Using Arrows to Point to How Memory Works

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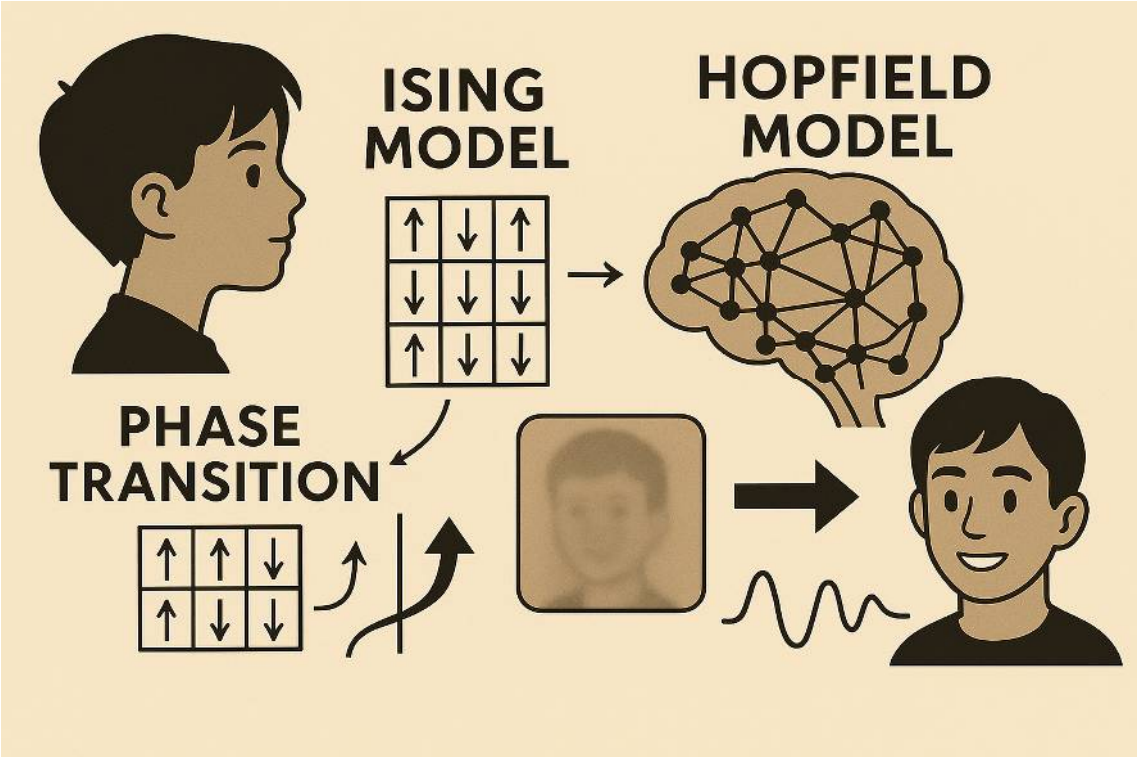

Part1: What I'm currently studying

When I was 12, I often forgot what I talked about with my friends or what I had studied. But later, many of those memories would suddenly come back. Isn't it interesting if that mechanism could be thought of using the rules of physics?

My current research is called the "Hopfield model", which is a mathematical model of how the brain works. It is a mathematical and physical model of the brain, but it can still "remember". To understand how the Hopfield model works, it helps to look at the Ising model, a simple physics model.

The Hopfield model is built on the Ising model, a simple physics model in which many "arrows" (representing particles or states) can point either up or down. These arrows

tend to align with their neighbors, especially at low temperatures, forming ordered patterns.

In the Hopfield model, we think of these arrows as brain cells—neurons—that are either active or inactive. When we give the system a partial input (like a blurry memory), the model evolves toward a complete, stable pattern, just like how our brain retrieves a full memory. This fascinating behavior can be analyzed using tools from physics.

Part2: Why it's interesting?

What is interesting about this model is that it not only explains the memory model but also relates to a physical phenomenon called “phase transition”. A phase transition is a sudden change in the state of something due to environmental changes, such as water becoming ice when cooled or water vapor when heated. This kind of behavior can also be observed in the Hopfield model. It can be analyzed using physics techniques that if the number of patterns to be stored is small, memory is possible (arrows are aligned), but if there are too many patterns to be stored, memory is not possible (arrows become disjoint).

Furthermore, this model can confirm real memory-like things such as “forgetting” and “making mistakes”. For example, I’m sure you have been confused by people telling you a lot of things. When your parents told you to clean up, do your homework, take a bath at what time, etc., you may have forgotten some of them or made a mistake in taking a bath at the wrong time. This corresponds to “forgetting” or “making a mistake”, and this phenomenon appears in the model!

I think it is interesting that memory can be explained in this way using physics. Moreover, the importance of this model was recognized when Professor John Hopfield

was awarded the Nobel Prize in Physics in 2024. It is very interesting that physics allows us to enter the world of information as well as the brain. By doing this research, we can not only deepen our understanding of the brain but also contribute to the development of AI.

Part3: Advice to My 12-Year-Old Self

I think that when I was 12, I didn't study much and just played all the time. But that's okay. You can keep playing. I want you to follow your curiosity and explore the things you find interesting. Why does this happen? What happens if I do this? I would like you to try to live your life with these questions in mind. This will lead you to what you want to do in the future. The important thing is not only to have knowledge, but also to ask questions.

Furthermore, when you have questions, don't be afraid to ask adults about what you don't understand. Not knowing something is not something to be ashamed of, but something cool to try to move forward and build up more knowledge.

I am currently studying in the graduate school of the University of Tokyo, but I wish I had questioned more things in my life. For example, I remember being confused during science experiments in junior high school, but I was afraid of being ridiculed, so I didn't ask the teacher any questions. Looking back now, if I had asked questions at that time, I might have discovered new interests sooner. If I had done so, I might have been more curious in my exploration, and I might have found my current research topic at an earlier stage. And even now, there are so many things I don't understand, but I live my life depending on the people around me.

Finally, I would like you to remember that the future is not something that is set in

stone, but something that you will create for yourself.

I was following my own interests and found myself at the intersection of the brain and physics. The path I took was not always straight, but as long as I kept going in the direction I thought was “interesting,” I found myself in the right place. I am sure that if I keep going in the direction that I think is “interesting,” I will get somewhere. So don't worry, just dive into all kinds of things.

Acknowledgment

I thank Prof. Mark Vagins and peer reviewer Rintaro Masaoka for giving me advise to improve this essay.

I used “ChatGPT” and “DeepL” for writing, checking mistakes and generating a image.