Do we have free will? - Experimental and Theoretical Considerations
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Is free will physically implementable? In what sense?

Shogo Tanimura

twitter@tani6s

Graduate School of Informatics, Nagoya University

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About myself

- Name: Tanimura, Shogo（谷村省吾）
- Theoretical physicist, mainly studying foundation of quantum theory, category theory, and recently AI.
- However, I am often concerned with philosophers, often discuss the free-will problem.

Brief history of my struggles against philosophers (Links are shown in my webpage)

- 2016, I was invited to a symposium on metaphysics of time. In 2109 they published a collection of articles including mine.
- 2019, I released a note in which I **strongly criticized** metaphysical arguments. Since that occasion, I have been regarded as **an enemy of philosophers**.
- 2020, I discussed Dennett's book, "Elbow Room: the variety of free will worth wanting", with a Japanese philosopher. The discussion was delivered online. I wrote a note on this subject.
- 2021, I discussed another book on free will and determinism with another philosopher. You can see the discussion via YouTube. I wrote a note on this subject again.
- 2021, I published an article on free will in a magazine, in which Dr. Masataka Watanabe also published an article.

What I talk today

- Naive definition of free will
- Conflict between free will and determinism
- Indeterminism in classical mechanics
- Asymptotic determinism from quantum mechanics
- Physical laws are helping free will
- How to implement free will onto machine

(Honestly speaking, what I am afraid is that I may tell you nothing new…)

Naive definition of free will

- **I can choose, decide, control or change my action independently from any other things.**

  For example, I can choose what I eat at lunch. I can decide a partner who is to be married with. I have a variety of choices. I can even create alternative choices for some subject. Other people, any other objects or any laws cannot enforce my decision. They cannot exactly predict my decision.

- **And I feel that I am considering and making my decision.**

Deterministic physical laws

- Classical mechanics (Newtonian mechanics) is deterministic. Once, the initial state of a system is known, the state at an arbitrary moment (either future or past) of the system is determined uniquely.
- Laplace's demon, who knows accurately a state of the universe at one moment and has infinite ability of calculation, knows the whole history of the universe.

https://en.wikipedia.org/wiki/Pierre-Simon_Laplace

Conflict between free will and determinism

- It seems that the laws of nature have determined the destiny of the whole universe, and, of course, any detail of human life, too. What you think and what you do are already determined from the beginning of the universe.
- **It seems that there is no room for free will.** Free will may be illusion, hallucination, or deception.
- This is **the notorious free-will problem.**

Other determinisms

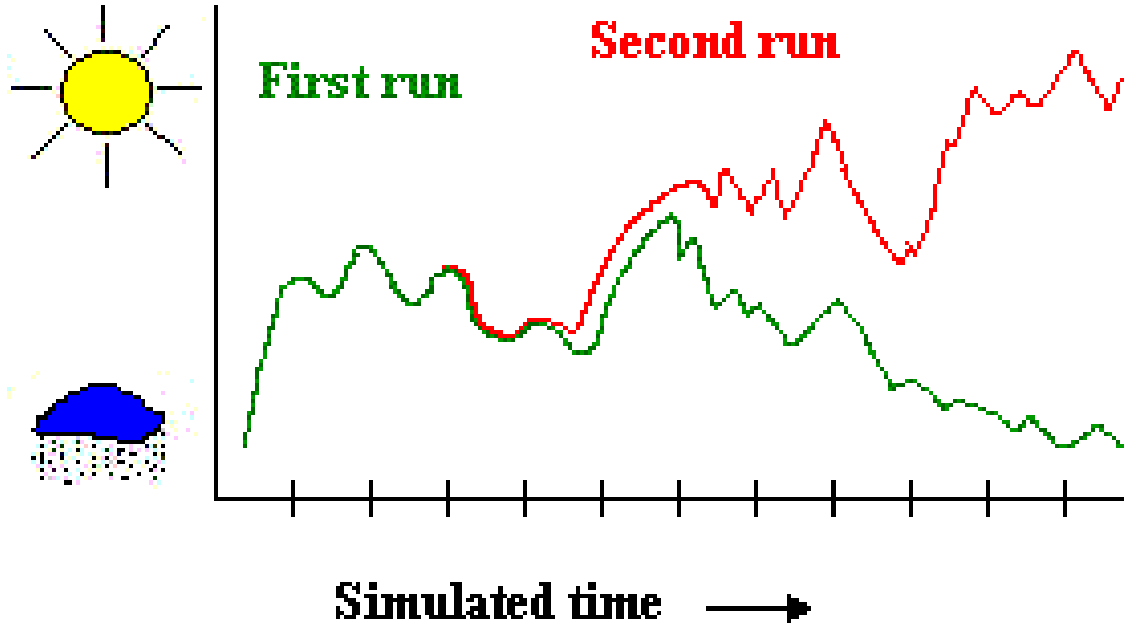
- **Genetic determinism**: A belief that personality, tendency, and talents are determined by gene.
- **Environmental determinism**: A belief that environment forms personality, tendency, and talents.
- **Fatalism** 宿命論 (**teleology** 目的論): Nature has its own purpose or goal. Nature enforces your future. Even if you attempt to change your future, you failed to change.
- Even more various determinism have been raised.

Determinism in physics

- Genes and environments affect human life but do not determine human life instantaneously in detail.
- In my talk, I concentrate on the determinism of physics, because it seems to be the most strongest realistic determinism.
- How do we reconcile the deterministic physics with free will?

Indeterminism in classical physics

- **Chaos**: For a nonlinear dynamical system, any tiny error in measurement of the initial state grows rapidly in time. Prediction for long-time future is pragmatically impossible.



https://www.abarim-publications.com/ChaosTheoryIntroduction.html

Indeterminism in classical physics

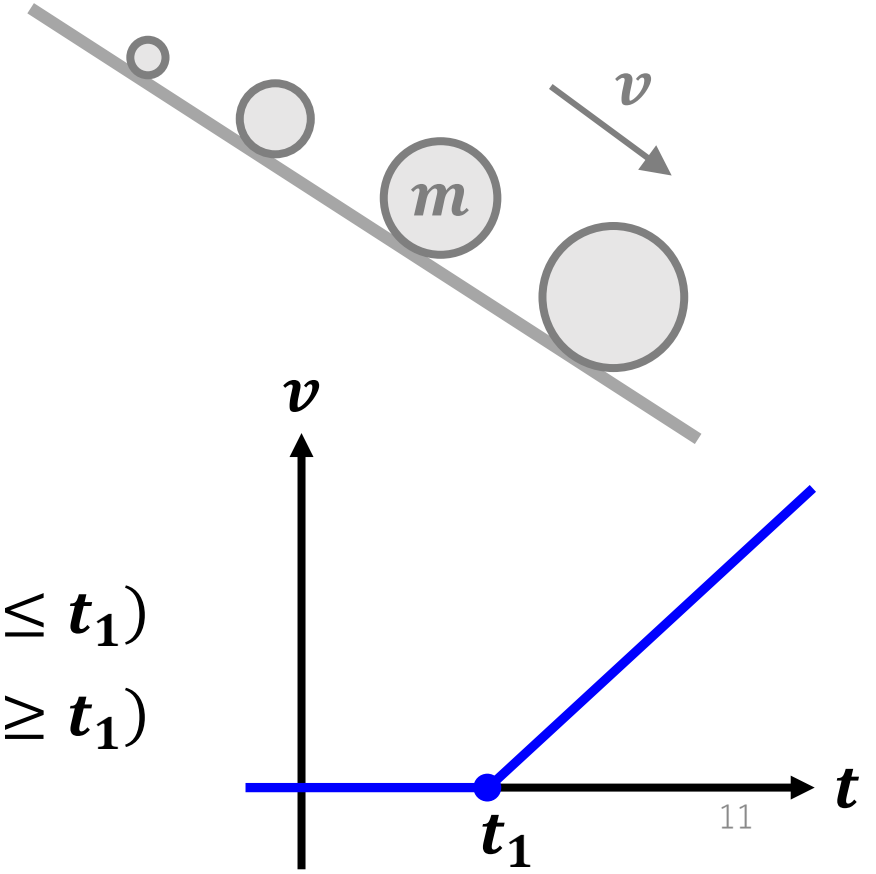
- **Non-uniqueness and branching of solution of nonlinear differential equation**: The time when the branching occurs is unpredictable. A model of a growing snow ball on a slope: $\boldsymbol{m}$ is mass, $\boldsymbol{v}$ is velocity of the snow ball.

$$\frac{\boldsymbol{d}}{\boldsymbol{dt}}(\boldsymbol{mv}) = \boldsymbol{mg}, \qquad \frac{\boldsymbol{d}}{\boldsymbol{dt}}\boldsymbol{m} = \boldsymbol{kv}$$

Initial condition: $\boldsymbol{m(0) = 0}, \quad \boldsymbol{v(0) = 0}$

Solutions ($\boldsymbol{t_1}$ is arbitrary branch time)

$$\boldsymbol{m(t)} = \begin{cases} \boldsymbol{0} \\ \boldsymbol{\frac{1}{6}gk(t - t_1)^2} \end{cases} \qquad \boldsymbol{v(t)} = \begin{cases} \boldsymbol{0} & \boldsymbol{(t \le t_1)} \\ \boldsymbol{\frac{1}{3}g(t - t_1)} & \boldsymbol{(t \ge t_1)} \end{cases}$$



Indeterminism in classical physics

- **Incompleteness theorem** (**conjecture**): Axioms for the whole set of statements of occurrences is not yet formulated. Even if it would be formulated, there might be an improvable statement. That means, **there is an event that we cannot mathematically deduce whether it will occur or not.**
- **Do chaos, non-uniqueness, or incompleteness of classical-mechanical laws support free will?**

Probabilistic quantum mechanics

- In microscopic world, quantum mechanics is dominant.
- By quantum mechanics, occurrences are predictable only in terms of probability. No rigorous predictions can be made.

Pessimistic opinions on quantum mechanics

- Philosopher's objection: "quantum mechanics is relevant only for atomic phenomena. It is irrelevant for human daily life or man mind."
- Another objection: "Probability implies randomness. But our free will is not random. Probability theory does not provide a firm foundation for free will."

Quantum mechanics is not ignorable for human life

- My answer: Your picture on quantum mechanics is not a correct view of the world. For example, you may have color vision. Colors of materials are determined by probability of absorption of photons by molecules, and the absorption probability obeys quantum mechanics. Most of bio-chemical reactions, like digestion, respiration, neuro-transmitter, and so on, are based on quantum-chemical processes, which are also probabilistic. So, **quantum mechanics is relevant for our daily life.**

Misunderstanding on probability

- “Probability implies randomness”.
- No, probability does not imply that everything happens randomly.
- Law of large number: For an additive observable $A = A_1 + \cdots + A_N$ with identical independent probability distribution, the relative fluctuation converges to zero as the number of samples goes to infinity:

$$\frac{\sigma(A)}{\langle A \rangle} \to \frac{1}{\sqrt{N}} \quad \text{for } N \text{ samples}$$

- For a macroscopic system which contains an enormous number of atoms, probabilistic predictions approach to deterministic predictions.

From probability to almost determinism

- Moreover, atoms are mutually interacting and have correlation. Hence they are not independent.
- A macroscopic system exhibits ordered robust structure. Its behavior is described in an almost deterministic causal manner.
- I would like to call this kind of approximate deterministic behavior of macroscopic system as **asymptotic determinism.**

Physical laws help free will

- Microscopic physical laws are probabilistic, but from them, stable structure and predictable behavior of a macroscopic system emerge.
- Using stability of almost classical macroscopic world, we can make reliable plans for future.
- Physical laws are not obstruction against free will.
- Free will should not be random, not be unpredictable. Free will should be coherent.

From where does freeness come?

Possible answer 1: **Far scattered causes**

I am influenced by many causes and I have long-term re-organized memory. I cannot recognize a single cause which decisively influences my decision. Then, I think that my decision comes from my mind. In this sense, independence of my decision may be an illusion.

A machine also can have this kind of free will if the machine has large enough memory and a kind of “forgetting” function (irreversibility of data processing).

From where does freeness come?

Possible answer 2: **Physical randomness**

When some candidate choices look almost equally favorable and I cannot chose one by reasoning, I may throw a quantum-mechanical dice in my brain, which generates random variables.

A quantum random-variable generator can be implemented in a machine.

https://saikoro-table.com/2017/05/06/saikoro-furikata/

Why do I have **a feeling that "I am choosing and controlling"** not like a machine without self-feeling?

There may be an evolutional merit. Assume that you have many possible choices for doing something. For simulating outcome of each possible choice and for making rational comparison among candidate choices, large work memory and much logical inference are necessary. For avoiding error in inference tasks, **self-monitoring system that checks one's logical and physical processing** may be advantageous for survival.

Answers to the first questions

Is free will physically implementable to a machine?

- Yes, of course. Why not? Human and animals are physical systems. I do not think that plants have free will. I do not welcome that a machine gets free will.

In what sense?

- Free will is a system of consideration and decision. It simulates results of possible choices, evaluates feasibility and outcome of each choice, and makes decision, under self-monitor for logical check. Physical laws do not obstruct but enable free will.

Thank you for your attention.

Experiment by Benjamin Libet

One's nerve system began signal for moving one's finger before one made a decision.

- I do not think that it is a serious problem. Human brain can make shortcut for a simple task without consulting with consciousness. Conscious process with free will works for a difficult task that needs reasoning and rational comparison.

Free will theorem in quantum mechanics

Conway and Kochen proved that if experimenters have free will for choosing setting of apparatus, elementary particles also must have free will for outcomes of measurements.

- I not think that we should receive their theorem seriously. In their theorem, free will means randomness and unpredictability. This kind of free will is not wanted.