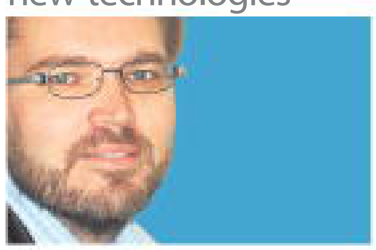
» SCIENCE TALK

Is reality a quantum hocus pocus?

Quantum physics' bizarre implications can be applied to create new technologies



By Vlatko Vedral

HUMANS have a deeply rooted desire to understand the world around them.

This desire defines us as intelligent beings and has been the driving force behind our civilisation's development.

Genetic engineering, telecommunications, microelectronics and pharmacology are all testament to how far we have progressed in our understanding of nature.

Our most accurate description of nature is currently in quantum physics, which is the science of things at the tiniest level at which they can exist independently. It is the basis of modern physics.

Over the last 100 years, we have found quantum physics able to accurately explain the behaviour of all atomic and subatomic particles and processes as well as the behaviour ofl arge systems, such as neutron stars.

While the theory has been extremely successful, we are still grappling with its totally bizarre and counter-intuitive implications.

The main bizarre consequence is that although we seem to perceive a well-defined reality around us, quantum physics suggests that there is no underlying single reality in the universe independent of us – and that our reality is actually only defined if and when we observe it.

For example, when a particle ofl ight or photon encounters a piece of glass like your bedroom window, two outcomes can occur.

One outcome is that the photon is reflected, and the other is that it passes through the glass.

Quantum physics tells us that if we observe the photon, we will never be able to predict the outcome in advance. The process is completely random.

But what happens if we do not observe the photon? Then quantum physics suggests that the photon takes both alternatives: It both goes through the glass and is reflected. It exists in two places simultaneously; that is, that there are two distinct realities.

But we seem to see only one reality around us. You never see the same person existing in two different places at the same time.

So how does the act of observation allow one reality to emerge out of two or more realities?

Quantum physics seems to imply that reality somehow emerges through interactions between observers and the observed.

This is reminiscent of a magician's trick, where the main point is to make a card appear from a pack of cards within which it did not exist.

To help the reader understand this point better, let me convey the same message through a simple game.

Suppose you have four players, each of whom is given four cards at the beginning of the game.

The goal of the game is for a player to obtain four of the same cards – like four aces or four 10s, for example – by exchanging cards with other players. The first person to do this is the winner.

A couple of rules apply:

The first is that you can ask for a card only if you already have at least one of those cards. So you can only ask someone for an ace if you are holding at least one ace.

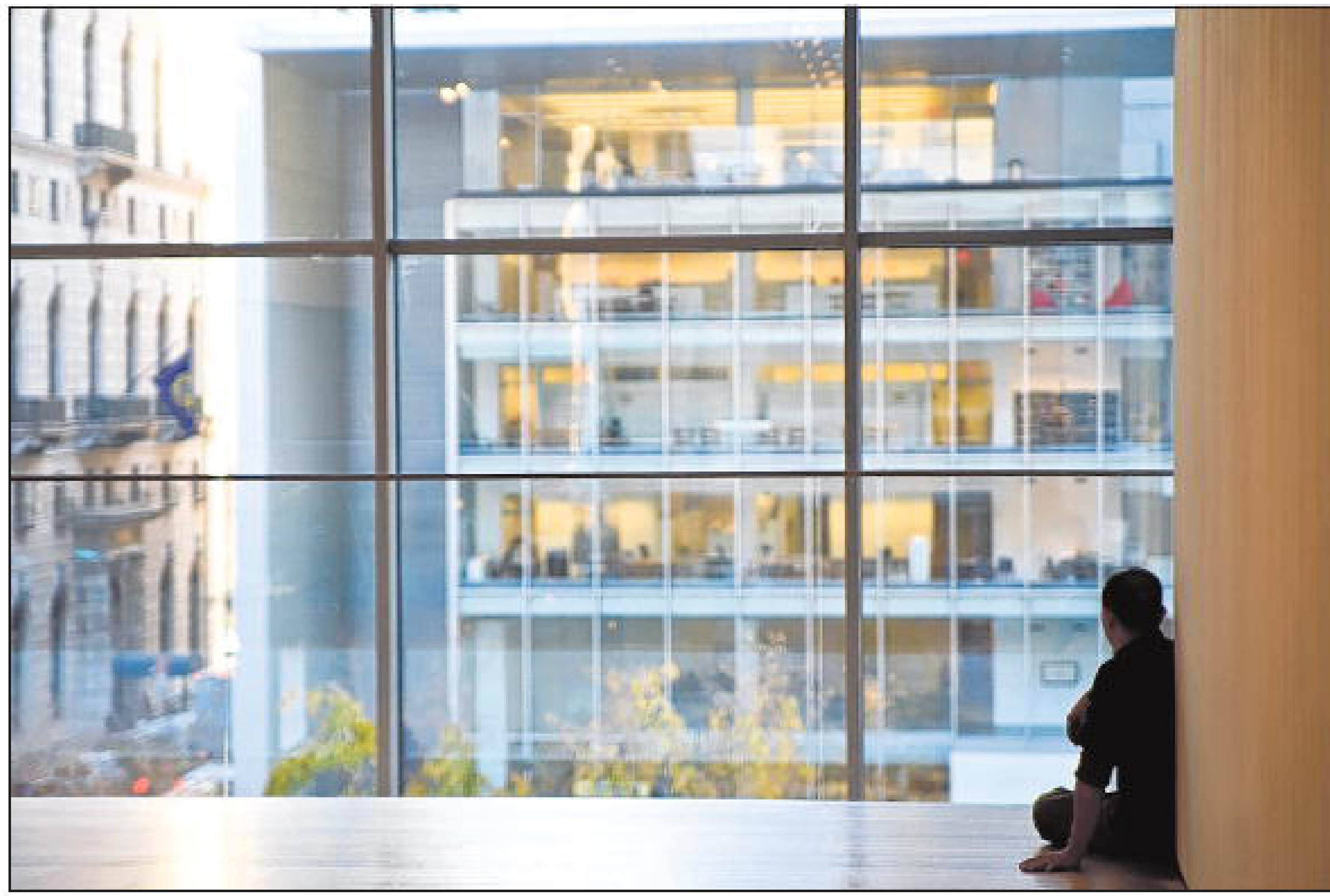


PHOTO: ISTOCK PHOTO

DUAL REALITIES: Quantum physics suggests that if no one is present to witness a photon ofl ight when it encounters a window, both possible alternatives happen: The light goes through the glass and is also reflected. It exists in two places simultaneously, indicating two distinct realiti es.

Now if the person says no, that means they do not have an ace and the game passes to the next player.

If they do have the card, they must give it to you and then you have the option of asking the same player again or another player.

When you ask for an ace, all other players immediately know that you have at least one ace. The next player in turn then knows what to get from you.

Of course this is a very simple game and really does not need more than a couple of rounds to find a winner.

The amazing thing is that we do not really need cards to play this game and this is where things get interesting.

The whole game can just be played inside the players' heads where each player imagines four completely arbitrary cards, which are non standard in that there is no limit on the type ofi mage or number ofi mages on any card.

For example, one person could imagine three elephant cards and a crocodile card, whilst someone else could imagine two aces and two apple cards.

As long as we add the requirement that you cannot start with four of the same cards then we know that you must be forced to ask at least one question.

Surprisingly, while there seem to be an infinite number of combinations, this is actually not a problem and we can always find a winner.

The saving grace is that the players cannot change any choices that would affect the consistency of the game so far, although they can change their cards throughout the game.

For example, if you have asked someone else for a card then you must at least possess a card of that type, and if someone has asked for a particular card then they must give up that card ifi t has been asked for by someone else.

This requirement of consistency and the ability to change your cards to win the game is what quickly narrows down the multitude of different possibilities as the game proceeds.

Answering and asking a question affects both the cards that you hold and the cards the other players hold.

In this way, the imagined version without physical cards or limits reduces to the fixed game and we ultimately end up with a definite winner.

In this card game, the questioning is analogous to experimentation in physics, where we start by observing an infinite number of possibilities.

Interacting with the system and modifying our experiments in line with the information available results in a smaller set of possible outcomes and then to an eventual winner – a single reality.

Experiments too have to be consistent with the rules of the game, the laws of physics.

Reality is therefore created by experiments in the same way as cards become created in this imaginary card game.

Through this analogy I hope to give a feel of the bizarreness of quantum mechanics.

So, does the absence of a unique reality independent of observers represent a problem to us?

Actually, it is to the contrary.

Rather than think ofi t as a problem, we physicists are now trying to utilise it in order to produce super-efficient new technologies by mobilising all possible realities at the same time.

This is happening right here in Singapore, where $150 million is being pumped into a National University of Singapore centre which is tapping into quantum physics to ease the current information technology storage crunch and to provide ultra-safe ways to code and decode information.

For example, researchers are also looking at building a device to trap atoms and control them to interact with light, resulting in a system of coding and decoding that is difficult to break.

Who knows, we may one day build quantum computers to solve problems faster and generate predictions for situations scientists cannot solve now.

Watch this space.

The writer is a principal investigator at the Centre of Quantum Technologies at the National University of Singapore, and a Professor of Quantum Information at University of Leeds, Britain.