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Description	

A Novel Game Information Dynamic Model based on Fluid Mechanics: Case Study using Base Ball Data in World Series 2010

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ABSTRACT

We propose a procedure to form information models based on equations of fluid mechanics. A novel game information dynamic model constructed using the procedure is proposed. This model is derived from a series of approximate solutions for flow past a flat plate at zero incidence. The five Base Ball games in the World Series 2010 are analyzed and the information dynamics is discussed in the light of the present model. It is found that the present model properly accounts for 'one-sided game' where information gradually approaches to the value of game outcome with increasing the game length near the end. The modelling of information using fluid mechanics equations allows application of well known physical concepts, like velocity, acceleration, momentum, force and energy, to information. We hope that the proposed procedure is general and can be applied to different games and real-world problems.

Keywords: 1, 2, 3, 4, 5.

INTRODUCTION

Information is a long persisting enigma for human beings, because we still do not fully understand what it is, when it appears or disappears, who it produces or destroys, where it comes from or go, and how it behaves.

Somebody says that information flows, while the others think that information is entropy [6]. The gap between the two viewing points is not small in practice: The former considers that information is tractable within physics, but the latter views that information is beyond physics, even though there is some relation to it. However, once one admits the notion that information flows, it may be natural to consider that motion of information particles having mass is governed by the basic equations for fluid mechanics. This becomes our strong motivation to use these equations for modelling game information dynamics. It is, therefore, hypothesized that information particles flow in exactly same manner as fluid particles.

It is known that the dependent variables in fluid mechanics are velocity, pressure, temperature and density, all of which depend on the position and time, and are considered to be information in flows. However, in information science the word information represents data such as evaluation function scores in chess, scores in baseball, and/or goals in soccer. Moreover, the information of the game outcome is the data of solved game uncertainty, for example. We consider that information is produced as the motion of particles arranged within each the infinitesimal volume, for, stationary particles provide us only trivial information. In this regard, it has been inferred by [7] that motion of the visualized fluid particles is detected by the eye almost instantaneously through the light having the enormous high speed, $3x10^{10}cm/s$, and is mapped on the retina first. It may be therefore evident that during this process, motion of the "fluid particles" are transformed into that of the "information particles" by the light carrying the images of fluid particles. The eye and brain work together in collecting the light reflecting from the visualized fluid particles and processing the information particles, which flow in our brain.

It may be expected that there are many parallels in the way the five sensory systems (eye, ear, nose, tongue and skin) process information. All of the stimuli caused by these systems are considered to be converted into electrochemical signals or information particles, which flow exactly in the same manner as fluid particles and result in the information. This infers that the perceived intensity due to a stimulus is nothing but the information. This analogy has been used by [8] to obtain the relationship between the magnitude of a physical stimulus(e.g. luminance, weight, sound pressure) and the corresponding experienced magnitude(brightness, heaviness, loudness). It is sometimes simply called the power law, which is applied to game-refinement by [2].

Salge and Mahlmann [4] have demonstrated game mechanics evaluation methods using information in games. The problem for AI (artificial intelligence) in game design, as Yannakakis and Hallam [10] point out, is not to create a good AI, but one that is enjoyable to play against, and one that can be used to improve the game itself. A more empirical way to approach to evaluate game mechanics would be to model an AI after actual neurological and physiological data, to stimulate the emotions of a real player [9].

The main purpose of the present study is to propose a novel information dynamic models for two teams (or players) based on fluid mechanics and to analyze the five Base

Ball games in World Series 2010 by using the proposed model.

MODELLING

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

(a) Assume a flow problem as the information dynamic model and solve it.

(b) Get the solutions, depending on the position and time.

(c) Examine whether any solution of the problem 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 mathematical 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 zero incidence as the information dynamic model (Figure 1).

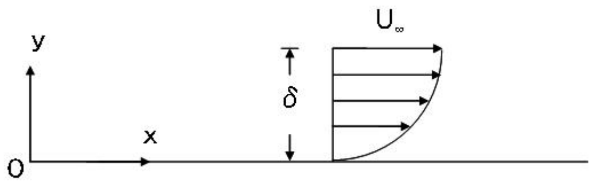

Figure 1: A definition sketch of flow past a flat plate at zero incidence.

The simplest example of the application of the boundary-layer equations, which is the simplified Navier-Stokes equations, is afforded by the flow along a very thin flat plate with zero incidence. Historically this is the first example illustrating the application of Prandtl's boundary-layer theory [3]; it has been discussed by [1] in his doctor's 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 shown in Figure 1. We shall consider steady flow with a free-stream velocity U_∞, which is parallel to the x-axis. The boundary-layer equations [5] become

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

$$\partial u/\partial x + \partial v/\partial y = 0 \quad (2)$$

$$y = 0 : u = v = 0; y = \infty : u = U_\infty \quad (3)$$

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, $U_\infty \cdot dU_\infty/dx = -1/\rho \cdot dp/dx$. The free-stream velocity U_∞ is constant in this case, so that dp/dx=0, and 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. The scale factors for u and y appear quite naturally as the free-stream velocity, U_∞ and the boundary-layer thickness, $\delta(x)$. Hence the velocity profiles in the boundary-layer can be written as

$$u/U_\infty = f(y/\delta) \quad (4)$$

[1] has obtained the solution in the form of a series expansion around $y/\delta = 0$ and an asymptotic expansion for y/δ very large, the two form being matched at a suitable value of y/δ. The analytical evaluation of the solution is beyond the scope of present study.

(b) The similarity of velocity profile is here accounted for by assuming that function f depends on y/δ only, and contains no additional free parameter. 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 $(y = \delta)$, in view of the boundary conditions for $f(y/\delta) = u/U_\infty$.

When using the approximate method, it is expedient to place the point at which this transition occurs 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 the boundary-layer equations tend asymptotically to the free-stream associated with the particular problem. The "approximate method" here means all the procedures 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, $u = U_\infty$ at $y = \delta$, must be satisfied.

The following velocity profile satisfies all of the boundary conditions as the approximate solutions on the flow past a flat plate at zero incidence,

$$u/U_\infty = [sin(\pi/2 \cdot y/\delta)]^n \quad (5)$$

in the range $0 \leq y/\delta \leq 1$, whereas for $y/\delta > 1$ we assume simply $u/U_\infty = 1$, where n is positive real number parameter. The Eq. (5) vanishes at the wall $(y/\delta = 0)$ and takes the value of 1 at the outer edge of the boundary-layer $(y/\delta = 1)$. That is, starting from 0 on the wall, the velocity u in the boundary-layer should join the free-stream at the finite distance from the wall $y = \delta(x)$. Thus, the Eq. (5) is considered as the approximate solutions on the flow past the flat plate at zero incidence. Now, we get the velocity in the x direction, which is one of the solutions for the assumed flow.

(c) Let us examine whether this solution is game information or not. Such an examination immediately provides us that the non-dimensional velocity varies from 0 to 1 with increasing the non-dimensional vertical distance y/δ in many ways as the non-dimensional information, so that these solutions can be game information. However, 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 [7], so that during these processes, motion of the "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 [7]. 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 eye. During this transformation, the flow solution in the physical space changes into the information in the information space.

(e) Proposed are correspondences between the flow and game information, which are listed in Table 1.

Table 1: 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 1, Eq. (5) can be rewritten as

$$I/I_0 = [sin(\pi/2 \cdot t/t_0)]^n \tag{6}$$

Introducing the following non-dimensional variables in (6),

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

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

$$\xi = [sin(\pi/2 \cdot \eta)]^n \tag{7}$$

where ξ is the non-dimensional current information, η the non-dimensional current game length, and n is a positive real number. The greater the value of n is the greater the strength of both teams (or players) for a game is, and the smaller the strength difference between numeral games, where each the game takes a unique value of n. A similar information dynamic model is derivable as

$$\xi = \eta^m \tag{8}$$

where m is a positive real number. Note that Eq. (8) is the power law [8].

It is also possible to discuss how the information velocity and information acceleration vary with the game length or time. The information velocity can be expressed by

$$d\xi/d\eta = n \cdot \pi/2[sin(\pi/2 \cdot \eta)]^{n-1} \cdot cos(\pi/2 \cdot \eta). \tag{9}$$

Information acceleration is expressed by

$$\frac{d^2\xi}{d\eta^2} = n\cdot(\frac{\pi}{2})^2\cdot\{(n-1)[sin(\frac{\pi}{2}\cdot\eta)]^{n-2}\cdot[cos(\frac{\pi}{2}\cdot\eta)]^2 - [sin(\frac{\pi}{2}\cdot\eta)]^n\} \tag{10}$$

BASE BALL GAMES IN THE WORLD SERIES 2010

The present model will be applied to five Base Ball games in World Series 2010. The relevant information is summarized in Table 2. Base Ball is a game of ball played two sides of nine players each, on a diamond enclosed by lines connecting four bases, a complete circuit of which must be made by a player after batting, in order to sore a run.

Table 2: Five Base Ball games in World Series 2010. ** Symbol(x) in this table means that no batting is done in the second half of the 9th inning, for the second batting team leads the score(s) at the end of the first half of the 9th inning.

		Score History	Final Score
First Game	Rangers	110 002 003	7
	Giants	002 060 03x	11
Second Game	Rangers	000 000 000	0
	Giants	000 010 17x	9
Third Game	Giants	000 000 110	2
	Rangers	030 010 00x	4
Fourth Game	Giants	002 000 110	4
	Rangers	000 000 000	0
Fifth Game	Giants	000 000 300	3
	Rangers	000 000 100	1

RESULTS AND DISCUSSION

In this section, the information dynamic model will be presented then results of the data analysis and the comparison between the present model and the relevant data will be presented and discussed.

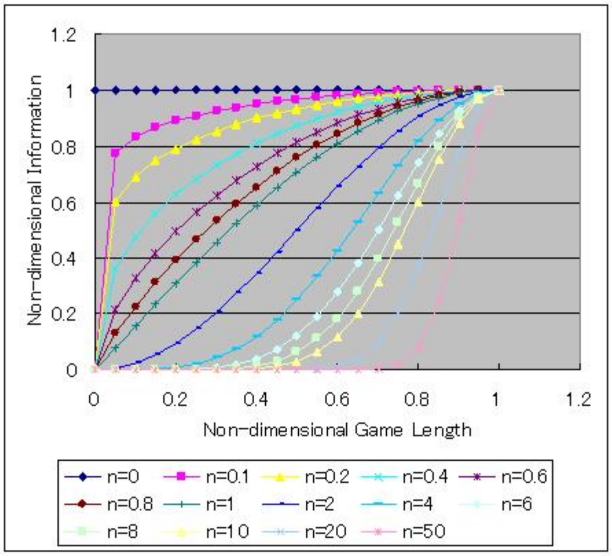

Figure 2: Non-dimensional information ξ against non-dimensional game length η for the present model.

Figure 2 shows the relation between the non-dimensional information ξ against non-dimensional game length η for the present model. When $n < 2$, ξ-curves are convex, while $n > 2$, ξ-curves are s-shaped. This means that all of the information for the present model are decelerated with increasing η near the end.

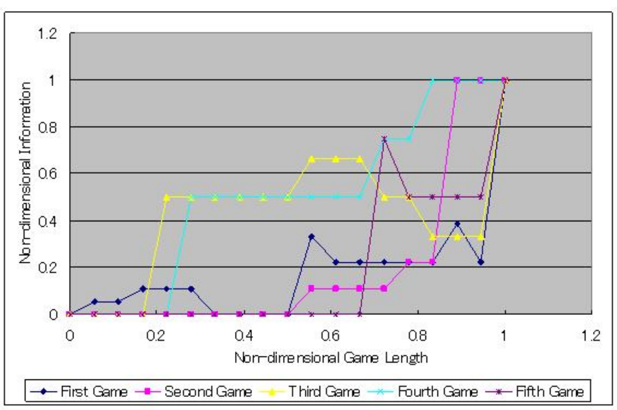

Figure 3: Non-dimensional game information ξ_B against non-dimensional game length η for the five Base Ball games in World Series 2010.

Figure 3 shows the relation between the non-dimensional game information ξ_B and non-dimensional game length η for the five Base Ball games in the World Series.

Non-dimensional game information ξ_B in Base Ball is here defined as follows:

When the total score(s) of the two teams at the end of game $S_t > 0$,

$$\xi_B = \begin{cases} |S_f(\eta) - S_s(\eta)|/S_t & \text{for } 0 \le \eta < 1, \\ 1 & \text{for } \eta = 1, \end{cases}$$

where $S_f(\eta)$ is the current score sum for the first batting team, and $S_s(\eta)$ the current score sum for the second batting team. At $\eta = 1$, ξ_B is assigned the value of 1, for at the end of game information must reach the total information of game outcome.

When $S_t = 0$,

$$\xi_B = \begin{cases} 0 & \text{for } 0 \le \eta < 1, \\ 1 & \text{for } \eta = 1. \end{cases}$$

Game length is defined as the current number of batting chances so far. It is normalized by the total game length to obtain the non-dimensional value η. There are two batting chances for one inning, for one team makes batting for the first half, while the other team for the second half. Each of the Base Ball games has 9 innings except for the extra-inning games, so that there are a total of 18 batting chances per game. This means that the total game length for the present five games is 18.

Figure 3 clearly indicates that non-dimensional information for these five games varies with the non-dimensional game length in different manner from each other. However, these games can be broadly divided into two groups: The first group consists of the first, third and fifth games. These three games have a common character that the information increases rapidly near the end. It has been suggested by [2] that games of the first group are accounted for by the power law (see Eq. (8)). The second group consists of the second and fourth games. These games have a common distinctive feature that the information gradually approaches to the full value of game outcome with increasing the game length near the end. This feature of the information for the second and fourth games is similar to that for the present model (see Eq. (7)). However, it may be evident that the games of the second group cannot be accounted for by the power law, for the information increases rapidly near the end in this law.

Refering to Table (2) we see that the second group games are characteristic in that one team scores no points, this can be called a one-sided game.

Figure 4 shows the relation between the non-dimensional information ξ and the non-dimensional game length η. In this figure, the non-dimensional information ξ_B for the second and fourth games, respectively, has been plotted and is compared with eight curves for present model. It may be clear that although the non-dimensional information for the second and fourth games, respectively,

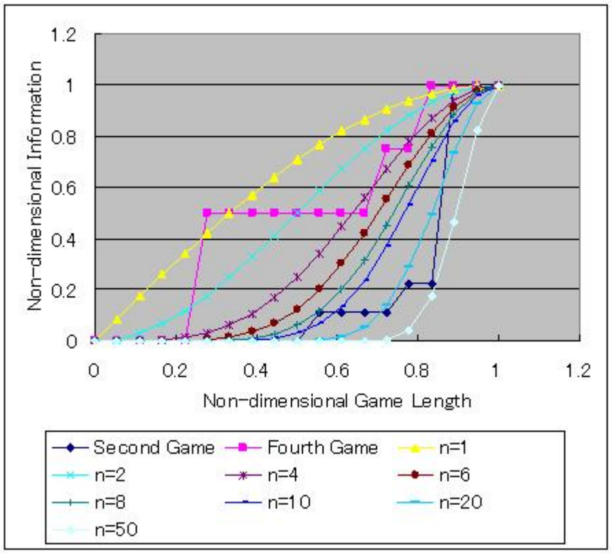

Figure 4: Non-dimensional information ξ against non-dimensional game length η: A comparison between the present model and the second group games.

proceeds in zigzag line, on the whole, the non-dimensional information for the second game seems to follow the model curve at n=20, while the non-dimensional information for the fourth game follows the model curve at n=2. It is, therefore, considered that the present model can properly account for the games of second group, or the one-sided games.

As shown in Figure 5, when n=20, the non-dimensional information velocity $d\xi/d\eta$ increases exponentially with increasing non-dimensional game length η from 0 , and takes the peak value of about 4.3 at $\eta = 0.85$. Then, $d\xi/d\eta$ decreases with increasing η and becomes 0 at $\eta = 1$. When n=2, $d\xi/d\eta$ increases with increasing η from 0 , and takes the peak value of about 1.6 at $\eta = 0.5$. Then, $d\xi/d\eta$ decreases with increasing η and becomes 0 at $\eta = 1$.

Note that the momentum is defined as the product of the mass and velocity, so that when the mass of information particles is constant, the information momentum depends on the game length in the same way as the information velocity. Thus, it is considered that Figure 5 also shows how the non-dimensional information momentum varies with the non-dimensional game length as well as with the parameter n.

As shown in Figure 6, when n=20, non-dimensional information acceleration $d^2\xi/d\eta^2$ increases exponentially with increasing the non-dimensional game length η from 0, and takes the peak value of about 23 at $\eta = 0.75$ and then decreases and finally becomes about -49 at $\eta = 1$. However, when n=2, $d^2\xi/d\eta^2$ decreases monotonously with increasing η from about 4.9 to -4.9, crossing the abscissa at $\eta \simeq 0.5$.

It is worth noting here that the force is defined as the product of the mass and acceleration, so that when the mass of information particles is constant, the information force depends on the game length in the same way as the information acceleration. Thus, it is considered that Figure 6 also shows how the non-dimensional force changes with non-dimensional game length η as well as with the parameter n.

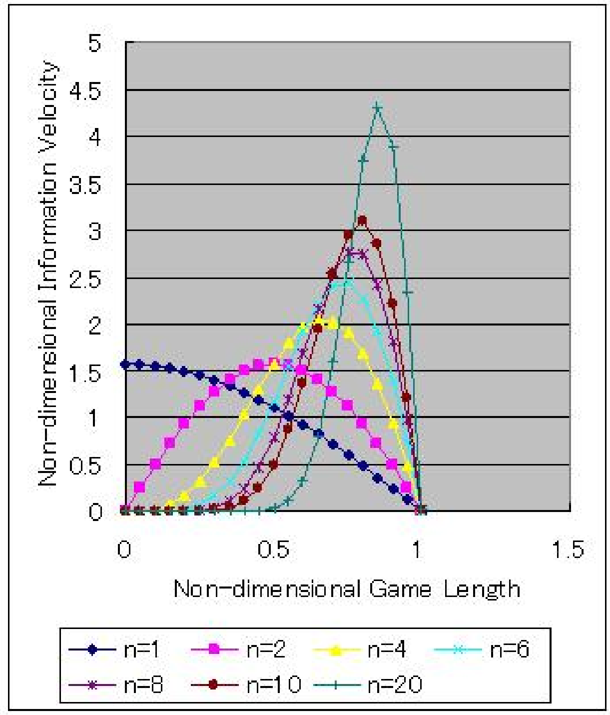

Figure 5: Non-dimensional information velocity $d\xi/d\eta$ against non-dimensional game length η for the present model.

CONCLUSION

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

A novel information dynamic model based on fluid mechanics has been proposed and is expressed by

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

where ξ is the non-dimensional information, η the non-dimensional game length, and n a positive real number. This model is derived from a series of approximate solutions for the flow past a flat plate at zero incidence.

The five Base Ball games in World Series 2010 have been analyzed and the information dynamics is discussed in the light of the present model. The present model makes it possible to discuss how the information, information velocity, information acceleration, information momentum and information force vary with the game length or time in games.

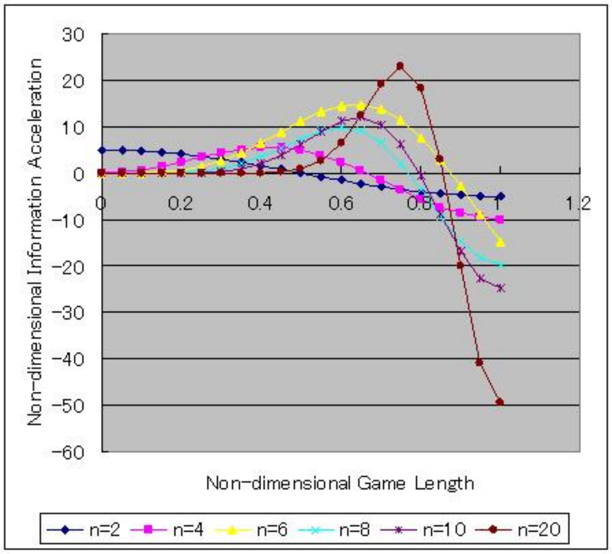

Figure 6: Non-dimensional information acceleration $d^2\xi/d\eta^2$ against non-dimensional game length η for the present model.

It is found that the present model properly accounts for a "one-sided game" where the information gradually approaches to the value of game outcome with increasing the game length near the end. It is realized that the second and fourth games are one-sided games, but the other three games, the first, third and fifth games are not.

It is suggested that the first, third, and fifth games, in which the information increases very rapidly with increasing the game length near the end and takes the maximum value at the end, are accounted for by the power law.

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