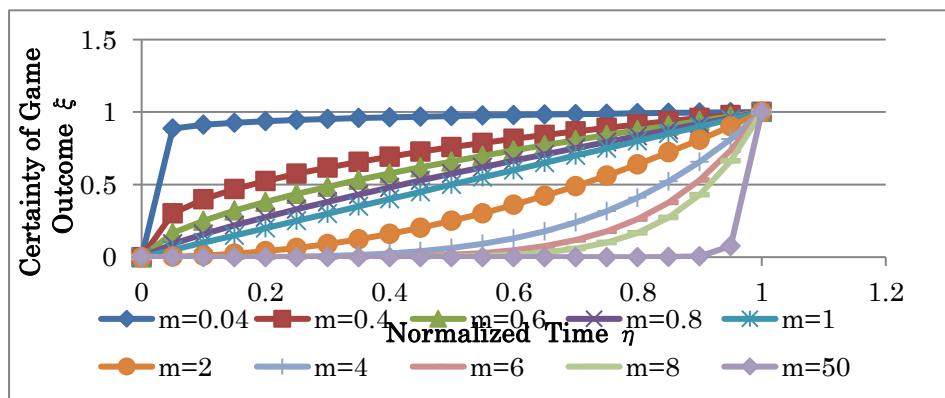


Figure 6 Certainty of game outcome ξ and normalized time η