Soft Turbulence in Bénard Convection towards Intelligent Virtual Agents

Takeo R.M. Nakagawa and Ai Nakagawa

Royal Academy of Hakusan, 2-14, Meiko, Hakusan 920-2152 Japan

npo.hakusan@kjc.biglobe.ne.jp

Abstract

This paper is concerned with intelligent virtual agents with reference to the soft turbulence in Bénard convection. It is found that the super complex systems can be only explored by syntheses together with intuition and/or imagination. This is not because we have limited tools to solve the super complex systems, but this approach is essential to solve such problems.

Keywords: Logics, Intelligence, Virtual Agents, Complex System, Synthesis, Intuition, Imagination, Bénard Convection, Soft Turbulence

1. Introduction

AI may be one of Intelligent Virtual Agents (IVAs), for it has interactive characters that exhibit human-like qualities and communicate with humans. IVAs are occurrence agents, so they cannot be grasped by hands, and thus they are time-perishable intangible experience, but they are complex virtual objects. Moreover, it seems that physics, philosophy, music, art, robot, mathematics, any model, environmental management system, computer, intuition, imagination, analysis, synthesis and many others, possess part of human-like qualities and communicate with humans, or with each other using natural human modalities such as facial expressions, speech and gesture. They are capable of real-time perception, cognition and action that allow them to participate in dynamic social environments to some extent. However, all of them are far from real IVAs, or human. It is hypothesized here that logic and/or mathematics are dispensable element of IVAs, and so anything whatever their names are, can become a real IVAs if logic in it becomes adequate enough. Hence, the logic dominant IVAs is the core of intelligent virtual science, an interdisciplinary approach to the study, design and implementation of IVAs systems.

Then, the problem is how we can achieve the thing or system, which is ideal in view of logical reasoning. Whether IVAs or the systems include customers or not is hot issue currently. However, to the present authors it is almost evident that IVAs or the systems must include their customers with no exception, for if IVAs are denied by the customers they are meaningless. Thus, IVAs are co-created by the provider and customer, and their life cycles are completed accordingly.

The main purpose of this paper is to demonstrate how logic dominant approach is important to develop the useful IVAs with reference to a novel approach to the theory of turbulence by Tsugé (1974).

2. Case Study for IVAs

As a case study for IVAs, let us consider turbulence thermal convection, or Bénard convection in a fluid layer between two walls, where temperature of lower wall T_{e1} is greater than that of upper wall T_{e2}.

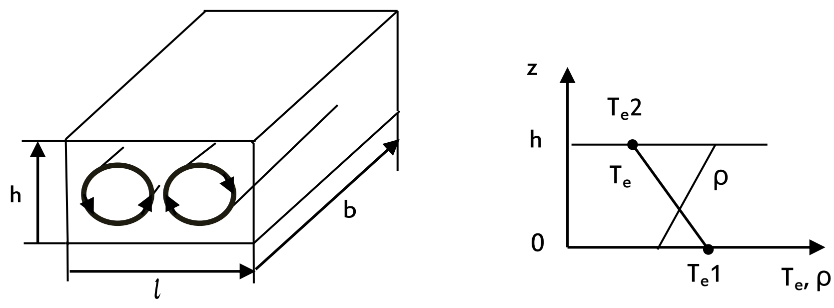


Figure 1 Thermal convection in a box at flow regime of thermally strained quiescence.

Figure 1 depicts the thermal convection in a box at flow regime of thermally strained quiescence, together with the temperature T_e and density ρ distributions between upper and lower walls, where l is the width being assumed to be infinitely long, h the height, b the depth and z the vertical coordinate.

Let the turbulence f(t) be a real periodic function with period T and such that

$\int_{-T/2}^{T/2} |f(t)|dt$ exists, where a function of f(t) of a real or complex variable t is periodic with the period T if and only if f(t+T)≡f(t). Then, function of f(t) may be expressed as follows,

$f(t)=1/2\cdot a_0+\sum_{k=1}^{\infty}(a_k\cos k\omega_0 t+b_k\sin k\omega_0 t)$,

with

$a_k=2/T\int_{-T/2}^{T/2}[f(t)\cos k\omega_0 t]dt$, $b_k=2/T\int_{-T/2}^{T/2}[f(t)\sin k\omega_0 t]dt$.

$(\omega_0=2\pi/T;\ k=0, 1, 2, \cdots)$.

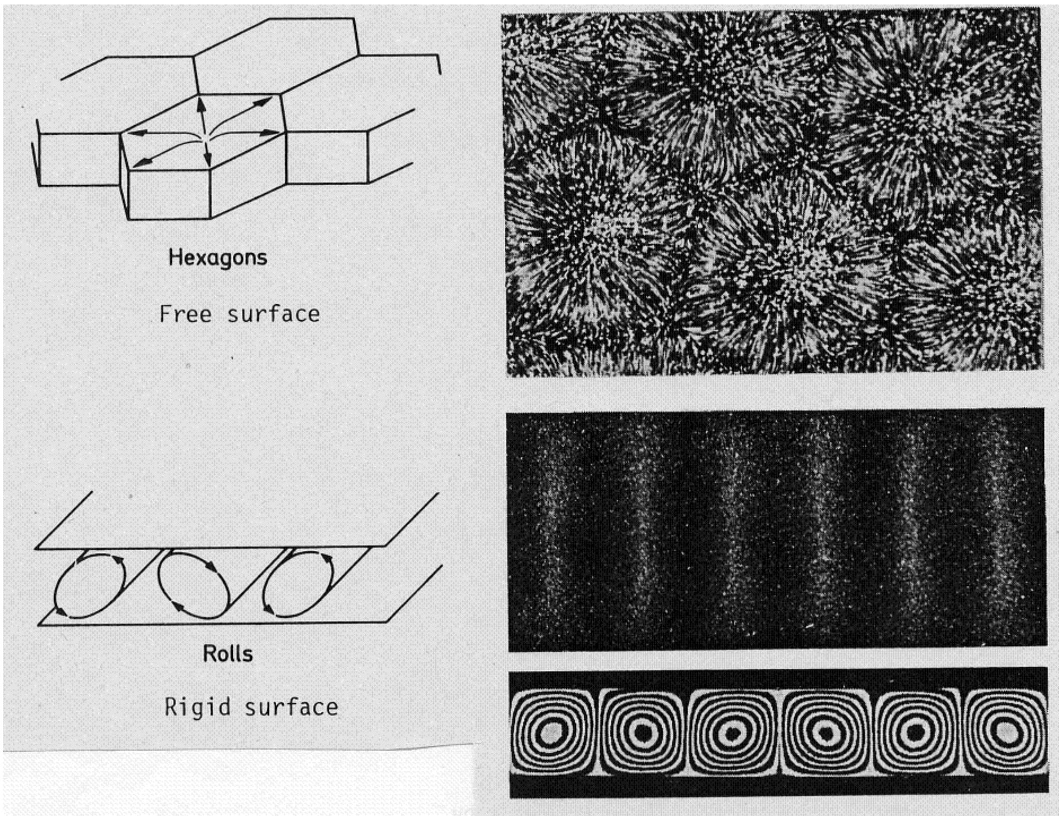


Figure 2 Bénard convection

Ishibashi et al. (1997) has solved this problem analytically with the aid of numerical computation , and have found that in the range of soft turbulence there exists the following relationship,

$N_u=R_a^{0.188}$, (1)

where $N_u=\dot{q}/\lambda\cdot h/(T_{e1}-T_{e2})$ is the Nusselt number, while $R_a=\alpha\cdot g\cdot h^3\cdot(T_{e1}-T_{e2})/(\nu\kappa)$ is the Rayleigh number. $\dot{q}$ is the specific heat transfer rate, λ the heat conduction coefficient, h the height between two walls, T_{e1} the temperature at the lower wall, T_{e2} the temperature at the upper wall, α the thermal expansion coefficient of fluid, g the gravitational acceleration, ν the kinematic viscosity of fluid, and $\kappa=\lambda/(\rho c)$, ρ the fluid density , and c the specific heat. Refer to Appendix for the details of their theoretical analyses.

The Nusselt number N_u denotes the normalized heat transfer rate between the two plates, while the Rayleigh number may be considered to represent the normalized temperature difference between the two plates, though this is the combined parameter consisting of thermal expansion of fluid, inertia of fluid motion, viscosity of fluid, and heat conduction. Figure 2 shows the sketches and photos for the two cases of Bénard convections, where one is free surface at the upper together with rigid boundary at the lower wall, while the other is rigid surfaces at the lower and higher walls, respectively.

The theoretical relation (1) has been derived by using the turbulent equations, which have been proposed by Tsugé et al(1984) based on the kinetic theory of turbulence. The results are drawn in Figure 3, where the ordinate is the Nusselt number Nu and the abscissa is the Rayleigh number Ra.

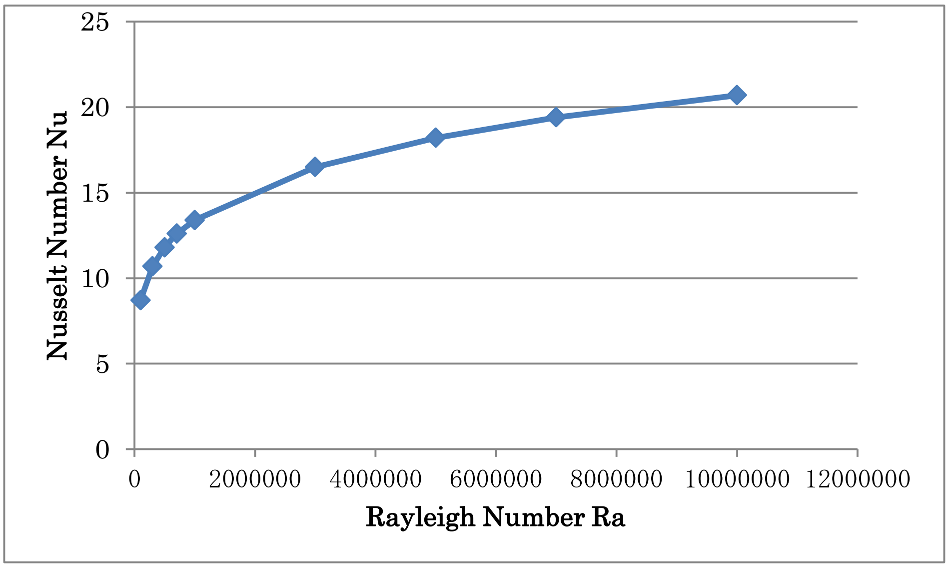


Figure 3 Nusselt number N_u against Rayleigh number R_a for soft turbulence in Bénard convection.

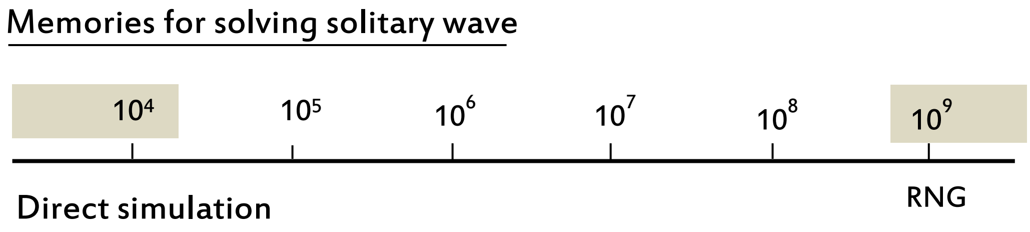
The theory shows a good agreement with the experiment by Khurana(1988); that is, it is confirmed that the maximum error is 8 % at most. Considering the fact that no empirical constant is introduced in the theory, this result is rather remarkable. Thus, Tsugé 's turbulent equation possesses high potential, promising as the candidate to be able to solve the many other difficult turbulent problems to which we are confronting currently.

Historically, once the main stream of turbulent research has been numerical analyses to examine the microscopic behaviour of fluid motions, to solve the Navier-Stokes equations by introducing tiny time step and space; that is so-called CFD (Computational Fluid Mechanics). However, irrespective of rapid increase of computer memories day by day, as already being pointed out, CFD involves an essential limitation of computer memories, so that CFD can compute only flow problems within the Reynolds number of 10^4, in which engineers are not interest, as explained in Figure 4. This figure suggests that unless we compute the solitary-wave in turbulent flow having the Reynolds number greater than 10^9 , the results must be unreliable. Furthermore, because the required computer memories are depending on the Reynlods number as $Re^{9/4}$, the necessary computer memory also increases with increasing the Reynolds number Re. Accordingly, this must provide us almost an un-surmountable barrier as far as we rely on the computer.

It may be, therefore, reached at the classical idea that the critical view point for solving turbulent problems is to realize the universal truth, 'simplicity of nature', which is well-known Albert Einstein's philosophy to understand the nature(Howard 2005). It may be evident that Einstein's view to the nature is no more than to point out the importance of IVA together with syntheses for interpreting the nature. The most adequate example to support this argument may be his mass(m)-energy(E) equivalence formula

$E=mc^2$,

where c is the light speed of $3x10^8$ m/s. This has been known as the world's most famous equation, for its simplicity and impact to the uncountable number of people.



- Direct simulation : Memory $\propto$ Re $^{9/4}$
- Renormalization group (RNG) theory : Memory ~10^9

Figure 4 Required memories for CFD

3. Concluding Remark

Tsugé(1974) 's approach to turbulence must be considered as the typical example, which manifests the triumph of IVA against the nature; that is, by conducting Fourier analyses, he has found that turbulence consists of a group of solitons. Because of their remarkable simplicity together with sound logics and mathematics, turbulence now becomes tractable not only numerically but mathematically to a meaning full level in the engineering . The super complex systems can be only explored by bright syntheses together with intuition and/or imagination. This is not because we have limited tools to solve the super complex systems, but this approach is essential to solve such problems like turbulence , biomechanics, elementary particles, and so forth.

Syntheses together with intuition and/or imagination are a refracted world of our will, but they are not the world for the weak people. They are rather strong seeing force into delineating a true image in the darkness. Their primary component is syntheses, but they have also the distilled component of intelligent analyses plus alpha. They may be named 'jumping force' more appropriately.

For developing more refined IVA, the logic dominant approach as introduced by Tsugé(1974) , Ishibashi et al. (1997) is absolutely required as necessary condition.

References

1. Howard, D.A.(2005) Albert Einstein as a philosopher of science. Physics Today 58, 34-40.

2. Ishibashi, K., Tsugé, S., Nakagawa, T.M.S. (1997) Solitary-wave solution of turbulence with application to Bénard convection. Proc. Eighth International Colloquium on Differential Equations (ed. D. Binov) International Science Pub. 5-25.

3. Kármán, von Th., Howarth, L.(1938) On the statistical theory of isotropic turbulence. Proc. Roy. Soc. London, A, Mathematical and Physical Sciences, 164, 192-215.

4. Khurana, A. (1988) Rayleigh-Bénard experiment probes transition from chaos to turbulence. Physics Today, 41(6), 17.

5. Tsugé, S.(1974) Approach to origin of turbulence on the basis of two-point kinetic theory. Phys. Fluids 17, 22-33.

6. Tsugé, S., Sagara, K., Kadowaki, S. (1984) *in*: Rarefied Gas Dynamics, vol.1,(ed. H.Oguchi), University of Tokyo Press, 19.

7. Tsugé, S., Ogawa, S.(1993) Molecular and turbulent transports competing in premixed flames.

8. Turbulence and Molecular Processes in Combustion (ed. T.Takeno) Elsevier, 35-50

9. Zocchi, G., Moses, E., Libchaber, A. (1990) Coherent structures in turbulent convection; an experimental study. Physica, A166, 387-407

10. Appendix: Solitary-wave solution of turbulence with application to Bénard convection(Tsugé et al. 1984).