International Journal of Social Science Studies
Vol. 11, No. 1; January 2023
ISSN 2324-8033 E-ISSN 2324-8041
Published by Redfame Publishing
URL: http://ijsss.redfame.com

The Importance of Quantum Information in the Stock Market and Financial Decision Making in Conditions of Radical Uncertainty

Ana Njegovanović[1]

[1] Zagreb, Croatia

Correspondence: Ana Njegovanović, Kamaufova street number 3, Zagreb, Croatia.

Received: November 13, 2023 Accepted: December 20, 2022 Available online: January 6, 2023

doi:10.11114/ijsss.v11i1.5872 URL: https://doi.org/10.11114/ijsss.v11i1.5872

Abstract

The Universe is a coin that’s already been flipped, heads or tails predetermined: all we’re doing is uncovering it the ‘paradox’ is only a conflict between reality and your feeling of what reality ‘ought to be’.

Richard Feynman

The aim of the research takes place through two parallel directions. The first is gaining an understanding of the applicability of quantum mechanics/quantum physics to human decision-making processes in the stock market with quantum information as a decision-making lever, and the second direction is neuroscience and artificial intelligence using postulates analogous to the postulates of quantum mechanics and radical uncertainty in conditions of radical uncertainty.

The world of radical uncertainty (radical uncertainty is based on the knowledge of quantum mechanics from the claim that there is no causal certainty). it is everywhere in our world. "Radical uncertainty is characterized by vagueness, ignorance, indeterminacy, ambiguity and lack of information. He prefers to create 'mysteries' rather than 'puzzles' with defined solutions. Mysteries are ill-defined problems in which action is required, but the future is uncertain, the consequences unpredictable, and disagreement inevitable. "How should we make decisions in these circumstances?" (J. Kay and M. King, 2020), while "uncertainty and ambiguity are at the very core of the stock market. "Narratives are the currency of uncertainty" (N. Mangee, 2022).

Keywords: quantum information, stock market, radical uncertainty, financial decision making, quantum technology

1. Introduction

The aim of the research takes place through two parallel directions. The first is gaining an understanding of the applicability of quantum mechanics/quantum physics to human decision-making processes in the stock market with quantum information as a decision-making lever, and the second direction is neuroscience and artificial intelligence using postulates analogous to the postulates of quantum mechanics and radical uncertainty in conditions of radical uncertainty.

The world of radical uncertainty (radical uncertainty is based on the knowledge of quantum mechanics from the claim that there is no causal certainty). it is everywhere in our world. "Radical uncertainty is characterized by vagueness, ignorance, indeterminacy, ambiguity and lack of information. He prefers to create 'mysteries' rather than 'puzzles' with defined solutions. Mysteries are ill-defined problems in which action is required, but the future is uncertain, the consequences unpredictable, and disagreement inevitable. "How should we make decisions in these circumstances?" (J. Kay and M. King, 2020), while "uncertainty and ambiguity are at the very core of the stock market. "Narratives are the currency of uncertainty" (N. Mangee, 2022).

In quantum information science, a physical approach to 'Information' is considered the best approach in explaining our understanding and processing of information in a quantum mechanical way. Quantum information science is reinforced with three pillars, 'Qubit', 'Superposition' and 'Entanglement' and their practical and technological applications. This facilitates knowledge about the physical properties of the nature of microscopic systems at the level of atoms and subatomic particles.

The physical approach to quantum information science is equally significant in the analysis of "consciousness", "free will" and "bioinformatics". Penrose and his collaborator, Stuart Hameroff, argued that human intelligence is far more subtle than 'artificial intelligence' and proposed a biological analogue to quantum computing involving microtubules. In neurons, microtubules (found in neurons in the brain) help control the strength of synaptic connections. In

Penrose-Hameroff's theory of orchestrated objective reduction, known as Orch-OR, moments of conscious awareness are governed by microtubules in our brain, which they believe have the ability to store and process information and memory. The Orch OR Model and biological theories of mind are important in the field known as "bioinformatics".

The concept of quantum information was established in the 1990s. It comes from research aimed at understanding how physics affects our ability to communicate and process information. Since the 1960s, Landauer has studied the thermodynamic cost of irreversible operations in calculus (1961). Charles Bennett showed that, using reversible computation, this cost should be avoided (1973). The limitations of measurement in quantum mechanics were explored in the works of John von Neumann (1932a and 1932b), and later by Alexander Holevo (1973b) and Carl Helstrom (1976). Holevo presented the idea of quantum communication channels and the limits of their ability to transmit classical information were established (1973a).

The quantum theoretical framework provides a wide range of interpretations of wave functions, allowing for multiple perspectives of physical finite reality. Physicists Rutherford, Sommerfeld and Bohr as pioneers in experimental and theoretical endeavors in the quantum domain were extended by pioneering contributions contributing to the development of modern quantum theory in the 1920s (Bohr used to introduce his attempts to explain clearly the principles of the quantum theory of the atom with an historical sketch, beginning invariably with the nuclear model proposed by Rutherford).

We witnessed the existence of points of contact between natural and social sciences, which resulted in the application of ideas, concepts and formalisms from physics, mathematics, and biology to economics and finance (N. Georgescu-Roegena, law of entropy, 1986). The last decade has witnessed an increasing number of references to quantum mechanics in the humanities and social sciences. However, it should be emphasized that there are few people who truly understand the structure of quantum mechanics, and little attention is paid to its development in the social sciences. However, recent literature shows a quantum 'turn' (A. Wendt, 1990) occurring in the social sciences. "The quantum turn is connected to the currents of abstraction and evolutionary globalization.

Let us indicate the importance of the discipline of information theory "The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point." (C.Shannon, 1948). Quantum information theory is largely motivated by the same problem, but with the difference that either the reproduction method or the message itself fundamentally involves quantum effects. Information theorists either ignored quantum effects or approximated them to make them amenable to classical analysis. In the last ten years, a systematic study of quantum information theory has begun. An interesting quote for analysis: "I think that I have never met a physicist who understood information theory. I wish that physicists would stop talking about reformulating information theory and would give us a general expression for the capacity of a channel with quantum effects taken into account rather than a number of special cases." (John R. Pierce, 2012).

The development of quantum information science can be attributed to convergent factors, the deeper understanding of classical information, coding, cryptography and computational complexity that has been gained in previous decades laying the groundwork for expansion into the quantum realm, and the development of sophisticated new laboratory techniques that have provided tools to manipulate and monitor behavior. of individual quanta in atomic, electronic and nuclear systems.

Today's digital computers process classical information encoded in bits, a quantum computer processes information encoded in quantum bits or qubits. A qubit is a quantum system that can exist in a coherent superposition of two different states and can be entangled with other such systems. Two different states can be internal electronic states of an individual atom, polarization states of a photon, or spin states of an atomic nucleus (examples). Entanglement is a subtle quantum type of correlation that has no classical equivalent, and can be described as two systems being entangled when their shared state is determined and less random than the state of either system by itself. Two properties of classical information are that we can read and copy them without interference and that the state of a composite system can be specified in its entirety by specifying the state of each of its parts. But the information conveyed by a quantum system violates such reasonable principles. Quantum information can be used to perform tasks that would be impossible or very difficult in the classical world.

In short, quantum information science emerged as a response to convergent scientific challenges, with the aim of examining the theory of computation. Namely, what limitations are imposed on computation by the fundamental laws of physics and how the power of computation can be improved by exploiting the structure of these laws, and the extension of communication theory. What are the ultimate physical limits to the performance of a communication channel, and how might quantum phenomena be exploited using new communication protocols? The big challenge is to understand and overcome the quantum effects that limit how precisely we can control and manipulate physical systems.

Current financial markets are among the most complex systems. There are sophisticated mathematical and scientific tools that try to make accurate predictions. However, unlike most scientific fields, modern markets lack a controlled environment in which to conduct experiments. To solve this once and for all, analysts and investors are increasingly turning to quantum computing. Namely, "the beauty and magic of finance attract professionals through stock exchanges all over the world, which is surpassed only by the magnitude of quantum physics".

Stock markets operate in a circular fashion, which is influenced by many factors. We know how artificial intelligence and machine learning have redefined trading rules and heuristics, although they have left some gaps. An analysis of a recent study on quantum gates (O. Racorean, 2015) opened up insights into how quantum computing methods similar to stock market operations have been found ("In quantum computing, arrays of quantum gates must be arranged in a predefined sequence that led to a quantum circuit as would solve a particular problem. What if the sequence of quantum gates is known, but both the problem to be solved and the outcome of the quantum circuit so defined remain in the shadows? This is the state of the stock market. The time series of stock portfolio prices are organized into braids that effectively simulate quantum gates in the Ising Anyons quantum computer model hypothesis" (Quantum Gates and Quantum Circuits of Stock Portfolio, 2015). Thus, quantum computing concepts such as braids, knots and variants of knots mimic the behavior of the stock market (O. Racorean). This opened up a series of speculations does the stock market mimic a quantum computing simulation.

A quantum computer can operate on qubits that can have multiple states simultaneously, unlike the binary digits of dual-state digital computers. A qubit's ability to exist in multiple states simultaneously can function effectively in optimization and forecasting situations, which is what stock markets depend on. Can stock market speculation be fully automated if it can take cues from quantum computing simulations? The likely answer would be 'No' for now.

We could emphasize the complexity of quantum mechanics in financial decision-making with the quote ": "Quantum mechanics is a terrible explanation for intelligent decision-making. We could also argue that Beethoven's sonata is the result of probabilistic wavefunction collapse because the large number of possible notes eventually "collapsed" to the final notes when he put pen to page. Are there any interesting analogies between quantum mathematical models and human activities? Maybe. But we have to be careful not to fall into the trap of thinking that a quantum model is ever a real explanation for real decision-making.” (E. Anderson, 2022).

Neuroscience and quantum physics examine two topics within neuroquantology. The first topic is the measurement problem in quantum mechanics. Another topic of neuroquantology is quantum neurobiology, that is, the brain does not only operate at the classical, macroscopic level, but also at the quantum microscopic level. We are treading the paths of better understanding of an interdisciplinary approach to the brain, including quantum mechanics and neuroscience.

The brain is much more than its constituent cells. Each neuron in the brain connects with thousands of other neurons like a synchronized symphony.

The coordination of countless bodily functions, behaviors and thoughts requires a large number of neurons to work cooperatively. Outcomes trigger connections between neurons, whether that involves communicating with a neighboring nerve cell or sending and receiving signals to and from distant brain areas. Advances in brain imaging reveal anatomical projections and functional connectivity patterns, allowing us to see their activation in real time.

The brain consists of electrically excitable neuronal networks regulated by the activity of voltage-gated ion channels. Mapping the molecular makeup of the brain will reveal nothing resembling feeling, sensation, or conscious experience. In classical physics, solving the mind-brain problem is a difficult task because no physical mechanism is able to explain how the brain creates an imperceptible, internal psychological world of conscious experiences and how these conscious experiences in turn direct underlying brain processes toward desired behavior. Modern quantum physics confirms the interplay between two types of physical entities in Hilbert space: unobservable quantum states are vectors that describe what exists in the physical world, and quantum observables, which are operators that describe what can be observed in quantum measurements. The quantum no-go theorems provide a framework for the study of the quantum dynamics of the brain, which must be governed by a physically acceptable spin Hamiltonian (a model of the quantum dynamics of the brain can be cast on a kind of the Heisenberg spin Hamiltonian). So, the quantum dynamics of the brain should be understood by the physics of quantum spin systems. of consciousness from unobservable quantum information integrated into quantum brain states explains the origin of the inner privacy of conscious experiences and examines the dynamic time scale of conscious processes to the picosecond conformational transitions of neural biomolecules.The Observable brain is an objective construct created from classical bits of information, which are bound by Hall's (Philip Hall) theorem , and obtained by measuring quantum brain observables.

The brain in information processing works on a knife edge between two dynamic phases. At the same time, the neuron networks are stable in storing information, but also the sensibility that allows sending signals to distant parts. Using methods taken from quantum field theory, M. Helias and his team confirmed the existence of critical points in the classical model of brain dynamics (L. Tiberi et al., 2022). In short, using the renormalization technique the researchers found that both nearby and distant neurons can effectively communicate with each other. At the same time, the ability to store memories is preserved. However, it should be emphasized that despite the evidence of critical dynamics in the brain, it is still not fully explained why our brain works the way it does. Of course, the new result is a step in that direction. The magic is also in the latest research where our brains could use quantum computing after adapting the idea developed to prove the existence of quantum gravity to research the human brain and its work (C. Kerskens, 2022) with a quote for the quantum brain "Quantum brain processes could explain why we can still outperform supercomputers when it comes to unforeseen circumstances, decision making, or learning something new. Our experiments performed only 50 meters away from the lecture theater, where Schrödinger presented his famous thoughts about life, may shed light on the mysteries of biology, and on consciousness which scientifically is even harder to grasp."

When mathematician Alan Turing asked the question "Can machines think?" (1950) opened the way for the search for artificial intelligence/ AI (1950), the only known systems that perform complex calculations were biological nervous systems. So it's no surprise that scientists in the emerging field of artificial intelligence have turned to brain circuitry as a source of guidance. One path taken since early attempts to perform intelligent computation with brain-like circuits (F. Rosenblat, 1958) and which has recently led to remarkable success, can be described as a highly reductionist approach to modeling cortical circuits. In its basic current form, known as the "deep network" (or deep network) architecture, this brain-inspired model is built from successive layers of neuron-like elements, connected by adjustable weights, called "synapses" after their biological counterparts (A. M. Turing, 2015). . The application of deep networks and related methods to artificial intelligence systems has been transformative. They have proven superior to previously known methods in central areas of artificial intelligence research, including computer vision, speech recognition and production, and playing complex games. Practical applications are already in widespread use, in areas such as computer vision and speech and text translation, and major efforts are underway in many other areas.

Thus, in the intertwining of neuroscience, quantum physics, artificial intelligence and finance with quantum information as a driver of knowledge about decision-making in the financial market necessarily requires knowledge and understanding of how the brain works (and leads to mind and behavior) which is the challenge of our time. However, this raises a number of questions. Our brain processes an incredible amount of information at any given time. No other computer on the market can match its computing power. But understanding this extraordinary power of the brain may require concepts borrowed from computer science as well as mathematics, engineering and physics. How are the billions of neurons that make up the brain similar to the microprocessors that make up a computer - and how are they different? What is the computing power of our brain? How does it allow the brain to interpret the outside world and use the information it receives to send messages to the body? New tools that analyze massive amounts of data and new ways of visualizing that analysis could spur new advances in fields such as economics/decision-making/finance, and even lead to new types of computers inspired by the elegant workings of the brain.

2. Theoretical Background

The Universe is a coin that's already been flipped, heads or tails predetermined: all we're doing is uncovering it. The 'paradox' is only a conflict between reality and your feeling of what reality 'ought to be'

Richard Feynman

Interpretation and understanding of information is one of the most difficult and complex scientific concepts (Adriaans, 2013, Floridi, 2015). The word 'information' has different meanings. But even when one formalism is considered, disagreements still arise in the interpretation of the term (Lombardi, Fortin & Vanni, 2015). New problems of interpretation have also appeared with the advent of quantum information, these problems are combined with difficulties in understanding the concept of information with the well-known fundamental puzzles derived from quantum mechanics itself. Such a situation is in contrast to the development of the research field 'quantum information theory', where new formal results are multiplying rapidly. "What is quantum information?". For now, we are far from an adequate definition. The views on this issue range from those who deny the existence of quantum information (Duwell, 2003), as well as those who believe that quantum information refers to information when it is encoded in quantum systems (Caves & Fuchs, 1996, Dieks, 2016).), and advocates who understand it as a new type of information that is different from classical information (Jozsa, 1998, Brukner & Zeilinger, 2001).

Information is a polysemantic concept that can be associated with different phenomena, the first difference is the difference between a semantic and a non-semantic view of information. According to the first point of view, information is something that carries semantic content (Bar-Hillel & Carnap, 1953; Bar-Hillel, 1964; Floridi, 2011); it is related to the semantics of concepts such as reference, meaning and representation. Semantic information is carried by propositions that intend to represent the state of affairs; therefore it has intentionality, "story", (intentionality, "aboutness") Non-semantic information deals with the compressibility of the properties of strings of system states and/or correlations between the states of two systems, regardless of the meaning of these states. However, this distinction is not yet concrete enough, because in the domain of mathematical information there are at least two different contexts in which the term information is important. In a computing context, information is something that must be calculated and stored efficiently; in this context, algorithmic complexity measures the minimum necessary resources to effectively reconstruct a single message (Solomonoff, 1964, Kolmogorov, 1965, 1968, Chaitin, 1966). In contrast, in the traditional communication context, whose classic place is Claude Shannon's formalism (Shannon, 1948, Shannon & Weaver, 1949), information is something that must be transferred between two points for the purpose of communication. Shannon's theory is purely quantitative, it ignores any question related to information content: "(semantic) aspects of communication are irrelevant to the engineering problem. A significant aspect is that the actual message is the one selected from a range of possible messages." (Shannon, 1948, p. 379). Thus, the new theory of reality (D. Deutscha, 2014), connects classical and quantum information under the same theoretical umbrella.

The laws of physics do not tell us what is possible and what is impossible, they are the result of what is possible and impossible. Thinking about physical transformations that are possible and impossible leads to the laws of physics.

Computer bits that obey quantum principles, such as superposition and entanglement, can perform some calculations much faster and more efficiently than those that obey classical rules. D. Deutsch (1985) hypothesized that a device made of such quantum bits (qubits) can be made universal, meaning that it can simulate any quantum system. D.Deutsch framed his proposal in the context of the "many worlds" interpretation of quantum mechanics (of which he is an advocate), comparing the process of one quantum calculation with the process of many parallel calculations that take place simultaneously in intertwined worlds. "Without Deutsch and Shor (Shor's algorithm is known for decomposing integers in polynomial time.) we would not have the field of quantum computing as we know it today" (A. Ekert, 1995), and emphasizing "David defined that field, and Peter took it to a whole other level by discovering the real power of quantum computing and showing that it can actually be done" (1995).

Radical uncertainty represents increased forms of ignorance in which individuals do not know what will happen and do “not even know what things might happen” (Kay & King, 2020, p. 24). This is because radical uncertainty is full of unforeseen, unpredictable, and unexpected changes, which makes adaptation and quick action impossible (Ehrig & Foss, 2021).

In quantum mechanics and „quantum field theory, a body of physical principles combining the elements of quantum mechanics with those of relativity to explain the behavior of subatomic particles and their interactions via a variety of force fields. Two examples of modern quantum field theories are quantum electrodynamics, describing the interaction of electrically charged particles and the electromagnetic force, and quantum chromodynamics, representing the interaction of quarks and the strong force. Designed to account for particle-physics phenomena such as high-energy collisions in which subatomic particles may be created or destroyed, quantum field theories have also found applications in other branches of physics) - wave function (ψ) - "Wave function, in quantum mechanics, a variable quantity that mathematically describes the wave characteristics of a particle. The value of a particle's wave function at a given point in space and time is related to the probability that the particle is there at that time. By analogy with waves such as those of sound, the wave function, denoted by the Greek letter psi, Ψ, can be thought of as an expression for the amplitude of a particle wave (or de Broglie wave), although for such waves the amplitude has no physical meaning square of the wave function, Ψ^2 however, has physical meaning: the probability of finding a particle described by a specific wave function Ψ at a given point and time is proportional to the value $\Psi 2$"- It should be emphasized and The dominant interpretation of the quantum wave function sees it as real – as part of the physical furniture of the universe. Some even go as far as to argue that the entire universe is a quantum wave function. But this interpretation runs into a number of problems, including a clash with Einstein's theory of relativity. Karl Popper prize-winner, Eddy Keming Chen, suggests that we instead interpret the wave function as the basis for a law of nature that describes how particles, fields and ordinary objects move through space and time. That way, a number of puzzles around quantum mechanics are solved. In this context, should we investigate the wave function in quantum finance? If by measuring the PDF (probability distribution function) of our data. Here in the financial market we can get the pdf of one variable or two variables and then calculate the quantum potential based on Bohm's quantum potential formulas. According to the results that the quantum potential maps give us, we are able to analyze different markets. Studying the financial markets and their trends, the implementation of the quantum approach can prove convincing. As such a reasonable tool is Bohmian quantum mechanics. To face the facts, quantum potential is used to model real markets. The outcome would provide information about expectations and constraints in the market under consideration. The probability distribution function of the variable represented by R is extracted from the market and replaced in Eq. (Lo, A. W., Wang, J.,2000), where the quantum potential of that market is obtained in terms of its variable. Having quantum potential information at hand based on desired time scales provides valuable information on the constraints placed on the variables of that market.

3. Methodology

„The quantum world defies common sense at every turn. Shaped over hundreds of thousands of years of biological evolution, our modern human brain struggles to make sense of things outside of our familiar naturalistic context. It is easy to understand a predator hunting its prey across a grassy plain; understanding most anything that happens at the subatomic levels can require years of intensive study and a ton of "gnarly" math. Therefore, it is not surprising that every year physicists bring astonishing new ideas and discoveries gathered from the deep foundations of reality, far beyond the limits of our perception. „ Scientific American , 2022

Quantum computers are expected to surpass the computational capabilities of classical computers and achieve a "tsumani" impact on numerous industrial sectors, such as global energy and materials, pharmaceuticals and medical products, telecommunications, travel, logistics and finance. The financial sector has a history of creating and first adapting new technologies. This is also true when it comes to quantum computing. Finance is estimated to be the first industry sector to benefit from quantum computing, not only in the medium and long term, but also in the short term, due to the large number of financial use cases amenable to quantum computing and their ability to be efficiently addressed even in the presence of approximation. Quantum computers are fundamentally different from classical computers, so much so that the algorithmic procedure for solving applications must be completely redesigned based on the architecture of the underlying quantum hardware. Most of the use cases that characterize the financial industry sector have a high computational complexity, and are therefore suitable for quantum computing. However, computational complexity is a problem in itself and is no guarantee that quantum computing can make a difference.

The starting point of financial decision-making is information/quantum information. „The distinction between reality and our knowledge of reality, between reality and information, cannot be made. There is no way to refer to reality without using the information we have about it.“(Anton Zeilinger, 2022). All computer systems rely on the ability to store and manipulate information. Today's classical computers operate on individual bits, which store information as binary states of 0 or 1. In contrast, quantum computers use the physical laws of quantum mechanics to manipulate information. At this level, a unit of information is represented by a quantum bit or qubit. Physically, a qubit is any two-level quantum system (Michael A. Nielsen and Isaac L. Chuang, 2010; Ramamurti Shankar, 1994). Mathematically, the state space of a single qubit can be associated with the complex projective line, denoted CP ^{1}(Oswald Veblen and John Wesley Young.,1918). However, one commonly considers qubit states as elements s ψ, called state vectors, of a two-dimensional complex-vector space but restrict consideration to those that satisfy kψk = 1 and allow for ψ qnd e na θψ to be used interchangeably (i.e., consider specific elements of the equivalence classes in CP^1). A state vector is usually denoted by using Dirac's "bra-ket" notation: ψ is represented by the "ket" |ψi. Examples of two single-qubit kets are the states 0 and 1, which are analogous to the classical bits 0 and 1.

Whereas, measurement in quantum mechanics consists of examining a system to obtain a numerical result. The measurement of a quantum system is probabilistic. A projective measurement of the system with respect to the Hermitian operator A.

We start with the premises that ψ and φ are functions, ∫dτ represents integration over all coordinates, and the operator Â is Hermitian by definition if

$\int\psi*A\text{^}\psi d\tau=\int(A\text{^}*\psi*)\psi d\tau(1)$

This equation means that the complex conjugate of Â can operate on ψ* to produce the same result after integration as Â operating on φ, followed by integration. To prove that a quantum mechanical operator Â is Hermitian, consider the eigenvalue equation and its complex conjugate.

$A\text{^}\psi=a\psi(2)$

$A\text{^}*\psi*=a*\psi*=a\psi*(3)$

Note that a* = a because the eigenvalue is real. Multiply Equations 2 and 3 from the left by ψ* and ψ, respectively, and integrate over all the coordinates. Note that ψ is normalized. The results are

$\int\psi*A\text{^}\psi d\tau=a\int\psi*\psi d\tau=a(4)$

$\int\psi A\text{^}*\psi*d\tau=a\int\psi\psi*d\tau=a(5)$

Since both integrals equal a, they must be equivalent.

$\int\psi*A\text{^}\psi d\tau=\int\psi A\text{^}*\psi*d\tau(6)$

The operator acting on the function, $A\text{^}*\int\psi*A\text{^}\psi d\tau=\int\psi A\text{^}*\psi*d\tau*$, produces a new function. Since functions commute, Equation 6 can be rewritten as

$\int\psi*A\text{^}\psi d\tau=\int(A\text{^}*\psi*)\psi d\tau(7)$

This equality means that Â is Hermitian.

Since the eigenvalues of a quantum mechanical operator correspond to measurable quantities, the eigenvalues must be real, and consequently a quantum mechanical operator must be Hermitian (Properties of Quantum Mechanical Systems, 2022).

Therefore,with respect to a Hermitian operator A, called an observable, results in the state vector of the system being orthogonally projected onto an eigenspace, with with orthogonal projector Πλ, and the observable quantity is the associated eigenvalue, λ. A potential projective measurement result λ is observed with probability equal to kΠλ ψik^2 .The expected value of the measurment is equal to hψ|A|ψi, where hψ, called a "bra," is the Hermitian adjoint. In physics, the quantum Hamiltonian is the observable for a system's energy. A ground state of a quantum Hamiltonian is a state vector ina n eigenspace associated with the smallest eigenvalue and thus has the lowest energy. Any physical transformation of a quantum system can be represented by a completely positive non-trace increasing linear operator.

The works of Nielsen and Chuang (Michael A. Nielsen and Isaac L. Chuang, 2010) and Kitaev et al. (A. Yu. Kitaev, A. H. Shen, and M. N. Vyalyi, 2002) are references on the subject of quantum computation. The Nelson covers a variety of topics from quantum information theory, while the Chuang focuses on quantum computational complexity theory.

The stock market is in a period of radical uncertainty where there are a lot of unknowns to deal with and few good answers about what the possibilities are.

Summary: The entanglement of quantum information theory in the stock market and decision making under radical uncertainties gives us information about the stages of the information system.

Stock market modeling and risk management are one of the most important topics in finance. Using a method borrowed from statistics and Bohm's quantum mechanics, he tries to find answers to the question of how the quantum potential controls the price return. The interrelationship between today's and yesterday's prices has led to the emergence of a quantum potential that describes the collective behavior of stock returns at different times. Using the empirical data of some market indices, quantum potential walls limit the variation of price returns to a certain interval where the distance between the walls can be a proxy for the risk of the relative stock index. Namely, research on different return frequencies shows that market risk increases as the distance between potential walls increases. The magnitude of risk is different for different indices which allows traders to decide on their portfolio selection and investment horizon. The conducted research (Quantum model for the stock market/2022) is in accordance with the behavior of developed and emerging markets. Since the stock index is based on the stock prices of many representative stocks, then it makes sense to consider the stock index as a macro system and take each stock as a micro object (C. Zhang and L. Huang, 2010). Each share is always traded at a certain price that shows the behavior of the particles. The share price always fluctuates in the market, which is a property of waves. Due to the wave-particle duality, we can consider the stock on the micro scale as a quantum system. It is the beginning of constructing a quantum model for the stock market based on the postulates of quantum mechanics. Analysis of the effects of discreteness of the stock price on quantum models for stock markets, shows that the minimum trading value of each stock is not zero, and the stock price and its trend satisfy the generalized uncertainty relation. This leads to the modification of all Hamiltonians of the stock markets and adds a term proportional to the fourth power of the trend to the Hamiltonians. The quantum model proposed by Zhang and Huang where there is a price limit rule and the information has a periodic fluctuation, the characteristic frequencies of the quantum system are obtained.

The application of quantum mechanics in financial markets draws much attention to modeling the behavior of finance according to the laws of quantum mechanics (C. Ye and J.P. Huang, 2008; A. Ataullah, I. Davidson, and M. Tippett, 2009; F. Bagarello, 2007; F. Bagarello, 2006; F. Bagarello, 2007; F. Bagarello, 2009; F. Bagarello, 2009). Schaden, contrary to stochastic descriptions, used quantum theory to model secondary financial markets to demonstrate the importance of trading in determining asset values (.M. Schaden, 2002). He considered securities and cash held by investors as a wave function for the construction of the Hilbert space of the stock market. One useful application of quantum theory to trading strategies is quantum game theory, which is a generalization of classical game theory to the quantum domain (D. Meyer, 1999; J. Eisert, M. Wilkens, and M. Lewenstein, . 1999). The theory is based on quantum cryptography and features superimposed initial wave functions, quantum entanglement of initial wave functions, and superposition of strategies in addition to its classical counterpart.

4. Artificial Neuronal Networks

The stock market is inextricably linked with the financial assets of states, companies and individuals, the tendency of movement is influenced by various macroeconomic and microeconomic factors: political climate, interest rates, market news, fiscal policy, commodity price index, investor psychology (J. Z. Wang, J. J. Wang, Z. G. Zhang, and S.P. Guo, 2011; J.L. Ticknor, 2013). So forecasting the trend in the stock market is a big challenge because the stock market is noisy, complex, nonlinear, non-parametric and non-stationary in nature (T. J. Hsieh, H. F. Hsiao, and W. C. Yeh, 2011; Y. A.

Zhang, B. Yan, and M. Aasma, 2020) “ Conventional stock market predictions are usually based only on economics, finance and simple mathematical statistical analysis. Nevertheless, with the strong advancement of artificial intelligence (AI)-related technologies and the increasing demand for stock market forecasting, stock market forecasting manipulated by intelligent technologies has evolved into a boom of research in economic and financial fields in recent years.

The essence of stock market forecasting is to discover the intrinsic rules of how stocks work in the market, but this is an extremely difficult challenge for investors. The application of nanophotonics technologies in the field of intelligence provides a new approach for forecasting the stock market, its unique advantages.

In practice, it is difficult to accurately predict the behavior of the stock market due to its high volatility. In order to improve market predictions, a method inspired by Elman neural network and quantum mechanics is presented. In order to make the network sensitive to dynamic information, an internal self-coupling signal that is extremely useful for system modeling is introduced in the proposed technique. A double chain quantum genetic algorithm is used to adjust the learning rates. This model is validated by forecasting the closing prices of six stock markets, the simulation results show that the proposed algorithm is feasible and effective. Therefore, the generalization of the method is considered favorable.

Theoretical analysis and application prove that quantum neural network (QNN) offers certain advantages: exponential storage capacity; simple structure; better stability; high calculation speed; and avoiding catastrophic forgetting (A.G. Zhang et al., 2022).

Unplanned events hit the stock market, from corporate scandals and technological breakthroughs to recessions and pandemics, the relationships that drive profits change in unpredictable ways. To deal with uncertainty, investors engage in narratives (R. Shiller (2017, p. 967) defines narrative economics as "the study of the spread and dynamics of popular narratives, stories, especially those of human interest and emotion, and how they change through time in understanding economic fluctuation”) that simplify the complexity of non-routine changes in real time.

This is one reason why speculative returns are so high “knowing better than the market what the future may bring” (Keynes, 1936, p. 170). "Individuals have an internal desire, especially when faced with uncertainty, to form opinions based on their own stories, experiences, perceptions and beliefs about a given situation. Our ignorance about the future, even imperfect reasoning, makes it impossible to objectively classify cases and all changes in the surrounding conditions, and the formation of opinions certainly affects the intrinsic value of the opinion itself" (Knight, 1921, p. 259).

The stock market is characterized by extreme fluctuations, non-linearity and changes in internal and external environmental variables. Artificial intelligence (AI) techniques can detect such non-linearity, resulting in significantly improved prediction results.

A neural network is defined as a software solution that uses machine learning (ML) algorithms to 'mimic' the operations of the human brain. Neural networks process data more efficiently and have improved pattern recognition and problem solving capabilities compared to traditional computers.

Neural networks mirror the behavior of the human brain, enabling computer programs to recognize patterns and solve common problems in the fields of artificial intelligence, machine learning, and deep learning.

A quantum neural network (QNN) is a machine learning model or algorithm that combines concepts from quantum computing and artificial neural networks. In the past, the term has been used to describe a variety of ideas, ranging from quantum computers that mimic the exact computations of neural networks, to general trainable quantum circuits that only slightly resemble the structure of a multilayer perceptron. Namely, for 90 years quantum physicists tried to design "quantum versions" of recurrent and feed-forward neural networks. These were attempts to translate the modular structure as well as the nonlinear activation functions of neural networks into the language of quantum algorithms. But it could be argued that chains of linear and nonlinear calculations are quite "unnatural" for quantum computers (This is not necessarily true for photonic quantum computers, which allow for very natural implementations of neural nets (Killoran et al., 2019; a GR. Steinbrecher et al. 2019)). More recent research such as the quantum version of Boltzmann machines, which are probabilistic graphical models that can be thought of as stochastic recurrent neural networks, play a role in the quantum machine learning literature. Thus, it has been proposed to use samples from a quantum computer to train classical Boltzmann machines or to interpret spins as physical units of a "quantum" Boltzmann machine model. It should be noted that this may not be true for photonic quantum computers, which allow very natural implementations of neural networks N. (Killoran et al. (2019) and GR. Steinbrecher et al. (2018)). Today, the term "quantum neural network" is used to refer to variational or parameterized quantum circuits. Although mathematically distinct from the inner workings of neural networks, the analogy highlights the "modular" nature of quantum gates in a circuit, as well as the widespread use of tricks from neural network training used in the optimization of quantum algorithms.

Some authors (Brock, W., Lebaron, B., Lakonishok, J., 1992; Sheikh, A.Z., Quiao, H., 2009; Gomes, C., 210) present empirical evidence confirming that the normal distribution does not correspond to the return behavior financial assets and which leads to an underestimation of risk. This underestimation of risk increases the likelihood of financial crises.

In accordance with the laws of quantum mechanics (principle of superposition and postulate of quantum measurement), the structure of QENN is similar to that of ENN, it is observed that the context neuron can store the state at the previous moment of itself (self-connection feedback).

The interplay between machine learning and quantum physics has an intriguing potential to bring practical applications to modern society (J. Biamonte, P. Wittek, N. Pancotti, P. Rebentrost, N. Wiebe and S. Lloyd, 2017; S. Das Sarma, D .-L. Deng and L.-M. Duan, 2019; V. Dunjko and H. J. Briegel, 2018). With the growth of deep learning, intriguing commercial applications have spread worldwide (Y. LeCun, Y. Bengio and G. Hinton, 2015; I. Goodfellow, Y. Bengio and A. Courville, 2016). Machine learning methods solve a number of problems (AlphaGo program, prediction and AlphaFold structures, D. Silver et al., 2016; D. Silver, 2017).

In short, artificial neural networks can be seen as an abstract model of the human brain, which lies at the heart of modern artificial intelligence (Y. LeCun, Y. Bengio and G. Hinton, 2015; I. Goodfellow, Y. Bengio and A. Courville, 2016). Feed-forward neural networks, IEEE Potentials (G. Bebis and M. Georgiopoulos, 1994; D. Svozil, V. Kvasnicka and J. Pospichal, 1997), colvutional (S. Lawrence, C. Giles, A. C. Tsoi and A. Back, 1997), recurrent (T. Mikolov, S. Kombrink, L. Burget, J. Cernocky and S. Khudanpur, 2011; W. Zaremba, I. Sutskever and O. Vinyals, W. Zaremba, I. Sutskever and O. Vinyals, 2014) and Artificial neural networks, which can be viewed as a very abstract model of the human brain, and capsule neural networks (G. E. Hinton, A. Krizhevsky and S. D. Wang, 2011; Z. Xinyi and L. Chen, 2018) each with its own special structures and abilities.

Radical uncertainty requires analysis of the fluctuation of financial time series, which raises many concerns. Predictions of stock market volatility has become a subject of discussion in economic research. The study of forecasting stock market volatility can be helpful to policy makers in making appropriate asset allocation and risk management decisions. Therefore, predicting the volatility of financial time series with reasonable accuracy deserves much attention. However, the stock market exhibits nonlinear and chaotic properties in nature (K. Oh and K. J. Kim, 2002; Y. Wang, 2003). At the same time, statistical models have certain difficulties in working with non-linear and non-stationary time series or in performing satisfactory prediction performance under the statistical assumptions of normally distributed observations. Prediction becomes more challenging.

An artificial neural network has advantages in learning from data samples and capturing non-linear relationships between interconnected neurons through training mode (Y. Wang, L. Wang, F. Yang, W. Di, and Q. Chang, 2021). It is capable of working with nonlinear high-dimensional data and approximating all nonlinear functions with arbitrary precision (F. Beritelli, G. Capizzi, G. Lo Sciuto, C. Napoli, and M. Woźniak, 2018; J. Zhang, J. Li, and R .Wang, 2020). So, a simple recurrent network, that is, the Elman neural network (Elman NN) (J. L. Elman, 1990) has shown the ability because it has the property of time variability. And the Elman NN is a kind of feedback network where the added layer connecting to the hidden layer can be considered as a time delay operator capable of remembering recent events. It is a time-varying predictive control system that has faster convergence and more accurate mapping capability.

We should also mention artificial neural networks such as wavelet neural network and radial basis function neural network M. Tripathy, 2010; L. Huang and J. Wang, 2018). Advanced artificial intelligence techniques such as expert systems (M. Bildirici, E. A. Alp, and Ö. Ö. Ersin, 2010; R. Dash, S. Samal, R. Dash, and R. Rautray, 2019) support vector machines (SVM)) (K. J. Kim, 2003; X. Y. Qian and S. Gao, 2018) and hybrid methods (G. Armano, M. Marchesi, and A. Murru, 2005; J. Patel, S. Shah, P. Thakkar, and K. Kotecha, 2015) are also applied in stock price forecasting. Some new models used random jump function or rms random time function with different neural networks (J. Wang, H. Pan, and F. Liu, 2012; J. Wang and J. Wang, 2016) proposed in financial market forecasting. .

Benioff and Feynman proposed the concept of quantum computing. Quantum Algorithms P. W. Shor and L.K. Grover has gained a lot of traction. The idea of QNN can influence quantum computing in the field of artificial intelligence. Prototypes for QNN are similar to classical neural networks first presented the concept of QNN. Gupta and Gia showed that QNN has almost the same computing power as CNN. Menneer and Narayan laid the foundations of basic concepts inspired by quantum theory for use in the design, development and implementation of neural networks.

The debate about quantum neural networks traces its origins to arguments for the role that quantum processes play in the living brain. So Roger Penrose claimed that the new physical binding of quantum phenomena to the general theory of relativity can explain mental abilities such as understanding, awareness and consciousness. However, this approach advocates the study of intracellular structures, such as microtubules, rather than that of neuronal networks themselves, and on the motivation that the field of classical artificial neural networks can be generalized in the quantum domain by an eclectic combination of that field with the promising new field of quantum computing. Both considerations suggest a new understanding of the mind and brain function as well as an unprecedented new ability to process information. Thus, quantum neural networks can be defined as the next step in the evolution of neurocomputing systems, focusing our attention on artificial rather than biological systems.

So, the stock market is a dynamic system composed of tangled relationships between financial entities, banks, corporations and institutions. A complex interactive system can be represented by a network structure. The underlying mechanism of the stock market establishes a time-evolving network between firms and individuals, which characterizes stock price correlations in time-sequential trades. Thus, the Laplacian matrix plays the role of the Hamiltonian network operator. The eigenvalues of the Hamiltonian specify the energy states of the lattice. These states are occupied by either indistinguishable bosons or fermions with appropriate Bose-Einstein and Fermi-Dirac statistics. Using the relevant partition functions, we evolve the thermodynamic entropy to explore the characteristics of the dynamical network. We conduct experiments to apply this new method to identify significant variations in network structure during financial crises. Thermodynamic entropy provides an excellent framework for representing the variations that occur in the stock market.

5. Quantum Brain and Quantum Computing with Money and Financial Decision-Making

The brain is a complex system (Bassett & Gazzaniga, 2011). The central components, neurons, are themselves complex dynamical systems with a wide range of internal time scales (Sejnowski, 2020, p. 30036). The complexity of the brain is manifested through non-local interactions in which dynamic activity in one place affects distant places without affecting intermediates (Nunez et al., 2015, p. 7). Each layer of the brain scale has its own spatial and temporal processes and dynamics (Breakspear, 2017, p. 340). The brain operates in a manner of dynamic coordination and on-the-fly synaptic rewiring across twelve orders of magnitude at nine levels of organization ranging from the central nervous system (10^{0} m) to tiny ion channels (10-12 m) (Sterratt et al., (2011).Sejnowski (2020, p. 30037) makes a similar statement.

With a quote for quantum computing "Living things are made of atoms according to the laws of physics, and the laws of physics present no barrier to reducing the size of computers until bits are the size of atoms and quantum behavior holds sway" Feynman et al. (2005) and Feynman (1985), namely, quantum computing is defined as the use of engineered quantum systems to perform calculations, precise manipulation of quantum objects (atoms, ions and photons) using external electromagnetic fields (Acin et al., 2018). Quantum computing incorporates the principles of quantum physics as an approach to understanding quantum mechanical phenomena. Quantum mechanics describes the behavior of quantum objects that differs from the macroscale classical domain through the properties of superposition, entanglement, and interference. Quantum communication involves the transfer of information about a quantum state between locations and quantum information science is a field that provides an information-theoretic interpretation of quantum physics in the implementation of quantum computing and quantum communication networks.

One of the first applications of quantum computing is quantum finance. Standardized quantum approaches and circuits are rapidly spreading to other fields such as neuroscience. Participants in the financial markets are early adopters of new technologies (J.P. Morgan, Goldman Sachs, Banco Santander, and other global financial institutions). Quantum finance applies theories and methods from quantum mechanics and economics to problems in finance, namely option pricing, trading strategies, risk management, and portfolio optimization. Markets are complex nonlinear dynamic systems that do not have formal solutions, and thus quantum mechanical methods such as wave function modeling have been a mainstay in computational finance (Haven, 2002). It may be possible to more effectively model market behavior with quantum platforms that include wave functions and path integrals (Baaquie, 2004; Orus et al., 2019).

Quantum neuroscience has the potential to bring the modeling of the human brain's 86 billion neurons and 242 trillion synapses within reach, even with existing quantum systems (a 53-qubit system has nine quadrillion states (253)). Available quantum cloud computing services could expand their offering to include brain study tools such as quantum machine learning, high-dimensional photonic entanglement and spiky neural networks. Advances in the fundamentals of physics and information theory point to the development of standardized neural circuits and quantum neuroscientific applications in wave function modeling, quantum biology and neuroscience, physics.

"If entanglement is the only possible explanation here then that would mean that brain processes must have interacted with the nuclear spins, mediating the entanglement between the nuclear spins. As a result, we can deduce that those brain functions must be quantum..” (C. Kerskens, 2022).

So, to clarify the quote above, using MRI designed to look for entangled spins, a scientific team (C. Kerskens, 2022) found MRI signals that resemble the shape of EEG signals, which measure electrical currents in the brain. These signals are usually undetectable by MRI, so scientists believe they were only able to observe them because the nuclear proton spins in the brain were entangled.

What is it that causes most conflict at every level of social interaction, from the family, to the village, up to the management of the city, the state or international organizations? It is the control of money.

Modern stock pricing approaches in quantitative finance are based on the Black-Scholes model (Black-Scholes is a pricing model used to determine the fair price or theoretical value for a call or a put option based on six variables such as volatility, type of option, underlying stock price, time, strike price, and risk-free rate. The quantum of speculation is more in case of stock market derivatives, and hence proper pricing of options eliminates the opportunity for any arbitrage. There are two important models for option pricing – Binomial Model and Black-Scholes Model. The model is used to determine the price of a European call option, which simply means that the option can only be exercised on the expiration date) and the underlying random walk hypothesis, but this works well in stable situations, but in sudden transitions, such as during an economic crisis, radical uncertainties make the random walk model fail and need are alternative descriptions. „So, The Black–Scholes model is a mathematical model simulating the dynamics of a financial market containing derivative financial instruments such as options, futures, forwards and swaps. The key property of the model is that it shows that an option has a unique price regardless of the risk of the underlying security and its expected return. The model is based on a partial differential equation (PDE), the so-called Black-Scholes equation, from which one can deduce the Black-Scholes formula, which gives a theoretical estimate of the correct price of European stock options.“ For this reason, several proposals based on the formalism of quantum mechanics have recently been forwarded. The stock market is an intrinsically contextual system in which decisions globally affect the market system and stock prices, determining non-classical behavior. Thus, a particular stock generally does not have a specific value, eg price, but its value is actualized as a consequence of contextual interactions in the trading process. This contextual influence is responsible for the non-Kolmogorov quantum behavior of the market at the statistical level, which leads to the use of quantum models in finance.

Like a quantum particle, the meaning of financial decision-making cannot be reduced to a single definition, but exists in a superposition of states whose measurement depends on the context.

The works of J. Busmeyer (2006) and Haven and Khrenikov (2013) on quantum decision-making and quantum social science point to the use of quantum calculus as a tool for probability modeling, and do not claim to build a theoretical model that would encompass other, fundamental aspects of decision-making.

The physical basis of decision-making lies in the debates about the existence of free will in philosophy, mainly for the defense of determinism (such as within the framework of the 'clock mechanism' of Newtonian physics), but also for the defense of libertarianism as in the works of Kane (1985). New proposals for linking physics and decision-making appear in Mousavi and Sunder using classical physics, as well as in Schade (2018) based on a multiversal interpretation of quantum mechanics.

The quantum revolution begins with the discovery of when, at the subatomic level, energy is exchanged in terms of discrete particles, quanta (Latin for "how much"). In economics, they are the equivalent of financial transactions, as well as "quanto costa" purchases, which makes the quantum connection somewhat clearer. Money behaves in a way as an object, but not as a classical one. It exhibits significant properties of quantum systems such as discreteness, indeterminacy, entanglement, duality, interference, and so on.

We might notice that such assets are the way money jumps. In physics, Erwin Schrodinger said, "If we have to go on with these damned quantum leaps, then I'm sorry I ever got involved," but with financial transactions, of course, the same thing happens all the time. A good example is when we touch the card in the store, the money does not flow out continuously, it just jumps.

In physics, the position of a particle is fundamentally indeterminate and somehow constructed by the measurement process. It's the same thing at markets. If you list your house for sale, you will have a vague idea of the price, but the actual cash value is only determined at the time of sale.

The dual real/virtual properties are reflected in two historical theories of money, namely bullionism – money is gold and nothing else as JP Morgan said – and chartalism, which is the idea that credit itself is money as Alfred Mitchell-Innes said next year. But then comes Bitcoin and on the one hand it seems to be completely virtual, but on the other hand it is also real as you will notice if you accidentally lose the hard drive where your bitcoins are located.

Let us translate the duality of money which is similar to the duality of light. The wave-particle complementarity is reflected in theories of light that go back millennia - Aristotle thought light was a wave, Newton thought it was particles, and it bounced back and forth until finally quantum theory came along and showed that it has properties of both at the same time. It's the same with money.

We treat preferences like fixed and known objects, adapted to some cognitive biases, but often our preferences are composed in response to questions that act as a kind of measuring event. Thoughts and ideas behave like objects in a way, but they are not classical objects. In physics, Bohr's wave-particle complementarity theory was inspired by the psychologist's observation that we can hold opposite ideas in the mind at the same time in superposition, and in fact it is these interference terms that play a very important role in quantum cognition as we shall see.

In physics, particles can be intertwined so that they act as a single system. A much more direct form of entanglement exists in the financial system where financial assets and virtual liabilities have these quantum entanglement characteristics.

Let's end rational financial decision-making with the thoughts of S. Žižek "a fact that is rarely noticed is that quantum physics seems to defy our common-sense view of material reality, but it seems to be somewhat better applied to human reality where the human spirit meets itself outside itself".

6. Conclusion

Quantum information, financial decisions, stock market, radical uncertainty (interdisciplinary field) directs us to R. Feynman "How to think like a genius", ""You have to keep a dozen of your favorite problems constantly present in your mind, although by and large they will lay in a dormant state. Every time you hear or read a new trick or a new result, test it against each of your 12 problems to see whether it helps. Every once in a while there will be a hit, and people will say: 'How did he do it? He must be a genius!'"

A computer stores information, sends and receives information, and processes it. In a classical computer, information travels as a series of bits—a pattern of 1s and 0s. As each bit arrives, the receiver does not know what value it will have; from their point of view, it is just as likely to be 0 as it is to be 1. Classical information is discrete, a bit is always either 0 or 1, and nothing in between. Bits are deterministic. To the extent that there is uncertainty in a bit, that uncertainty exists in the mind of someone who has not yet received the message (or in the possibility that an error could change the value of the bit). Classical information is a local bit can suggest what's coming, but observing that bit doesn't actually affect the other bits. The rules of classical information are intuitive and easy to take for granted. Quantum information is not discrete. A classical bit is definitely 0 or 1, but a quantum bit, a qubit, can be a bit of both. This feature allows the qubit to carry different types of information, continuous information about the relative balance of 0 and 1 within the qubit. Quantum algorithms can sometimes take advantage of this fact to work more efficiently than their classical counterparts. Quantum information is not deterministic. When we look at the classical bit, it is simply 0 or 1, as it was before and will be after, barring the possibility of error. Not so with qubits, which are affected by the measurement. Although a qubit can be any mixture of 0 and 1, measuring it - as one would have to do to read the result of a calculation - forces it to be either 0 or 1. So it takes a lot more than 10 classical bits to simulate 10 quantum bits, suggesting that one could do much more with 10 quantum bits than with 10 classical bits. However, there isn't simply more information in a quantum bit - quantum superposition, measurement and entanglement mean that the way we process and interact with quantum information is fundamentally different. Consequently, this would mean that quantum computers could be better than classical ones even when it comes to solving some deterministic problems. A classic example is factoring or finding prime numbers that multiply to form another number. Although there is only one way to factor any number, factoring large numbers is a very difficult problem on classical computers. On a quantum computer, this is relatively easy.

These differences do not mean for now that quantum computers are better than classical computers in everything, however, quantum information opens up new possibilities, and the future is still unwritten. With quantum computing, we are radically changing the way we use nature to compute.

“The reason why building large-scale quantum computers is building hard is because eventually, you have errors. One way to reduce these errors is to make your qubits better and better. Still, another more systematic and ultimately practical way is to do something called quantum error correction. Even if you have some errors, you can correct these errors during your computation process with redundancy.” (M. Lukin, 2022).

Quantum information systems derive their power from the controlled interactions that generate quantum entanglement. Building scalable quantum information systems requires programmable operations between desired qubits within a quantum processor. In the most advanced approaches, qubits interact locally, constrained by the coupling associated with their fixed spatial arrangement.

Briefly: Quantum information theory combines ideas from classical information theory, quantum mechanics and computer science. Theorems and techniques of various branches of mathematics and mathematical physics, especially group theory, probability theory and quantum statistical physics find application in a fascinating and rapidly growing field.

Classical information theory is the mathematical theory of information processing tasks such as storing and transmitting information, while quantum information theory is the study of how such tasks can be performed using quantum mechanical systems. It deals with how the quantum-mechanical properties of physical systems can be used to achieve efficient storage and transmission of information. Fundamental quantum mechanics leads to important differences between quantum and classical information theory.

In quantum information processing systems, information is stored in the quantum states of the physical system. Quantum mechanics is based on certain postulates. However, these postulates are valid only for closed (or isolated) quantum systems. In the real world, there are no perfectly isolated systems. Real systems suffer from unwanted interactions with the outside world and are open. In quantum information processing systems, these interactions manifest as noise that damages the information encoded by the system. This leads to errors. This noise process is known as decoherence. Such noise processes need to be understood and controlled in order to build efficient quantum information processing systems. It is important to research the behavior of open systems.

In the world order, there is a tendency towards multipolarity, which may imply realignment into regionally and ideologically aligned groups. This raises the questions of how this multipolarity could look like in practice, will the economy remain global in nature and will we find new effective mechanisms for cooperation outside the economy? Years of relative moderation in international politics are giving way to increasing political polarization among blocs. How effectively will global and local institutions and leadership adapt to and shape this different world order?

Across all technology platforms, the key drivers of digitization and the latest age of connectivity are approaching saturation. However, a number of powerful transversal technologies, particularly artificial intelligence (AI) and bioengineering, may combine to create another great wave of progress in the next era. At the same time, technology could move to the forefront of geopolitical competition and call into question the very meaning of being human. What impact will the next wave of technology have on work and social order? How will technology, institutions and geopolitics interact?

Global finance is a perfect example of a complex system, which consists of an interconnected system of subsystems with breaking points, emergence, asymmetries, unwanted consequences, the structure of "parts within parts" (Herberta Simona, 2001), and all other features defining complexity. It is shaped by numerous internal and external trends and shocks, which it also influences and generates. And since the system (in most parts) also reacts to predictions about it, it can be called a "second-level" chaotic system (Yuval Harari, 2020).

"Capitalism produces profit – and loss – through unexpected changes. You can have knowledge and be skilled and roughly right, (Mangee, 2020) but you cannot know exactly what it looks like ex ante. When we look at the slide in the stock market that is currently underway, we can think of each moment in time as a junction of intersecting narrative highways about non-routine events. So you have a 10% stock market correction. What does that mean? The novelty-narrative hypothesis says that we must take seriously that non-perfect events happen every day replicas of the past. We're still learning about what omicron did and didn't do to the economy. The past doesn't predict the future in a mechanical way."

Interdisciplinary knowledge, technology, research, information are the basis of the coming (early phase of the seismic order) time, through quantum entanglement. This is a world of uncertain futures and unpredictable consequences, about which there is necessary speculation and inevitable disagreement, disagreement that will often never be resolved, and this is the world we mostly encounter.

References

A. Ataullah, I. D., & M. Tippett, (2009). A wave function for stock market returns. *Physica A, 388,* 455-461. https://doi.org/10.1016/j.physa.2008.10.035

A. Dosovitskiy et al., (2010). *An image is worth 16x16 words: Transformers for image recognition at scale.* arXiv:2010.11929.

A. Yu. Kitaev, A. H. Shen, & M. N. Vyalyi. (2002). *Classical and Quantum Computation. American Mathematical Society, USA.* https://doi.org/10.1090/gsm/047

Acin, A., Bloch, I., & Buhrman, H. et al. (2018). The quantum technologies roadmap: A European community view. *New. J. Phys., 20*(8), 080201. https://doi.org/10.1088/1367-2630/aad1ea

Alexandre, M., Ivan, O., Mark, P., & Daniel, V. (2020). *A game plan for quantum computing, 2020.*

Anscombe, F., & Aumann, R (1963). A definition of subjective probability. *Annals of Mathematical Statistics, 34,* 199-205. https://doi.org/10.1214/aoms/1177704255

Artin, E. (1947). Theory of Braids. *Ann. of Math, 2*(48), 101-126. https://doi.org/10.2307/1969218

Athalye, V. et al. (2011) Investigation of the Leggett-Garg Inequality for Precessing Nuclear Spins. *Physical Review Letters, 107,* 130402. https://doi.org/10.1103/PhysRevLett.107.130402

Athalye, V., & Kumar, A. (2006). Decoherence of superposition of molecular chiral states due to Rayleigh scattering. *Journal of Physics B: Atomic, Molecular and Optical Physics, 39,* 2633. https://doi.org/10.1088/0953-4075/39/12/002

Baaquie, B. (2013). Statistical microeconomics. *Journal of Physics A, 392,* 4400-4416.

https://doi.org/10.1016/j.physa.2013.05.008

Baaquie, B. (2018). *Quantum Field Theory for Economics and Finance.* Cambridge University Press: Cambridge, UK. https://doi.org/10.1017/9781108399685

Bachelier, L. (1900) Th éorie de la sp éculation. In Annales Scientifiques de l'Ecole Normale Supérieure; Société Math ématique de France: Paris. *France. 17,* 21-86. https://doi.org/10.24033/asens.476

Bassett, D. S., & Gazzaniga, M. S. (2011). Understanding complexity in the human brain. *Trends Cogn. Sci., 15,* 200-9. https://doi.org/10.1016/j.tics.2011.03.006

Beck, M. (2012). *Quantum Mechanics: Theory and Experiment.* Oxford University Press: New York, NY, USA.

Bohm, D., & Hiley, B. (1993). *The Undivided Universe: An Ontological Interpretation of Quantum Theory.* Routledge: New York, NY, USA. https://doi.org/10.1063/1.2808635

Bonesteel, N. E., Hormozi, L., Zikos, G., & Simon S. H. (2005). Braid Topologies for Quantum Computation. *Phys. Rev. Lett, 95,* 140503. (arXiv:quant-ph/0505065). https://doi.org/10.1103/PhysRevLett.95.140503

Bravyi, S. (2006). *Universal Quantum Computation with the ν = 5/2 Fractional Quantum Hall State, Phys. Rev. A 73, 042313.* (arXiv:quant-ph/0511178). https://doi.org/10.1103/PhysRevA.73.042313

Breakspear, M. (2017). Dynamic models of large-scale brain activity. *Nat. Neurosci., 20,* 340-52. https://doi.org/10.1038/nn.4497

Brock, W., Lebaron, B., & Lakonishok, J. (1992). Simple technical rules and stochastic properties ofstock returns. *Journal of Finance, 47,* 1731-1764. https://doi.org/10.1111/j.1540-6261.1992.tb04681.x

Brooks, M. (Ed.) (1999). *Quantum computing and communications.* Springer-Verlag, Berlin7Heidelberg. https://doi.org/10.1007/978-1-4471-0839-9

Busemeyer, J. R. et al. (2006) Quantum dynamics of human decision-making. *Journal of Mathematical Psychology, 50,* 220. https://doi.org/10.1016/j.jmp.2006.01.003

Busemeyer, J., & Bruza, P. (2012). *Quantum Models of Cognition and Decision.* Cambridge University Press: Cambridge, UK. https://doi.org/10.1017/CBO9780511997716

C. Ye & J. P. Huang, (2008). Non-classical oscillator model for persistent fluctuations in stock markets. *Physica A, 387,* 1255-1263. https://doi.org/10.1016/j.physa.2007.10.050

C. Zhang & L. Huang, (2010). A quantum model for the stock market. *Physica A, 389*(2010), 5769-5775. https://doi.org/10.1016/j.physa.2010.09.008

Chateauneuf, A. (1994). Modelling attitudes towards uncertainty and risk through the use of Choquet integral. *Annals of Operations Research, 52,* 3-20. https://doi.org/10.1007/BF02032158

Chateauneuf, A., & Jaffray, J. Y. (1989). Some characterizations of lower probabilities and other monotone capacities through the use of Mobius inversion. *Mathematical Social Sciences, 17,* 263-283. https://doi.org/10.1016/0165-4896(89)90056-5

Chichilnisky, G. (2008). *Markets, Information and Uncertainty: Essays in Economic Theory in Honour of Kenneth J. Arrow.* Cambridge University Press: Cambridge, UK.

Chichilnisky, G. (2015). *A Topological Characterization of the Space of Events and Frameworks of Rn,* Working Paper. Stanford University: Stanford, CA, USA.

Choquet, G (1955). Theory of capacities. *Annales de l'Institut Fourier, 5,* 131-295. https://doi.org/10.5802/aif.53

D. Meyer, (1999). Quantum strategies. *Phys. Rev. Lett., 82,* 1052-1055. https://doi.org/10.1103/PhysRevLett.82.1052

D. Silver et al., (2016). Mastering the game of Go with deep neural networks and tree search. *Nature, 529,* 484. https://doi.org/10.1038/nature16961

D. Silver et al., (2017). Mastering the game of Go without human knowledge. *Nature, 550,* 354. https://doi.org/10.1038/nature24270

D. Svozil, V. K., & J. Pospichal, (1997). Introduction to multi-layer feed-forward neural networks, Chemom. *Intell. Lab. Syst., 39,* 43. https://doi.org/10.1016/S0169-7439(97)00061-0

Debreu, G. (1959). *Theory of Value. Yale University Press: New Haven, CT, USA.* Press: Cambridge, UK.

Deutsch, D. (1985). *Quantum theory, the Church-Turing principle and the universal quantum computer.* Proceedings of the Royal Society of London, A400, pp.97-117. https://doi.org/10.1098/rspa.1985.0070

Dürr, D., & Lazarovici, D. (2020). *Understanding Quantum Mechanics: The World According to Modern Quantum Foundations.* Springer: Cham, Switzerland. https://doi.org/10.1007/978-3-030-40068-2

Everett, H. (1957). Relative state" formulation of quantum mechanics. *Review of modern physics, 29,* 454-462. https://doi.org/10.1103/RevModPhys.29.454

F. Bagarello, (2006). An operatorial approach to stock markets. *J. Phys. A, 39*(2006), 6823-6840. https://doi.org/10.1088/0305-4470/39/22/001

F. Bagarello, (2007). Stock markets and quantum dynamics: a second quantized description. *Physica A, 386,* 283-302. https://doi.org/10.1016/j.physa.2007.08.031

F. Bagarello, (2007). The Heisenberg picture in the analysis of stock markets and in other sociological contexts. *Qual. Quant., 41,* 533-544. https://doi.org/10.1007/s11135-007-9076-4

F. Bagarello, (2009). A quantum statistical approach to simplified stock markets. *Physica A, 388,* 4397-4406. https://doi.org/10.1016/j.physa.2009.07.006

F. Bagarello, (2009). Simplified stock markets described by number operators. *Rep. Math. Phys. 63*, 381-398. https://doi.org/10.1016/S0034-4877(09)90010-6

F. Beritelli, G. Capizzi, G. Lo Sciuto, C. Napoli, & M. Woźniak, (2018). A novel training method to preserve generalization of RBPNN classifiers applied to ECG signals diagnosis. *Neural Networks, 108,* 331-338. https://doi.org/10.1016/j.neunet.2018.08.023

Fama, E. (1965). The Behavior of Stock Market Prices. *J. Business 38*, 34-105. https://doi.org/10.1086/294743

Feynman, R. (1986). Quantum mechanical computers. *Foundations of Physics, 16,* 507-531. https://doi.org/10.1007/BF01886518

Feynman, R. et al. (2010). *The Feynman Lectures on Physics: Volume III.* Basic Books: New York, NY, USA.

Fisher, M. P. A. (2015). Quantum cognition: The possibility of processing with nuclear spins in the brain. *Ann. Phys.*, *362*, 593. https://doi.org/10.1016/j.aop.2015.08.020

G. Armano, M. Marchesi, & A. Murru, (2005). A hybrid genetic-neural architecture for stock indexes forecasting. *Information Sciences, 170*(1), 3-33. https://doi.org/10.1016/j.ins.2003.03.023

G. Bebis, & M. Georgiopoulos, (1994). Feed-forward neural networks. *IEEE Potentials, 13,* 27. https://doi.org/10.1109/45.329294

G. E. Hinton, A. Krizhevsky & S. D. Wang, (2011). *Transforming auto-encoders.* Springer, Berlin, Heidelberg, ISBN 9783642217340. https://doi.org/10.1007/978-3-642-21735-7_6

Georgescu-Roegen, N. (1966). *Analytical Economics: Issues and Problems.* Harvard University Press: Cambridge, MA, USA. https://doi.org/10.4159/harvard.9780674281639

Gomes, C. (2010). *Maximus investment fund, Tech. report.* GoBusiness, (2010)

Hameroff, S., & Rasmussen, S. (1990) Microtubule Automata: Sub-Neural information Processing in Biological Neural Networks. In: Theoretical Aspects of Neurocomputing, M. Novak and E. Pelikan (Eds.), *World Scientific,* Singapore, pp.3-12.

Haven, E. E. (2002). A discussion on embedding the Black-Scholes option pricing model in a quantum physics setting. *Phys. A: Stat. Mech. Appl., 304*(3-4), 507-24. https://doi.org/10.1016/S0378-4371(01)00568-4

Haven, E., & Khrennikov, A. (2013). *Quantum social science.* Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9781139003261

Hawkins, R. J., & Frieden, B. R. (2017). Quantization in financial economics: An information theoretic approach. In Haven, E & Khrennikov, A (Eds.), *The Palgrave Handbook of Quantum Models in Social Science;* Springer: Berlin, Germany. https://doi.org/10.1057/978-1-137-49276-0_2

Holland, P. (1993). *The Quantum Theory of Motion.* Cambridge University Press: Cambridge, UK. https://doi.org/10.1017/CBO9780511622687

I. Goodfellow, Y. Bengio & A. Courville, (2016). *Deep learning.* MIT Press, Cambridge, US, ISBN 9780262337373

J. Biamonte, P. Wittek, N. Pancotti, P. Rebentrost, N. W., & S. Lloyd, (2017). Quantum machine learning. *Nature, 549,* 195. https://doi.org/10.1038/nature23474

J. Devlin, M. W., Chang, K. L., & K. Toutanova, (2018). BERT: Pre-training of deep bidirectional transformers for language understanding, arXiv:1810.04805.

J. Eisert, M. W., & M. Lewenstein, (1999). Quantum games and quantum strategies. *Phys. Rev. Lett. 83,* 3077-3080. https://doi.org/10.1103/PhysRevLett.83.3077

J. L. Elman, (1990). Finding structure in time. *Cognitive Science, 14*(2), 179-211. https://doi.org/10.1207/s15516709cog1402_1

J. L. Ticknor, (2013). A bayesian regularized artificial neural network for stock market forecasting. *Expert. Syst. with Appl., 40*(14), 5501-5506. https://doi.org/10.1016/j.eswa.2013.04.013

J. Patel, S., Shah, P. T., & K. Kotecha, (2015). Predicting stock market index using fusion of machine learning techniques. *Expert Systems with Applications, 42*(4), 2162-2172. https://doi.org/10.1016/j.eswa.2014.10.031

J. Wang & J. Wang, (2016). Forecasting energy market indices with recurrent neural networks: case study of crude oil price fluctuations. *Energy, 102*(1), 365-374. https://doi.org/10.1016/j.energy.2016.02.098

J. Wang, H. Pan, & F. Liu, (2012). Forecasting crude oil price and stock price by jump stochastic time effective neural network model. *Journal of Applied Mathematics, 2012, 15.* https://doi.org/10.1155/2012/646475

J. Z. Wang, J. J. Wang, Z. G. Zhang, & S. P. Guo, (2011). Forecasting stock indices with back propagation neural network. *Expert. Syst. with Appl. 38,* 14346-14355. https://doi.org/10.1016/j.eswa.2011.04.222

K. J. Kim, (2003). Financial time series forecasting using support vector machines. Neurocomputing, 55(1-2), 307-319. https://doi.org/10.1016/S0925-2312(03)00372-2

K. Oh & K. J. Kim, (2022). Analyzing stock market tick data using piecewise nonlinear model. *Expert Systems with Applications, 22*(3), 249-255. https://doi.org/10.1016/S0957-4174(01)00058-6

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica, 2,* 263-292. https://doi.org/10.2307/1914185

Khrennikov, A. (2010). *Ubiquitous Quantum Structure: From Psychology to Finance.* Springer: Berlin, Germany. https://doi.org/10.1007/978-3-642-05101-2

Killoran, N., Bromley, T. R., Arrazola, J. M., Schuld, M., Quesada, N., & Lloyd, S. (2019). Continuous-variable quantum neural networks. *Phys Rev Res, 1*(3), 033,063. https://doi.org/10.1103/PhysRevResearch.1.033063

Klibanoff, P. et al. (2005). A smooth model of decision-making under ambiguity. *Econometrica, 73,* 1849-1892. https://doi.org/10.1111/j.1468-0262.2005.00640.x

L. Huang & J. Wang, (2018). Global crude oil price prediction and synchronization based accuracy evaluation using random wavelet neural network. *Energy, 151*(15), 875-888. https://doi.org/10.1016/j.energy.2018.03.099

L. Tiberi et al., (2022). Gell-Mann–Low criticality in neural networks, Phys. Rev. Lett. 128, 168301 (2022). „ Gell-Mann–Low criticality in neural networks. *Phys. Rev. Lett. 128,* 168301. https://doi.org/10.1103/PhysRevLett.128.168301

La Mura, P. (2009). Projective Expected Utility. *Journal of Mathematical Psychology, 53,* 408-414. https://doi.org/10.1016/j.jmp.2009.02.001

Li, Y., & Zhang, J. E. (2014). Option pricing with Well-Titchmarsh theory. *Quantitative Finance, 4,* 457-464. https://doi.org/10.1080/14697680400008643

M. Bildirici, E. A. Alp, & Ö. Ö. Ersin, (2010). TAR-cointegration neural network model: an empirical analysis of exchange rates and stock returns. *Expert Systems with Applications, 37*(1), 2-11. https://doi.org/10.1016/j.eswa.2009.07.077

M. Schaden, (2002). Quantum finance. *Physica A, 316,* 511-538. https://doi.org/10.1016/S0378-4371(02)01200-1

M.-H. Guo et al., (2022). Attention mechanisms in computer vision: A survey. *Comp. Visual Media, 8,* 331. https://doi.org/10.1007/s41095-022-0271-y

Mantegna, R., & Stanley, E. (1999). *Introduction to Econophysics: Correlations and Complexity in Finance.* Cambridge University. https://doi.org/10.1017/CBO9780511755767

Michael, A. N., & Isaac L. C. (2010). *Quantum Computation and Quantum Information.* Cambridge University Press.

Michael, A. N., & Isaac L. C. (2020). *Quantum Computation and Quantum Information.* Cambridge University Press.

Modinos, A. (2014). *From Aristotle To Schrödinger: The Curiosity of Physics.* Springer: Cham, Switzerland. https://doi.org/10.1007/978-3-319-00750-2

Nayak C., Simon S. H., Stern A., Freedman M., & Das Sarma, S. (2008). Non-Abelian Anyons and Topological Quantum

Computation, Rev. Mod. *Phys., 80,* 1083, arXiv:0707.1889. https://doi.org/10.1103/RevModPhys.80.1083

Nielsen M., & Chuang I. (2000). *Quantum Computation and Quantum Information.* Cambridge University Press, 2000

Nunez, P. L. (1974). The brain wave equation: A model for the EEG. *Math. Biosci., 21,* 279-9-97. https://doi.org/10.1016/0025-5564(74)90020-0

Nunez, P. L., Srinivasan, R., & Fields, R. D. (2015). EEG functional connectivity, axon delays and white matter disease. *Clin. Neurophysiol., 126*(1), 110-20. https://doi.org/10.1016/j.clinph.2014.04.003

Oswald, V., & John, W. Y. (1918). *Projective geometry, 2.* Ginn, 1918.

Penrose, R. (1994). *Shadows of the Mind. A search for the missing science of consciousness.* Oxford University Press, New York, Oxford.

Preskill, J., Topological quantum computation, Lecture notes for Caltech course # 219 in Physics, http://www.theory.caltech.edupreskill/ph229/#lecture

R. Dash, S. Samal, R. Dash, & R. Rautray, (2019). An integrated topsis crow search based classifier ensemble: in application to stock index price movement prediction. *Applied Soft Computing, 85,* 1-14. https://doi.org/10.1016/j.asoc.2019.105784

Racorean O. (2014). *Crossing of Stocks and the Positive Grassmannian I : The Geometry behind Stock Market.* https://doi.org/10.2139/ssrn.2512437

Racorean O. (2014). *Decoding Stock Market Behavior with the Topological Quantum Computer.* https://doi.org/10.2139/ssrn.2514779

Racorean, O. (2014). *Braided and Knotted Stocks in the Stock Market: Anticipating the flash crashes.* https://doi.org/10.2139/ssrn.2524847

Ramamurti, S. (1994). *Principles of quantum mechanics*. Springer Science & Business Media, 1994.

Reginatto, M. (1998). Derivation of the equations of non relativistic quantum mechanics using the principle of minimum Fisher information. *Physical Review A, 58,* 1775-1778. https://doi.org/10.1103/PhysRevA.58.1775

Russell, S., & Norvig, P. (2020). *Artificial Intelligence: A Modern Approach* (4th ed.). Pearson Series in Artificial Intelligence; Pearson Education: Hoboken, NJ, USA, 2020.

S. Das Sarma, D. L. Deng & L.-M. Duan, (2019). Machine learning meets quantum physics. *Phys. Today, 72,* 48. https://doi.org/10.1063/PT.3.4164

S. Lawrence, C. Giles, A. C. Tsoi & A. Back, (1997). Face recognition: A convolutional neuralnetwork approach. *IEEE Trans. Neural Netw., 8,* 98. https://doi.org/10.1109/72.554195

Savage, L. (1954). *The Foundations of Statistics.* J. Wiley: New York, NY, USA.

Schade, C. D. (2018). *Free will and consciousness in the multiverse: physics, philosophy and quantum decision making.* Springer, Berlin. https://doi.org/10.1007/978-3-030-03583-9

Schlosshauer, M. (2007). *Decoherence and the Quantum to Classical Transition.* Springer: Berlin, Germany.

Schrödinger, E. (1935). Die gegenwärtige Situation in der Quantenmechanik. *Naturwissenschaften, 23,* 823. https://doi.org/10.1007/BF01491987

Sejnowski, T. J. (2020). The unreasonable effectiveness of deep learning in artificial intelligence. *Proc. Natl. Acad. Sci., 117*(48), 30033-8. https://doi.org/10.1073/pnas.1907373117

Sheikh, A. Z., & Quiao, H. (2009). Non-normality of market returns. *The Journal of Alternative Invest-ments, 12*(3). https://doi.org/10.3905/JAI.2010.12.3.008

Steinbrecher, G. R., Olson, J. P., Englund, D., & Carolan, J. (2019). Quantum optical neural networks. *npj Quantum Inf 5*(1), 1-9. https://doi.org/10.1038/s41534-019-0174-7

Sterratt, D., Graham, B., Gillies, A., & Willshaw, D. (2011). *Principles of Computational Modelling in Neuroscience.* Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511975899

T. J. Hsieh, H. F. Hsiao, & W. C. Yeh, (2011). Forecasting stock markets using wavelet transforms and recurrent neural networks: An integrated system based on artificial bee colony algorithm. *Appl. Soft Comput., 11*(2), 2510-2525. https://doi.org/10.1016/j.asoc.2010.09.007

T. Mikolov, S. Kombrink, L. Burget, J. C., & S. Khudanpur, (2011). Extensions of recurrent neural network language model. *IEEE ICASSP, 5528.* https://doi.org/10.1109/ICASSP.2011.5947611

T. Young, D. Hazarika, S. Poria & E. Cambria, (2018). Recent trends in deep learning based natural language processing [Review Article]. *IEEE Comput. Intell. Mag. 13,* 55. https://doi.org/10.1109/MCI.2018.2840738

V. Dunjko, & H. J. Briegel, (2018). Machine learning & artificial intelligence in the quantum domain: A review of recent progress. *Rep. Prog. Phys. 81,* 074001. https://doi.org/10.1088/1361-6633/aab406

Vaidman, L. (2019). Quantum Nonlocality. *Entropy, 21,* 447. https://doi.org/10.3390/e21050447

von Neumann, J., & Morgenstern, O. (2007). *Theory of Games and Economic Behavior.* Princeton University Press: Princeton, NJ, USA. https://doi.org/10.1515/9781400829460

W. Zaremba, I. Sutskever & O. Vinyals, (2014). *Recurrent neural network regularization.* 2014, arXiv1409.2329.

Weigend, A. S., & Gershenfeld, N. A. (1994). *Time series Prediction: Forecasting the Future and Understanding the Past.* Reading, MA: Addison Wesley.

Wigner, E. P. (Ed.) (1967). Remarks on the mind-body question. In *Symmetries and Reflections,* Indiana University Press: Bloomington, IN, USA, 171-184.

Y. A. Zhang, B. Yan, & M. Aasma, (2020). A novel deep learning framework: Prediction and analysis of financial time series using CEEMD and LSTM. *Expert. Syst. with Appl. 159*, 113609. https://doi.org/10.1016/j.eswa.2020.113609

Y. LeCun, Y. Bengio & G. Hinton, (2015). Deep learning. *Nature, 521,* 436. https://doi.org/10.1038/nature14539

Y. Wang, (2003). Mining stock price using fuzzy rough set system. *Expert Systems with Applications, 24*(1), 13-23. https://doi.org/10.1016/S0957-4174(02)00079-9

Y. Wang, L. Wang, F. Yang, W. Di, & Q. Chang, (2021). Advantages of direct input-to-output connections in neural networks: the Elman network for stock index forecasting. *Information Sciences, 547*(8), 1066-1079. https://doi.org/10.1016/j.ins.2020.09.031

Z. Xinyi & L. Chen, (2018). *Capsule graph neural network.* ICLR, Vancouver, BC, Canada, 2018.