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Modeling and Resolving Uncertainty in DIKWP Model

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Abstract: The paper examines the various uncertainties encountered in high-frequency trading (HFT) environments and delves into the multiple challenges faced by HFT firms in navigating the Dodd–Frank Wall Street Reform and Consumer Protection Act (referred to as the "Dodd–Frank Act"), particularly during the initial stages of its enactment. These challenges include the ambiguity surrounding the definition of HFT, the lack of clarity regarding regulatory requirements and boundaries, inconsistencies in enforcement resulting from deviations in understanding the content, and the absence of detailed descriptions of the Act's provisions. These hurdles significantly impact not only the daily operations of HFT firms but also pose higher demands on their long-term strategic planning and risk management. Drawing upon the Data, Information, Knowledge, Wisdom, and Purpose (DIKWP) model, this study employs an innovative analytical framework. Through the comprehensive application of Cognitive Space, Concept Space, and Semantic Space, it provides a systematic methodology for identifying and analyzing the aforementioned issues. This approach not only aids firms in better comprehending and adhering to complex regulatory requirements but also enables them to explore new business opportunities and competitive advantages while ensuring compliance.

Keywords: DIKWP model; uncertainty analysis; Cognitive Space; Concept Space; Semantic Space

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1. Introduction

In the era of digital finance, the emergence of high-frequency trading (HFT) systems signifies a significant advancement in financial markets, utilizing sophisticated algorithms and high-speed data networks to execute trades at speeds measured in milliseconds or even microseconds, surpassing the capabilities of human traders [1]. These systems analyze market conditions and execute orders based on predetermined criteria, aiming to profit from minute price discrepancies across different trading venues. The introduction of HFT is marked by its ability to enhance liquidity, narrow spreads, and improve market efficiency, yet it has also raised concerns regarding market stability and fairness [2]. Within these HFT systems, proprietary algorithms are strictly confidential, making it challenging for regulatory agencies and participants to fully comprehend their operations and impact [3,4].

The Dodd–Frank Wall Street Reform and Consumer Protection Act, enacted in response to the 2008–2009 financial crisis, significantly reshaped the of the U.S. financial industry. Aimed at preventing the recurrence of such a devastating economic downturn, the Act introduced comprehensive reforms designed to increase transparency, strengthen financial stability, and enhance consumer protection across financial markets [5]. Notably, the legislation impacted areas including HFT, which has become a prevalent practice due to technological advancements in trading platforms. The Dodd–Frank Act addresses concerns related to HFT by implementing stricter oversight and reporting requirements for trades and entities engaged in this practice. This includes increased scrutiny on liquidity provision, manipulative trading practices, and the systemic risk posed by the high-speed, algorithm-driven trading strategies that characterize HFT [6]. These measures reflect a broader regulatory effort under Dodd–Frank to ensure a more resilient financial system by mandating a range of risk management protocols and enhancing the overall accountability of financial institutions.

Against this backdrop, HFT enterprises confront unprecedented compliance challenges, particularly due to the ambiguous definition of HFT and regulatory boundaries within the legislation. These challenges not only affect the daily operations of enterprises but also significantly impact their strategic decision-making. To address these challenges, we introduce the Data, Information, Knowledge, Wisdom, and Purpose (DIKWP) model, which originated from Professor Yucong Duan's research on artificial consciousness and artificial intelligence [7,8], aiming to conduct an in-depth analysis of the key issues faced by HFT in the regulatory compliance process through this model. The DIKWP model provides a systematic analytical framework by distinguishing and correlating five dimensions: Data, Information, Knowledge, Wisdom, and Purpose, and processing them into corresponding Data Graphs (DGs), Information Graphs (IGs), Knowledge Graphs (KGs), Wisdom Graphs (WGs), and Purpose Graphs (PGs). Under the guidance of purpose [9], it assists financial enterprises in better understanding and managing complex regulatory requirements. Specifically, this study categorizes challenges as the "4-N" problems, Incompleteness, Inconsistency, Imprecision, and Incorrectness, which highlight the uncertainties faced by enterprises in complying with regulations. To address the challenges of uncertainty, we will explore and analyze the action strategies and decision-making processes of HFT enterprises in the face of the Dodd–Frank Act through Cognitive Space, Concept Space, and Semantic Space:

- Cognitive Space (ConN) focuses on cognitive activities in the decision-making process, including how to identify, process, and utilize information to form knowledge, wisdom, and purpose, to support compliance and business decisions;
- Concept Space (ConC) provides us with a framework for understanding and organizing the relationship between regulatory requirements and business practices. By mapping key concepts and their interactions, it reveals the possibilities and challenges of compliance pathways;
- Semantic Space (SemA) emphasizes the relationships between semantic units, including the associations and dependencies among vocabulary, regulations, and concepts, thereby ensuring the accurate transmission and interpretation of information and knowledge.

Based on the research and discoveries of predecessors [9], driven by purpose, we present in Figure 1 an analytical and processing framework for content(CT) resources across the three spaces mentioned from the perspective of stakeholders. Furthermore, based on the three aforementioned spaces and Figure 1, our definitions for Data, Information, Knowledge, Wisdom, and Purpose are as follows:

1. **Data (DIKWP-Data)**
    - **Definition:** Data semantically can be regarded as the concrete manifestation of identical semantics within cognition. This definition emphasizes that in the Cognitive Space, data as cognitive objects are not merely records of facts or observations but are outcomes of cognitive processing that require classification within the Concept or Semantic Spaces. The interpretation involves the cognitive agent's semantic matching and probabilistic confirmation of these data records as cognitive objects. This approach highlights the cognitive attributes of data in communication and thinking, indicating that the significance of data as cognitive objects is realized through specific semantic recognition and conceptual confirmation by the cognitive agent in comparison with existing concepts and semantics. This process underscores the dynamic interaction between the cognitive agent and data, enriching the understanding of how data is assimilated and utilized within cognitive frameworks. In the Concept Space, the concept of data represents the semantic affirmation of specific facts or observations within the Concept Space of a cognitive subject and is validated as the same object or concept by

corresponding with some identical semantics included in the consciousness space (not the subconscious space) of the cognitive subject and existing cognitive conceptual objects. In processing the concept of data, the cognitive subject often seeks and extracts specific identical semantics that defines this data concept, thereby unifying them under the same concept based on corresponding identical semantics. For example, when observing a flock of sheep, although each sheep may vary slightly in size, color, and gender, through accurate individual correspondence of identical semantics or probabilistic correspondence of semantic collections, cognitive processing categorizes them under the concept of "sheep" because they share a precise or probabilistic correspondence of semantics for the concept of "sheep". Identical semantics can be concrete, such as recognizing the concept of an arm by matching the number of fingers, color similarity, and shape between a silicone arm and a human arm, or it can be probabilistically chosen by selecting the target object that shares the most identical semantics with the arm concept. Additionally, the silicone arm's lack of a real arm's rotational functionality, defined by the identical semantics of "being able to rotate", can lead to a conceptual veto, thus determining it not to be a data concept of an arm.

- **Mathematization of data:** In the DIKWP model, the concept of data is viewed as a concrete manifestation of the same semantics within cognition. Mathematically, the semantic set corresponding to the data concept, denoted as D, can be defined as a vector space where each element $d \in D$ is is a vector representing a specific semantic instance. These semantic instances are grouped under the same semantic attribute S by sharing one or more semantic features F, defined as

$$S = \{f_1, f_2, \ldots, f_n\} \tag{1}$$

where f_i represents a semantic feature of the data concept. The Equation (1) highlights the structural organization of semantic attributes within data, emphasizing the methodical approach to classifying and understanding data within cognitive frameworks based on shared semantic characteristics. Consequently, we can define the set of data concepts as:

$$D = \{d | d \ sharing \ S\}, \tag{2}$$

This description emphasizes the semantic multidimensionality and structural nature of data concepts, while providing a mathematical foundation for subsequent processing and analysis of these data concepts.

- **Data concepts and semantic recognition:** In the DIKWP model, the processing and understanding of data concepts involve more than just recording objective facts. It encompasses how cognitive agents match these factual semantics with pre-existing semantic cognitive structures. This process underscores the importance of semantic recognition, namely how cognitive agents identify and categorize objects through semantic features within data concepts.
- **Data concepts and concrete manifestations of the same semantics:** In the DIKWP model, data concepts are not merely observations and records of the real world but are considered concrete manifestations of cognitive agents' understanding of identical semantic attributes, transcending the traditional view of them as mere objective recordings. These concepts are subjective interpretations mediated by cognitive processes, relying on the memory and processing capabilities within cognitive agents' semantic and Concept Spaces. This reflects a transformation and connection between the real world and the cognitive agent's spaces, making data concepts deeply rooted in the subjective Concept Space and contextual Semantic Space of the subject. As such, their recognition and interpretation must consider the agent's background knowledge, experiential information, and cultural semantic context. Data concepts are confirmed through

interpretation and semantic matching, serving as a bridge between objective reality and subjective cognition. This scenario reflects a Platonic idea where real-world entities, as concepts, are mere shadows of their ideals ("the same semantics"), emphasizing that the cognitive value of data concepts lies not only in their objective manifestations but also in how they enable cognitive agents to seek and confirm common semantics, thus facilitating semantic resonance and cognitive confirmation. The interaction between data concepts and data semantics within the cognitive agent is both a reflection of the external world and a pursuit of revealing inherent semantic essences, highlighting the agent's role in the transformation of conceptual semantics and the creativity of concept existence, as well as the symbolic language interaction between data concepts and cognitive agents.

- **Cognitive properties of data and semantic entities:** The DIKWP model's cognitive definition of data concepts and data semantics emphasizes the cognitive nature of data and its role as a semantic entity. In philosophy, this touches upon discussions of the "essence of things" and the notion of being "true to its name". Data concepts are not merely objective, symbolized records; they are entities imbued with specific data semantics. These data semantics are confirmed and attributed through the cognitive subject's processing that spans Concept and Semantic Spaces. This cognitive processing reveals that knowledge generation is not merely a mapping of the objective world but also a subjective construction process based on the transformation from semantics to concepts. This perspective aligns with Kant's transcendental philosophy, which posits that while knowledge about the world partly stems from external stimuli, it is largely determined by our cognitive structures.

2. **Information (DIKWP-Information):**
    - **Definition:** In the DIKWP framework, the concept of information corresponds to one or several "different" semantics within cognition. The informational semantics of the information concept refer to the semantic association in the Semantic Space between DIKWP cognitive objects in a cognitive agent's space and previously recognized DIKWP cognitive objects, facilitated by the cognitive agent's intentional concepts or semantic intents. This process forms either a recognition of sameness (corresponding to data semantics) or a recognition of difference, through probabilistic confirmation of "different" semantics or logical judgment, forming informational semantics, or generating new semantic associations ("new" representing a type of "different" semantics).In processing information concepts or informational semantics, cognitive processing identifies differences between inputted data, information, knowledge, wisdom, or intentions, and the recognized DIKWP cognitive objects, corresponding to various semantics and classifying this information. For example, in the Cognitive Space of a parking lot, while all cars may be recognized under the concept of "car", each car's parking spot, time parked, wear level, owner, functionality, payment records, and experiences represent semantic differences driven by different cognitive intents in the Semantic Space, eventually correlating to different informational semantics. These different semantics associated with informational objects often exist in the cognitive agent's cognition, frequently unexpressed explicitly, such as a depression patient using the concept of "low spirits" to express an increase in the negative degree of their current emotional state compared to past emotions within their Cognitive Space. The cognitive agent selects the concept of "low spirits" in their Concept Space to reflect the targeted informational semantics intended to express their cognitive state. However, the informational semantics interpretation of "low spirits" in the communicative partner's Cognitive Space may not align with the cognitive agent's informational semantics, or in other words, there exists a difference in semantics, thus failing to convey the intended informational semantics

objectively to the communicative partner, making this informational semantics a subjective cognitive informational semantics.

- **Mathematical representation of information semantic processing:** Information semantics in the DIKWP model corresponds to data semantics, information semantics, knowledge semantics, wisdom semantics, and purpose semantics, generating new associated semantics driven by specific purpose. In the Semantic Space, information semantics I map a set of inputs X to a new semantic association Y:

$$I : X \rightarrow Y \tag{3}$$

where X represents a collection or combination of data semantics, information semantics, knowledge semantics, wisdom semantics, and purpose semantics (i.e., DIKWP content semantics), and Y represents the newly generated DIKWP content semantic associations. This mapping emphasizes the dynamic and constructive nature of the information semantic generation process. In the DIKWP model, information semantics corresponds to the expression of various different semantics in cognition. Through the cognitive purpose of the cognitive subject, information semantics generates new semantic associations by linking the semantics corresponding to data, information, knowledge, wisdom, and purpose with the existing cognitive objects of the cognitive subject. In the Cognitive Space, this process includes not only the resemanticization and transformation of known DIKWP content (involving semantic connectivity that forms what is called cognitive understanding) but also involves the dynamic process of generating new DIKWP cognitive semantics and continually forming cognitive understanding through such recombination and transformation. The generation of information semantics is about how different sets or combinations of data semantics, information semantics, knowledge semantics, wisdom semantics, or purpose semantics are linked through the specific purpose of the cognitive subject, thereby confirming in the Cognitive Space what is referred to as cognitive understanding. This process corresponds to how the cognitive subject in the Semantic Space forms connections, supplements, and judgments of semantics to address fragmented, missing, or uncertain semantic links using generated information semantics, thereby aiming to eliminate cognitive uncertainty arising from semantic uncertainty. This process involves associating, comparing, and conceptually matching observed phenomena or cognitive input content with existing DIKWP content through the Cognitive Space in the Semantic Space, and further recognizing and categorizing new DIKWP content using certain different semantics. In AI, this can correspond to forming explanations and managing relationships between DIKWP content, such as by analyzing correlations between DIKWP contents through algorithms, thereby extracting valuable information semantics. Information semantics processing is a dynamic cognitive process, focused on how the subjective purpose of the cognitive subject links DIKWP content semantics with the existing cognitive objects' DIKWP content semantics of the cognitive subject, thereby generating valuable semantic associations. The value of information lies in becoming a bridge connecting data, information, knowledge, wisdom, and purpose, revealing the cognitive subject's understanding of DIKWP content semantics.
- **The construction properties of information semantics:** The generation and understanding of information are not passive reception processes but active construction processes. Information semantics depend on the existing DIKWP content and Purpose-Driven cognitive frameworks. This perspective resonates with Kant's epistemology, which posits that a cognitive agent's understanding of the world is shaped through intrinsic perceptual frameworks and a priori concepts. The value of information lies in its ability to expand or reconstruct our cognitive frameworks, thereby enhancing our understanding of the world.

- **Diversity and depth of information semantics:** In the DIKWP framework, information processing transcends mere data aggregation and focuses on the dynamic relationships and the generation of new semantic associations among data, information, knowledge, wisdom, or intentions. This process embodies Heraclitus's theory of flux—everything flows, nothing stays the same. The value of information lies in its fluidity and its potential to provoke change, rather than being a static record of facts. Information serves as a crucial link connecting different cognitive states, facilitating the transition of cognitive agents from one state of understanding to another.
- **Dynamism of information and cognitive structures:** Within its definition, the DIKWP model emphasizes the role of information as a bridge connecting different semantic entities. This aligns with Gilles Deleuze's theory on "Difference and Repetition". Deleuze posits that the process of cognition is conducted through recognizing differences among things, which is central to information processing. Information not only encompasses the semantic differences within DIKWP content but also engages with existing knowledge structures through these differences, creating new knowledge. This dynamic process of updating cognitive structures is key to cognitive development and the growth of knowledge.

3. **Knowledge (DIKWP-Knowledge):**
   - **Definition:** The semantic correspondence of the knowledge concept pertains to one or more "complete" semantics within the Cognitive Space. The semantics of the knowledge concept are derived from the cognitive agent's activity of abstracting semantic integrity from the content of DIKWP using certain assumptions. This involves the understanding and interpretation of the semantic relationships among the DIKWP content by the cognitive agent. Essentially, this process constructs the semantic connections between the cognitive input content of the DIKWP, encountered during cognitive interaction activities, and the agent's pre-existing DIKWP content. This construction corresponds to one or more "complete" semantics within a higher-order Cognitive Space, bearing a fully confirmed cognitive purpose. When dealing with the concept of knowledge, the brain abstracts at least one concept or pattern corresponding to a complete semantic through observation and learning. For instance, it is not possible to determine through observation alone that all swans are white. However, within the Cognitive Space, the cognitive agent can, through hypothesis (a higher-order cognitive activity imparting complete semantics), assign "complete" semantics to partial observation results. This means attributing the semantic of "all" to the observation, thereby forming the knowledge rule that "all swans are white", which corresponds to the knowledge semantics possessing the complete semantic of "all". Knowledge K is represented as a semantic network, where nodes represent concepts, and edges represent the relationships between concepts:

$$K = (N, E) \tag{4}$$

where N represents the set of concepts, and E represents the set of relationships between these concepts. Knowledge represents the transformation of the DIKWP content from a state of non-understanding to a corresponding cognitive state of understanding, bridged by the use of complete semantics, and reinforced through verification. The construction of knowledge not only relies on the accumulation of data and information but, more importantly, on abstraction and generalization during cognitive processes to form an understanding of the essential nature and intrinsic connections of things. The existence of knowledge is evident not only at the individual level but also at the collective or societal level, being shared and disseminated through culture, education, and tradition. Knowledge semantics are structured understandings formed after deep processing and internalization of the DIKWP content (corresponding to the Semantic Space within the Concept Space through "complete" semantics). The definition of knowledge within the DIKWP framework reflects a profound understanding of the world and the grasp of complete semantics. This aligns with Aristotle's concept of formal causes, wherein the essence and purpose of things can be explored and understood through reason and experience.

- **Mathematization of knowledge:** In DIKWP model, the mathematical representation of knowledge is helpful to understand its integrity and structure. The semantic attribute set S of knowledge concept is expressed as:

$$S = \{f_1, f_2, \ldots, f_n\} \quad (5)$$

Among them, f_i represents a semantic feature of knowledge concept. The knowledge concept set K contains all instances that share a complete semantic attribute set:

$$K = \{k | k \ sharing \ S\}, \quad (6)$$

The process of knowledge generation can be expressed as:

$$I : X \rightarrow Y \quad (7)$$

Among them, X represents the set or combination of data semantics, information semantics, knowledge semantics, wisdom semantics and purpose semantics (that is, DIKWP content semantics), and Y represents the generated new knowledge semantic association.

- **Processing and generation of knowledge semantics:** Knowledge serves as the bridge in the cognitive state transformation of DIKWP content from non-understanding to understanding, with its validation reinforcing the confirmation of knowledge. The construction of knowledge relies not merely on the accumulation of data and information, but more significantly on abstraction and generalization during cognitive processes, leading to an understanding of the essence and intrinsic connections of things. The existence of knowledge manifests not only at the individual level but also at the collective or societal level, shared and disseminated through culture, education, and tradition. Knowledge semantics are structured understandings formed after the deep processing and internalization of DIKWP content. This understanding corresponds to the Semantic Space within the Concept Space, facilitated by "complete" semantics. The definition of knowledge within the DIKWP framework reflects a profound understanding of the world and a grasp of complete semantics. This notion aligns with Aristotle's concept of formal causes, wherein the essence and purpose of things can be explored and understood through reason and experience. In the DIKWP model, the formation of each knowledge rule represents the cognitive agent's grasp of the inherent laws and essence of things. From a philosophical perspective, knowledge is not only the product of cognitive processes but also the purpose and guidance of these processes. The formation and application of knowledge demonstrate the cognitive agent's adaptation to and transformation of the world, embodying a Semantic Space understanding of the deeper laws of the real world.
- **Cognition and construction of knowledge:** The generation and comprehension of knowledge constitute an active construction process, relying on pre-existing DIKWP content and a hypothesis-driven cognitive framework. The diversity and depth of knowledge semantics are reflected in their completeness and structural integrity. Knowledge encompasses not only the semantic completeness of DIKWP content but also creates new knowledge by linking these complete semantics with existing knowledge structures. This dynamic process of updat-

ing cognitive structures is crucial for cognitive development and the growth of knowledge.

- **Philosophical significance of knowledge:** In the DIKWP model, knowledge is not merely a record of observations and facts, but a systematic understanding formed through hypotheses and higher-order cognitive activities. The semantic completeness and systematic nature of knowledge reflect the cognitive agent's profound understanding and interpretation of the world. The process of knowledge generation emphasizes the agency and creativity of the cognitive agent in understanding and interpreting the world. By using hypotheses and abstraction, partial observations are endowed with complete semantics, thereby forming systematic knowledge. Knowledge semantics are not just an aggregation or reorganization of DIKWP content semantics; they represent the creation of new semantic associations, reflecting the cognitive agent's active exploration and interpretation of the world. Through hypotheses and higher-order cognitive activities, the knowledge generation process can reveal deep connections and intrinsic logic among phenomena, providing a more comprehensive and profound understanding of the world.
- **Dynamism of knowledge semantics:** The generation of knowledge semantics is a dynamic process, involving how the cognitive agent links different DIKWP content semantics through hypotheses and higher-order cognitive activities to form new knowledge semantics. Within the Cognitive Space, this process includes not only the recombination and transformation of known DIKWP content but also the creation of new cognitive understandings and knowledge semantics through such recombination and transformation. This dynamism is evident in the process of knowledge generation and updating. Through continuous observation, learning, and verification, the cognitive agent can form and refine systematic knowledge structures. These knowledge structures not only explain phenomena but also predict future behaviors and characteristics, providing a deeper understanding of and guidance for the world.

4. **Wisdom (DIKWP-Wisdom):**
    - **Definition:** Wisdom corresponds to aspects such as ethics, social morality, and human nature, representing a set of values that are relatively fixed in relation to the current era, derived from culture and human social groups, or individual cognitive values. When processing wisdom, it is necessary to integrate these data, information, knowledge, and wisdom, and apply them to guide decision-making. In the Concept Space, wisdom functions as a sophisticated concept that represents the extensive application and deep understanding of data, information, and knowledge. Wisdom's role within this space is not only as an integrator of information but also as an embodiment of values and principles. It encompasses concepts such as ethics, morality, and humanity, which are formed within sociocultural contexts and interact within the Concept Space to collectively guide decision-making processes. In the Semantic Space, the application of wisdom demonstrates how to select and balance between various concepts and values. Wisdom in Semantic Space serves to explain and connect these concepts, identifying their interrelationships and potential conflicts, thereby guiding how to make appropriate decisions in specific situations. Therefore, wisdom is not merely a result of data or information processing; it is a profound and value-driven decision-making process. It involves not just computation or logical reasoning but a deeper understanding and application of human behavior, social norms, and ethical principles. The complexity and depth of wisdom are indispensable in the decision-making process, ensuring that decisions are not solely focused on efficiency but are also a profound expression of humanity, ethics, and morality. For example, when facing decision-making challenges, Cognitive agents should

consider a comprehensive set of factors including ethics, morality, and feasibility, rather than solely focusing on technical efficiency or effectiveness.

- **Mathematization of wisdom:** Wisdom W functions as a decision function that integrates data, information, knowledge, wisdom, and purpose to produce value-driven data, information, knowledge, wisdom, and purpose:

$$W : \{D, I, K, W, P\} \rightarrow \{D^*, I^*, K^*, W^*, P^*\} \quad (8)$$

where D, I, K, W and P respectively represent data, information, knowledge, wisdom, and purpose, while D^*, I^*, K^*, W^* and P^* processed by the wisdom function represent the corresponding output data, information, knowledge, wisdom, and purpose respectively.

- **Differences between information and wisdom:** Information primarily involves semantic associations and logical verifications of various data, knowledge, and viewpoints within the Semantic Space, forming specific informational semantics. This process is usually driven by specific purpose, incorporating and transforming known cognitive objects to generate new semantic associations. The core of information lies in its expression of "different" semantics within cognition, and through intention-driven cognitive processing, it identifies and differentiates these distinctions for classification and understanding. Wisdom, on the other hand, represents a higher level of cognitive activity. It involves not only the acquisition and processing of information but also how to utilize this information for effective decision-making and action. The manifestation of wisdom is based on information, combined with individual or collective experiences, values, and long-term objectives, to conduct ethical and moral considerations, and engage in more complex thinking and planning. Wisdom thus involves a broader semantic understanding, such as considering information within a larger social, cultural, and ethical framework, as well as predicting and planning for future possibilities.
- **Significance of wisdom:** Wisdom represents an advanced form of the comprehensive application and deepened understanding of data, information, and knowledge. Within the Concept Space, wisdom not only integrates information but also embodies a set of values and behavioral norms. It includes concepts such as ethics, morality, and humanity, which are shaped within sociocultural contexts and interact to collectively guide decision-making. In the Semantic Space, the application of wisdom highlights the ability to choose and balance diverse concepts and values. By analyzing and connecting different concepts, it reveals their inherent relationships and potential conflicts, thus guiding appropriate decision-making in specific situations. The essence of wisdom transcends mere data processing or informational conclusions; it is a decision-making process deeply influenced by cultural and value systems. The practice of wisdom relies not just on computational logic but also on a profound understanding and application of human behavioral logic, social norms, and ethical principles. The complexity and depth of this process ensure that decision-making is not only technically efficient but also deeply reflective of human nature, ethical standards, and moral principles, demonstrating the humanitarian and ethical dimensions of decision-making.
- **Cognitive value and creativity of wisdom:** In the cognitive process of wisdom, data and information are endowed with a deeper significance that transcends their apparent surface value. This transcendence is manifested not only in the profound interpretation of information but also in how these elements are integrated into the cognitive agents' existing knowledge systems, leading to the generation of new insights that are both enlightening and innovative. Wisdom in this process is not merely about accumulating knowledge but also involves exploring the deep connections between pieces of knowledge and how they collectively shape our understanding of the world. Additionally, wisdom enables

cognitive agents to move beyond existing knowledge frameworks, uncovering the latent possibilities hidden behind information to solve complex problems. This capability is exemplified by the ability to examine issues from diverse perspectives, utilizing interdisciplinary knowledge to devise solutions that are both novel and practical. For instance, in autonomous driving technology, by integrating visual data, map information, and traffic regulations, systems can creatively plan safe and efficient travel routes. The cognitive process of wisdom emphasizes that the concept of information is not static but continuously evolves through the interactions, thoughts, and innovations of cognitive agents. The creativity in semantic transformation lies in its capacity to dynamically adjust the meaning of information based on the current tasks, goals, or contexts, thereby fostering adaptive cognitive behaviors. This creativity is not only evident in adapting to the external world but also in the continuous restructuring and optimization of internal cognitive structures, propelling cognitive agents towards higher levels of cognitive development.

5. **Purpose (DIKWP-Purpose):**
    - **Definition:** Purpose corresponds to a tuple (input, output), where both input and output consist of content from data, information, knowledge, wisdom, or purpose. Purpose represents the stakeholders' understanding of a phenomenon or issue (input), as well as the goals they aim to achieve through the processing and resolution of this phenomenon or issue (output). In the Concept Space, purpose serves as a bridge connecting input to output, demonstrating the transformation from an abstract understanding (conceptualized input) to specific actions or outcomes (conceptualized output). This transformation process relies not only on the processing of data and information but more crucially on the use of knowledge and wisdom to optimize and guide the process. The handling of purpose in this space illustrates how cognitive agents utilize existing concepts and theories to formulate and achieve objectives. In the Semantic Space, the processing of purpose is manifested in understanding and interpreting the relationships between various concepts. Moreover, the realization of purpose depends on a deep semantic understanding of input concepts and the effective construction of output concepts. This includes comprehending the deep meanings behind input data, predicting the potential impacts of outputs, and based on these insights, continuously refining purpose processing strategies to optimize the overall process.
    - **Mathematical representation of purpose processing:** When processing purpose, cognitive agents process the input based on predefined objectives (output), and through learning and adaptation, they progressively align the output closer to the predetermined objectives.

$$P = (Input, Output) \tag{9}$$

where both input and output involve content from data, information, knowledge, wisdom, or purpose. In the processing of purpose, a series of transformation functions T implement the conversion from input to output based on the content of the input and the predefined objectives:

$$T : Input \rightarrow Output \tag{10}$$

- **Processing purpose semantics in cognition:** Purpose semantics in cognitive processing exhibit significant complexity, rooted in their multidimensionality, subjective context dependency, dynamic development, expressive ambiguity, hierarchical nesting, and considerations of ethics and privacy. Specifically, the parsing and understanding of purpose are cognitive activities that span multiple disciplinary boundaries, including linguistics, psychology, and sociology.

Cognitive systems must not only capture the literal meaning of expressed language but also delve into implicit information such as the speaker's background knowledge, emotional tendencies, and socio-cultural context. This undoubtedly sets high standards for the semantic parsing depth and contextual awareness of cognitive systems. Furthermore, the interpretation of purpose is constrained by the cognitive framework of the subject and the specific communication environment, leading to potential differences in how individuals interpret the same information. Additionally, the meaning of the same expression can vary across different contexts, further complicating the processing. The dynamic evolution of purpose necessitates that cognitive processing mechanisms flexibly adapt to conversational dynamics, promptly adjusting understanding models to cope with information updates and environmental changes. Ambiguity and uncertainty, especially prevalent in natural language communication, require the application of contextual reasoning, pragmatic principles, and even intuition to accurately discern purpose. Hierarchical and nested structures mean that a single communicative act may contain multiple purposes, demanding deep parsing capabilities from cognitive systems.

- **Purpose-Driven significance:** Purpose-Driven approaches emphasize that any action, decision-making, or creative process should be explicitly centered around a core purpose or objective. This approach relies not merely on the technical processing of data and information but more significantly on the profound utilization of knowledge and wisdom. This implies that during the decision-making and action processes, a comprehensive consideration of historical experiences, expert knowledge, and an understanding of the essence of matters is employed to optimize path selection and strategy formulation. Purpose-Driven methods compel cognitive agents to dynamically use existing concepts and theoretical frameworks to form and adjust strategies aimed at achieving goals. This requires the ability to flexibly navigate within the Concept Space, selecting the most suitable conceptual tools to analyze problems and devise effective solutions. In the Semantic Space, Purpose-Driven approaches underscore a deep understanding of the relationships between concepts and their underlying meanings, ensuring that outputs are not only technically feasible but also highly congruent with the goals in terms of context and significance. This process necessitates a precise grasp of the deep meaning of inputs while creatively constructing output concepts that can effectively convey intentions and produce the desired impact. Moreover, the practice of Purpose-Driven approaches is a cyclical feedback process that includes continuous adjustments and optimization of intention processing strategies, enabling systems or individuals to learn and progressively improve, better adapting to environmental changes.

Initially, leveraging the viewpoints presented in papers [7–9], we categorize content resources into several types of graphs, including Data Graphs (DGs), Information Graphs (IGs), Knowledge Graphs (KGs), Wisdom Graphs (WGs), and Purpose Graphs (PGs), and subsequently analyze and process them from the viewpoint of stakeholders driven by purpose and value. When stakeholders integrate concepts from content resources with individual or systemic intrinsic cognitive mechanisms, coupled with personal experiences and knowledge, unique understandings and interpretations are formed, thereby establishing a mapping from the Cognitive Space to the Concept Space. For instance, consider the concept of "blue"; while individuals may possess diverse cognitive interpretations and expressions of blue, blue remains a consistent attribute in the objective reality for the average person. Conversely, when one perceives the color blue, it may not necessarily appear blue to all observers, illustrating the biases caused by subjective inputs and outputs.

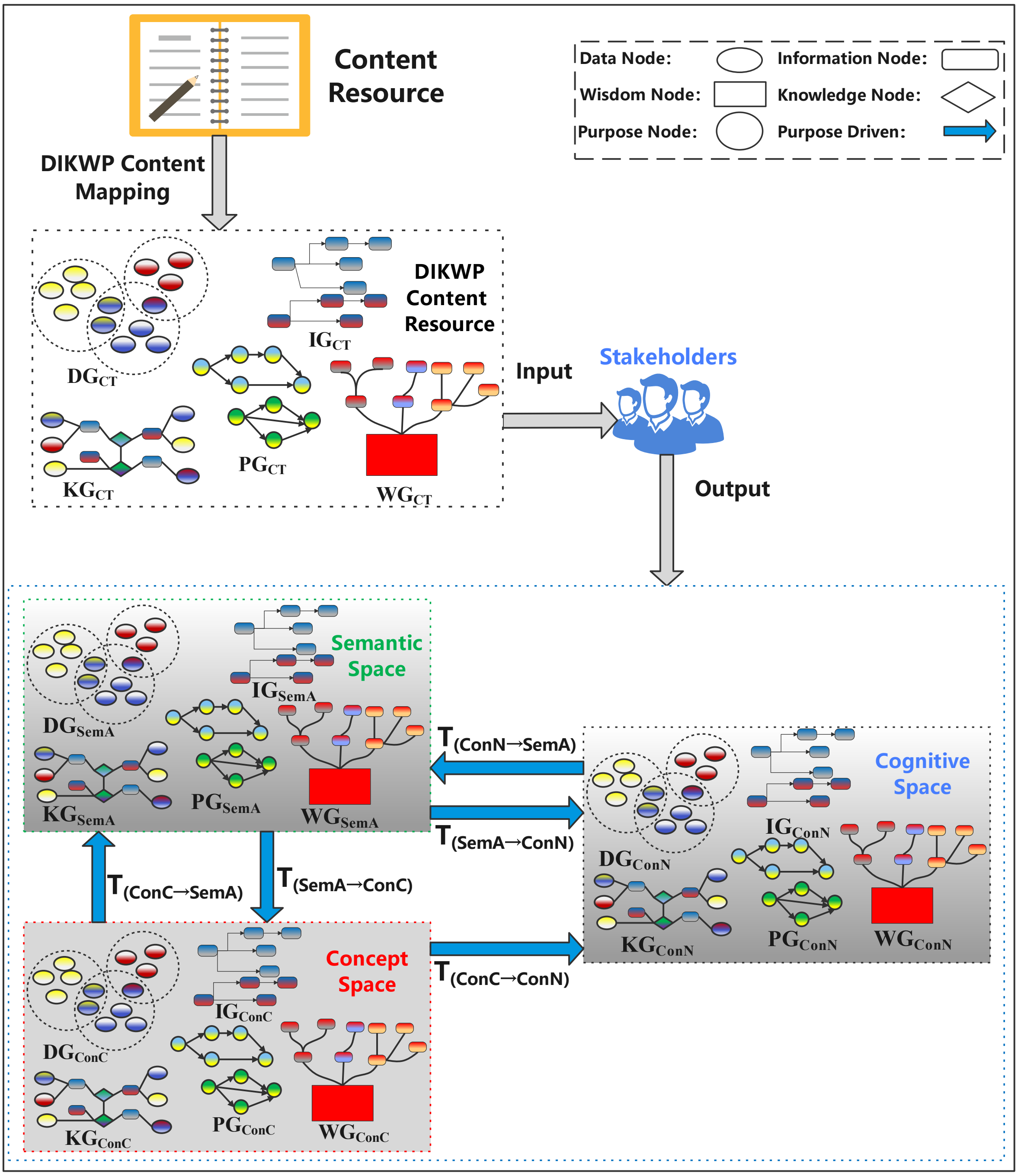

Figure 1. Analysis and processing of Concept Space, Cognitive Space, and Semantic Space for the content resource under Purpose-Driven.

Hence, we emphasize the concept of the Semantic Space, wherein feedback from the external world regarding semantic expressions is conveyed through the Semantic Space, subsequently influencing the Concept Space and Cognitive Space, thereby engendering a closed-loop process of cognitive updating and learning. By integrating mapping and feedback processes, we derive the dynamic and interactive DIKWP model framework, wherein the Cognitive Space, Concept Space, and Semantic Space interact and influence each other, presenting a comprehensive process from subjective understanding to objective semantic processing. Through the mapping from the Semantic Space to the Cognitive Space, we can explain the problem of stakeholders forming different cognitions and thus taking different actions based on the same concept mapped into the Concept Space among different stakeholders. This further underscores the importance of the Semantic Space as a tool for cognitive mapping. The definitions, operations, and processing procedures of the three spaces in Figure 1 are elaborated upon in Sections 4.1–4.3, respectively, while their interplay and transformation will be discussed and elucidated in Section 4.4. Through the comprehensive analysis of these three spaces as shown in Figure 1, this paper not only explores how HFT companies can ensure compliance while seeking new business opportunities but also proposes strategies for utilizing the DIKWP model to enhance internal compliance auditing, risk management capabilities, and communication with regulatory agencies. This multidimensional analytical approach provides new perspectives and tools for understanding and addressing regulatory challenges in the financial technology field, assisting HFT enterprises in maintaining competitiveness and innovation in a complex regulatory environment. The main contributions of this paper are as follows:

1. **Innovative application of the DIKWP model:** Our study innovatively applies the DIKWP model to analyze and address the complexity involved in HFT and its regulation. This approach enables a nuanced understanding of the regulatory challenges and operational uncertainties faced by HFT companies, providing a structured framework for addressing these issues;
2. **Addressing uncertainty in HFT regulations:** We analyzed the inherent uncertainty in regulations affecting HFT practices during the early stages of the Dodd–Frank Act. By dissecting issues related to vague definitions, regulatory requirements, interpretational differences, and lack of detailed descriptions, this research offers clear insights for more effectively managing regulatory compliance;
3. **Elaboration on Concept, Cognitive, and Semantic Spaces:** We provide detailed explanations and a set of definitions and analytical methods for Concept Space, Cognitive Space, and Semantic Space within the context of the DIKWP model. This enhances understanding of how HFT companies interpret, adapt to regulatory requirements, and formulate strategies around regulatory demands, thereby leveraging these spaces to improve operational coordination and decision-making.

2. Problem Description

One of the primary challenges of HFT lies in the inherent uncertainty of input data content and output results [10]. The rapid execution speed and algorithmic nature of HFT imply that minor errors or delays in market data could lead to significant and unpredictable outcomes, potentially exacerbating market volatility. Departing from the context of HFT, characterized by its real-time nature and speed, we have reviewed previous research and identified a series of short-term issues that may affect the profitability of systems. We classify these issues into types based on market, internal, and regulatory aspects, each type encompassing several sub-issues, with each sub-issue potentially serving as a factor influencing the profitability of HFT. We categorize each type of problem into several domains, wherein we summarize each sub-issue, provide examples, and assign numerical identifiers for semantic association e_x.

2.1. Uncertainty in Market Conditions

The behavior of financial markets is exceedingly complex, influenced by political events [11,12], market sentiment [13,14], corporate performance [15], and numerous other factors [16–19]. These conditions are subject to a constant change, resulting in inherent uncertainty in market predictions.

2.1.1. Political Factors

- **Geopolitical tensions (e_1):** Geopolitical tensions, such as sudden outbreaks of conflict, wars, or sanctions, typically lead to fluctuations in global stock markets. These fluctuations not only impact global markets but also have a particular influence on companies or industries with significant interests in regions of geopolitical tension. For instance, during a political crisis in 2014, concerns over escalating tensions between Country A and Country B led to turmoil in the global energy markets. Country A is one of the world's largest natural gas suppliers, and any threat to its supply capacity could result in energy price volatility. During this period, stocks related to the energy sector, especially European energy companies reliant on Country A's energy supplies, may experience price fluctuations. HFT may exploit this volatility by swiftly buying and selling energy stocks to generate profits, while closely monitoring any further political developments that could affect energy supply and prices.

- **Policy changes (e_2):** Changes in government or international organizations' policies, such as adjustments to trade policies or monetary policies, can significantly impact economic activities and the profitability of multinational corporations. For example, in 2018, Country D's imposition of tariffs on goods from Country C intensified global trade tensions, leading to profound effects on global stock markets, commodity markets, and currency markets. High-frequency traders may analyze the impact of such policy changes on different markets and assets, adjusting stock trading strategies swiftly in the short term to capture price fluctuations and generate profits.

2.1.2. Market Sentiment

Investors' emotions and expectations can also significantly impact market prices, often based on investors' perceptions rather than actual economic indicators.

- **Market overreaction (e_3):** Market participants may overreact to certain news or events, leading to sharp short-term fluctuations in asset prices that may be unrelated to fundamentals. For example, if the CEO of a large technology company suddenly announces their resignation, even though the long-term impact of this resignation on the company's fundamentals may be limited, the stock price may experience a significant decline in the short term due to market sentiment. High-frequency traders can profit from these short-term price fluctuations by capturing them swiftly after the news is announced, trading based on anticipated systematic model expectations.
- **Unconfirmed news (e_4):** Unconfirmed news or rumors spread on social media and news websites can quickly alter market sentiment, causing short-term fluctuations in the prices of certain assets. For instance, if rumors about the imminent acquisition of a listed company circulate online, even though this news is unconfirmed, the company's stock price may temporarily rise due to investors buying in. High-frequency traders may capitalize on these short-term price movements for trading, but they also face high risks because once the news is confirmed to be false, the stock price may quickly fall back, indicating that precise control over risk assessment is required.
- **Herd behavior (e_5):** Investors may mimic the behavior of other investors rather than make investment decisions based on their analysis, leading to herd behavior in the market, and exacerbating asset price fluctuations. For example, when a particular stock or industry suddenly becomes favored by the market, a large number of investors may follow suit and buy-in, driving up prices. However, this price increase is often not supported by the fundamentals of the company. Once the trend reverses, followers may rush to sell their stocks, causing prices to plummet sharply. High-frequency traders can identify the formation and reversal of such trends through algorithms, thus swiftly entering and exiting the market when market sentiment changes, capturing profits.

2.1.3. Counterparty

Counterparty uncertainty is a key challenge in HFT, as the outcome of the market depends not only on the decisions of individual participants but also on the collective behavior of all market participants [20–22]. The presence of this uncertainty complicates the formulation and execution of HFT strategies.

- **Competitors executing similar strategies (e_6):** When multiple participants in the market simultaneously execute similar trading strategies, competition may lead to diminishing profit margins. If multiple high-frequency traders are exploiting the same arbitrage strategy, such as a rapid response strategy based on certain economic indicators, arbitrage opportunities in the market may quickly disappear, as the first participant to execute the trade captures the profit, leaving subsequent participants finding the market adjusted without the expected profit space.

- **Opposing strategy opponents (e_7):** Other traders may be executing strategies that are entirely opposed to yours, which may directly impact your trading results negatively. For instance, if one HFT firm is executing a buy strategy based on pattern recognition, while another firm may be executing a sell strategy based on the same data or predictive model. If the latter's trading volume is larger or executed faster, it may lead to market price trends contrary to the expectations of the former, resulting in losses for the former.
- **Unpredictable market participant behavior (e_8):** Market participant behavior may be driven by various factors, including irrational behavior, making it extremely difficult to predict the behavior of other participants. For example, the 2021 GameStop (GME) trading event [23] demonstrated the extreme unpredictability of collective market participant behavior when driven by non-traditional factors such as collective action on social media. This behavioral pattern is far from predictable based on traditional financial theories and is challenging for HFT algorithms to accurately forecast.
- **Opponents using covert strategies (e_9):** New participants may continuously join the market, employing covert strategies or using technologies not widely known, adding additional uncertainty to market behavior. For example, an emerging HFT firm may develop an advanced artificial intelligence algorithm capable of identifying and exploiting minor fluctuations in the market more rapidly. The deployment of such a new algorithm may suddenly alter market dynamics, causing unexpected impacts on existing participants.

2.2. Uncertainty of Internal Conditions

The internal condition uncertainty of HTF firms poses a significant issue, as it directly impacts the speed of trade execution and the efficiency of data processing. This uncertainty may stem from various factors, including the stability of technical equipment, the performance of software systems, the reliability of network connections, and the proficiency of personnel in financial expertise and legal understanding [24]. Changes or failures in these factors may result in delays or interruptions in trade execution, thus affecting the effectiveness of trading strategies. Therefore, continuous optimization of internal conditions is imperative for HFT firms to ensure the stability and efficiency of trading systems as well as the professionalism of personnel, thereby guaranteeing the successful execution of trading strategies.

2.2.1. System Uncertainty

- **Network latency (e_{10}):** In HFT, even milliseconds of delay can lead to significant losses, as market conditions can change drastically within extremely short periods. For instance, consider a trading firm that relies on the fastest network connection from New York to London to execute arbitrage strategies. However, due to the cross-geographical nature, the risk associated with network connectivity is much higher compared to intra-geographical risks. If this network connection experiences delays due to technical issues, the firm may miss out on executing lucrative trades, or worse, they may fail to withdraw in time before market conditions deteriorate, resulting in losses.
- **Processing latency (e_{11}):** The impact of processing latency on HFT is significant, as in this trading mode, the advantages of every millisecond or even microsecond can determine profits or losses. For example, a company encounters technical issues during the development of its trading system, resulting in a 5-millisecond delay in the execution of trade orders. Although seemingly insignificant, in the world of HFT, such delays can have substantial effects. Due to execution latency, when the company's algorithms identify an arbitrage opportunity and attempt to execute trades, market prices have already adjusted, causing the arbitrage opportunities to vanish. This

implies that the company may have missed out on numerous potentially profitable trading opportunities.

- **System failures (e_{12}):** Defects introduced during software updates or modifications are common issues in HFT systems. Even with rigorous testing, defects may remain undetected, especially those that manifest only in actual trading environments. For instance, a financial services company in 2012 updated its trading software one day, and a flaw in the new software resulted in abnormal behavior of the trading system, erroneously executing millions of orders at high speed that should not have been executed. Within less than an hour, this system failure incurred hundreds of millions of dollars in losses for the company. This event underscores the importance of software updates and defect management in HFT systems. When new code runs in an actual trading environment, even after rigorous testing, undiscovered software defects may exist.

2.2.2. Differences in Content Understanding

Differences in content understanding have complex implications for HFT, as they can both increase market volatility and provide opportunities for traders employing different strategies. For HFT firms, understanding the diversity in information interpretation within the market and leveraging advanced natural language processing (NLP) techniques and machine learning algorithms to enhance the accuracy and responsiveness of their information parsing are key to improving trading efficiency and profitability. Additionally, this underscores the need for regulatory bodies to be as clear and precise as possible when disseminating market-sensitive information to minimize unnecessary market fluctuations.

- **Differences in market data interpretation (e_{13}):** Various HFT algorithms may interpret the same set of market data differently, leading to divergent or diversified trading decisions. For instance, during the release of significant information in the stock market, different HFT systems may have varied interpretations of the positive or negative impact of the data. Some algorithms may interpret it as a bullish signal and opt to buy related stocks, while others may perceive it as bearish and choose to sell. Such differences in content understanding can increase market volatility in a short period.
- **Diverse interpretations of news reports (e_{14}):** News reports and announcements often contain ambiguous or multi-interpretable language, prompting different trading systems to interpret this information based on their algorithms. For example, if a large tech company's financial report exceeds market expectations but its future revenue forecast appears slightly conservative, various HFT systems may react differently. Some may focus on the short-term bullish aspects and buy, while others may be concerned about the uncertainty in long-term revenue forecasts and choose to sell. Such diversity in news interpretation can lead to significant fluctuations in stock prices.
- **Differing interpretations of regulatory announcements (e_{15}):** Regulatory announcements from governing bodies typically have a direct impact on the market, but the complexity of their language and terms sometimes leads to varying interpretations and expectations. For example, if a regulatory agency issues new rules aimed at tightening oversight of HFT, some trading entities may interpret it as a direct threat to their business model and decrease trading activities. In contrast, others may seek gray areas within the new regulations, attempting to adjust their strategies to continue leveraging the advantages of HFT. Such differing interpretations of regulatory content may result in divergent behaviors among market participants, consequently affecting market structure and liquidity.

2.3. Regulatory Uncertainty

The uncertainty of regulatory compliance is a significant and intricate issue within the realm of HFT. This primarily arises due to the potential evolution of interpretations of laws and regulatory guidance over time, alongside potential shifts in the enforcement efforts and priorities of regulatory bodies. Such uncertainty may result in trading strategies originally designed to be compliant suddenly facing legal risks [25,26].

2.3.1. Changes in Regulatory Interpretations

The shifting interpretations of regulations pose a significant source of uncertainty for financial markets, particularly for trading strategies reliant on precise legal interpretations.

- **Increased compliance costs (e_{16}):** Regulatory agencies' new interpretations of existing rules may escalate compliance costs for enterprises. Companies may need to allocate additional resources to comprehend new interpretations, adjust their business processes, update compliance strategies, or even redesign products or services. For instance, financial regulatory bodies may reinterpret rules regarding algorithmic trading, necessitating entities employing algorithms in trading to engage in more frequent self-assessment and reporting. For HFT firms, this could entail investment in advanced compliance monitoring systems, thereby escalating operational costs.
- **Adjustment of business models (e_{17}):** When regulatory interpretations change, businesses may need to modify their business models, especially if the new interpretations impact their core revenue streams. For example, if regulatory bodies decide to classify a widely adopted HFT strategy as market manipulation, trading firms relying on this strategy may have to completely revamp their trading models, potentially affecting their profitability and business continuity.

2.3.2. Regulatory Enforcement

Changes in enforcement intensity are particularly crucial in stock markets and the realm of HFT due to the sensitivity of these domains to regulatory environment shifts. Regulatory agencies may alter the enforcement intensity of certain existing regulations or policies, which, while not involving the formulation of new laws or rules, significantly impact the behavior and strategies of market participants.

- **Increased transparency requirements (e_{18}):** Regulatory bodies demanding enhanced transparency in situations necessitating more disclosure of trading information may affect the operational methods of HFT firms. For instance, regulatory agencies may require all trading entities, including HFT firms, to provide more detailed trading data and strategy information to augment market transparency. This may compel HFT entities to adjust their data reporting processes and systems; while this aids regulatory bodies in better monitoring market activities, it may also increase the operational burden and costs for trading firms, as well as the risk of technology strategy leaks.
- **Enhanced monitoring of abnormal trading activities (e_{19}):** Regulatory agencies intensifying monitoring efforts on abnormal trading activities, especially those indicative of market abuse or manipulation, represent a significant change. For example, regulatory bodies adopting more advanced surveillance technologies to identify abnormal trading patterns may more frequently flag certain trading activities of HFT firms as suspicious. This may result in these firms facing more investigations and reviews, compelling them to adjust trading algorithms to mitigate the risk of being flagged by regulatory agencies as suspicious trades.

3. Problem Definition

HFT serves as a vital component of financial markets and is directly influenced by changes in regulatory environments [25,26]. However, the ambiguity and uncertainty of regulatory announcements present a challenging issue for HFT firms. To address this, we have selected the implementation of regulatory laws such as the Dodd–Frank Act as a case study. Studying how HFT firms respond to these regulatory challenges not only aids in understanding the adaptability and resilience of HFT firms but also provides insights into the stability of financial markets. In order to prevent systemic financial risks caused by financial storms like the one in 2008–2009, the United States enacted the Dodd–Frank Act in 2010, which mainly aimed to reduce risks in the financial system, improve transparency, and protect the financial rights of investors. The scope of this act is very broad, with Titles I to XVI covering topics ranging from strengthening the regulation of large insurance companies and financial derivatives and requiring hedge funds to publicly disclose product information and protect consumer financial rights. Its content exceeds 800 pages, making it the largest act in recent times [27]. However, at the beginning of the enactment of the Dodd–Frank Act, some of these provisions are relatively vague, leaving considerable room for interpretation regarding their implementation and enforcement. For example, the provisions regarding the use of insider information and the prohibition of fraudulent activities in Sections 746 and 747 of the Act are essentially aimed at consumer protection, yet they have been subject to controversy due to their lack of mens rea requirements. This is because instances of unfair transactions may sometimes be a result of subjective malice, while in other cases, they may arise inadvertently [28]. Furthermore, regarding the content of Section 747 (6), wherein it stipulates that the Commission may promulgate such rules and regulations as it deems necessary or appropriate in the public interest and for the protection of consumers to carry out the purposes of Section 747 (5), which prohibits transactions and practices detrimental to the maintenance of a fair and orderly market, such ambiguous provisions may grant law enforcement officials considerable discretionary power during the enforcement process. HFT firms, in particular, often face various moral condemnations [29,30] for actions perceived as undermining fair trading practices, which may compel them to incur additional compliance costs to ensure adherence to relevant laws and regulations, thus minimizing various forms of scrutiny from law enforcement authorities.

Based on the relevant definitions and methods of the DIKWP model, we conduct DIKWP transformation analysis on the case study across four dimensions: incompleteness, inconsistency, imprecision, and incorrectness, and construct an impact matrix.

3.1. Incompleteness of Content

Based on the content in Table 1, we employ the DIKWP model and semantic existence calculation to analyze the uncertainty issues arising from the incompleteness of the case study's content while ensuring compliance with the law and the company's profitability purpose. Specifically, we identify the following uncertainties resulting from the content's incompleteness:

- **Lack of descriptive details in the legislation:** Initially, the legislation lacked specific details, including the identification and management of trading activities deemed to pose risks to market stability, compliance with targeted regulatory requirements, understanding regulatory expectations, and addressing potential regulatory enforcement and penalty standards.

3.2. Inconsistency of Content

Based on the content in Table 2, we have analyzed the uncertainty issues in the case study resulting from the inconsistency of its DIKWP due to its content, starting from the purpose of not violating the law and ensuring profitability for the company, based on the relevant definitions of the DIKWP model and semantic existence computation. One such issue is as follows:

- **Inconsistencies in Implementation Due to Content Understanding Bias:** For instance, legislation that proposes overly broad content, incorporating numerous complex stipulations and requirements, leads to certain provisions being subject to ambiguity and interpretative leeway. This, in turn, results in inconsistencies in the execution of the legislation due to variances in understanding. These discrepancies arise as different implementers interpret the broad and complex language of the law in diverse ways, which affects the uniformity and efficacy of its application.

Table 1. Analysis of the incompleteness in the transformation of DIKWP elements.

	Data	Information	Knowledge	Wisdom	Purpose
Data	N/A	Ambiguous Legislation: Vague definitions hinder accurate translation into regulatory information.	Unclear Provisions: Lack of explicit guidelines hampers the conversion of data into knowledge.	Diverse Data Interpretation: Varied interpretations may lead to different decision-making strategies.	Unclear Business Objectives: Data fails to directly reflect the company's specific purpose.
Information	Over-Simplification: Simplifying complex information into data may lead to the loss of critical details.	N/A	Information Overload: A vast amount of regulatory information may be challenging to integrate into practical knowledge.	Subjectivity in Interpretation: Subjective interpretations of information may influence decision-making.	Disconnect between Information and Objectives: Collected information may not accurately reflect the pathway to achieving purpose.
Knowledge	Underutilization: Existing knowledge fails to translate into practically actionable data.	Lag in Updates: Delayed knowledge updates result in inaccurate information interpretation.	N/A	Knowledge Limitations: Inherent knowledge may restrict innovative decision-making.	Execution Bias: Existing knowledge may not fully align with the requirements for implementing new regulations.
Wisdom	Practice Deficiency: Wisdom is challenging to directly translate into specific data operations.	Ethical Considerations: Ethical and moral considerations influence information processing.	Innovation Constraints: Traditional wisdom may limit the acceptance of new knowledge.	N/A	Decision Conflicts: Considerations based on wisdom may conflict with business purpose.
Purpose	Difficulty in Concretizing Objectives: purpose is challenging to be transformed into clear data forms.	Goal-oriented Information Selection: Selecting information based on purpose may overlook crucial data.	Strategy Formulation: Purpose guide the formation and application of knowledge strategies.	Value-Driven Decision Making: Purpose influence the application of wisdom and decision-making direction.	N/A

The "N/A" means that the DIKWP element corresponding to the target can be directly transformed.

3.3. Imprecision of Content

Based on the content in Table 3, we have analyzed the uncertainty issues in the case study resulting from the imprecision of its DIKWP due to its content, starting from the purpose of not violating the law and ensuring profitability for the company, based on the relevant definitions of the DIKWP model and semantic existence computation. One such issue is as follows:

- **Ambiguity in regulatory requirements and boundaries:** Due to certain provisions of the legislation being rather vague, HFT companies are required to expend more resources in interpreting regulations to ensure compliance with legal requirements. This entails not only direct financial costs, such as hiring legal consultants for advice, but also time costs, especially in the initial phase of new regulations. The uncertainty regarding compliance may necessitate a more cautious approach by companies, thereby slowing down their decision-making and trading speed.

Table 2. Analysis of the inconsistency in the transformation of DIKWP elements.

	Data	Information	Knolwdge	Wisdom	Purpose
Data	N/A	The uncertainty caused by inconsistency lies in the differences in interpreting trading data, such as varying understandings of what constitutes "abnormal trading behavior".	Inconsistencies in data quality and completeness may affect knowledge construction, such as developing risk assessment models based on incomplete trading data.	Subjectivity in data interpretation may influence wise judgments regarding compliance and risk, such as how to remain competitive while adhering to regulatory requirements.	The objectives of data collection may vary due to inconsistent understandings, such as collecting data related to regulatory reporting vs. data related to profit optimization.
Information	N/A	N/A	Different interpretative frameworks of information may lead to inconsistencies in knowledge construction, such as varying understandings of market trends.	In the transformation from information to wisdom, stakeholders' values may result in different uses of the same information, influencing decisions regarding compliance and risk management.	Inconsistent interpretation of information and goal setting may result in a disconnect between objectives and actual operations, such as misunderstandings of regulatory information leading to non-compliant transactions.
Knowledge	N/A	N/A	N/A	The transformation of knowledge into wisdom is influenced by individual or corporate values, which may lead to different applications of compliance and ethical standards.	Inconsistencies between knowledge and purpose may result in strategy implementation not aligning with company objectives, such as conflicts between risk preferences and compliance requirements.
Wisdom	N/A	N/A	N/A	N/A	Wisdom significantly influences the formation of purpose, but differences in individual or team values may lead to different strategies and goal setting.
Purpose	The direction of data collection and analysis is influenced, but if the goals are unclear or changeable, it may result in inconsistent data strategies.	Purpose-Driven information needs, if inconsistent with actual operations, may lead to overlooking important information.	Purpose influence the direction of knowledge application, and inconsistency may result in a disconnect between strategic execution and actual needs.	Purpose are influenced by wisdom, but inconsistent values may lead to misjudgments in execution direction.	N/A

The "N/A" means that the DIKWP element corresponding to the target can be directly transformed.

Table 3. Analysis of the imprecision in the transformation of DIKWP elements.

	Data	Information	Knowledge	Wisdom	Purpose
Data	N/A	Ambiguous regulatory requirements may result in collected data not meeting the expectations of regulatory agencies.	Insufficient data can impact the accurate understanding of regulatory implications.	Data uncertainty leads to incomplete considerations in decision-making.	The imprecision of data results in the inability to accurately devise compliance strategies.
Information	N/A	Imprecise interpretation of information leads to discrepancies in understanding regulations.	The diversity of information results in ethical decision-making dilemmas.	Imprecise information affects the clarity of compliance objectives.	N/A
Knowledge	Enhancing understanding of regulatory purpose.	N/A	Limited knowledge restricts effectiveness in complex decision-making.	Knowledge constraints impact strategy formulation and goal attainment.	Enhancing understanding of regulatory purpose.
Wisdom	Data selection and optimization from the perspective of wisdom.	Wisdom guides deeper information analysis.	Wisdom aids in identifying critical knowledge.	N/A	Wisdom directs goal setting and strategic realignment.
Purpose	Purpose-Driven data collection and analysis.	Clear goal-setting guides information gathering and utilization.	Objective-driven accumulation and application of knowledge.	N/A	N/A

The "N/A" means that the DIKWP element corresponding to the target can be directly transformed.

3.4. Incorrectness of Content

Based on the content in Table 4, we analyzed the uncertainties arising from the incorrectness of DIKWP in the case, guided by the DIKWP model and relevant definitions of semantic existence computation, without violating the law and ensuring the company's profitability purpose.

- **Misunderstanding of HFT definition:** The lack of clear definition or ambiguity in the definition of HFT in the regulations may lead to misunderstandings among companies. This could result in the incorrect adjustment or cessation of certain legitimate trading strategies, or the oversight of some regulated activities.

In summary, these issues underscore the key challenges that HFT firms face in complying with the Dodd–Frank Act, including the difficulty in interpreting regulations, the increase in compliance costs, and the uncertainty and inconsistency in implementing compliance strategies. The key to addressing these issues lies in enhancing internal compliance auditing and risk management capabilities, and continuously monitoring regulatory changes to ensure the flexibility and adaptability of strategies and operations.

Table 4. Analysis of the incorrectness in the transformation of DIKWP elements.

	Data	Information	Knowledge	Wisdom	Purpose
Data	N/A	Data of incompleteness or incorrectness collection.	N/A	N/A	N/A
Information	N/A	N/A	Misinterpretation or oversimplification of information.	N/A	N/A
Knowledge	N/A	N/A	N/A	Decision-making based on incorrect information.	N/A
Wisdom	N/A	N/A	N/A	N/A	Wisdom directs goal setting and strategic realignment.
Purpose	Collecting irrelevant or misleading data.	N/A	N/A	N/A	N/A

The "N/A" means that the DIKWP element corresponding to the target can be directly transformed.

4. Problem Processing

In order to address the issues encountered in the case analysis presented in the previous section, we will utilize concepts and methods related to Concept Space, Cognitive Space, and Semantic Space to analyze and attempt to address these problems.

4.1. Concept Space

Below is a Concept Space (ConC) definition and attributes tailored to the impact of the Dodd–Frank Act on HFT firms. The construction of the Concept Space aims to analyze the main issues faced during the implementation of the act and their implications for HFT.

4.1.1. Definition

As illustrated in Figure 2, a Concept Space is a collection of related concepts interconnected by specific attributes and relationships, forming a directed or undirected graph based on the symmetry of concept relations. Drawing upon Zaharudin's perspective [31], we have constructed a conceptual graph in the Concept Space of HFT features. In this graph, we classify concepts based on the mapping of data, information, knowledge, wisdom, and purpose [7–9]. This classification includes data nodes, information nodes, knowledge nodes, wisdom nodes, and purpose nodes, forming data graphs, information graphs, knowledge graphs, wisdom graphs, and purpose graphs, respectively. Together, they constitute the conceptual graph in the Concept Space of HFT features. We use $Graph_{ConC}$ to represent them here. Thus, a Concept Space can be represented using the following equation:

$$Graph_{ConC} = (V_{ConC}, E_{ConC}) \tag{11}$$

where V_{ConC} is the set of nodes representing concepts, and E_{ConC} is the set of edges representing relationships between concepts.

4.1.2. Basic Attributes

In the Concept Space, each concept $v \in V_{ConC}$ is associated with a set of attributes $A(v)$ and relationships $R(v, v)$ with other concepts. For the attributes

$$A(v) = \{a_1(v), a_2(v), \ldots, a_n(v)\} \tag{12}$$

where each $a_i(v)$ represents an attribute of concept v. Therefore, the concepts defined for the issues discussed in the previous section are as follows:

- According to the definition of HFT (V_h)[31], where the attribute is

$$A(v) = \{a_{h1}, a_{h2}, a_{h3}, a_{h4}, a_{h5}\}, \quad (13)$$

the attributes represented from a_{h1} to a_{h5}, respectively, are whether it is algorithmic trading, whether high-speed and sophisticated computer programs or systems are used for trading, order-to-trade ratio threshold, short-term holding threshold, and whether positions are closed at the end of the trading day.

- Regulatory boundaries (V_b), with attributes as follows:

$$A(v) = \{a_{b1}, a_{b2}, a_{b3}, a_{b4}, a_{b5}\} \quad (14)$$

where attributes represented by a_{b1} through a_{b5}, respectively, are the statutory item, type of regulation, upper regulatory limit, lower regulatory limit, and penalty content.

- Interpretation details of the legislation (V_d), with attributes as follows:

$$A(v) = \{a_{d1}, a_{d2}, a_{d3}\} \quad (15)$$

where a_{d1} represents the content of the statute, a_{d2} represents the provisions of the statute, and a_{d3} represents the interpretation of the statute.

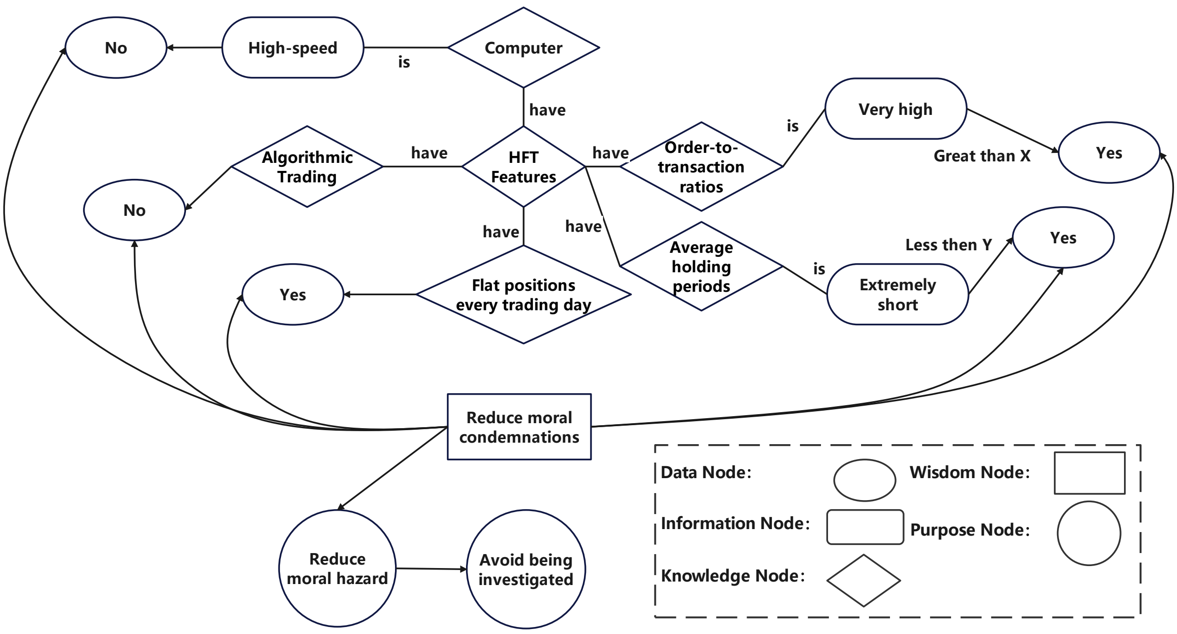

Figure 2. A case of Concept Space.

4.1.3. Relation

In the Concept Space, $R(v, v')$ denotes the relationship between concepts v and v'. If the graph is directed, then $R(v, v')$ is not equivalent to $R(v, v)$; if the graph is undirected, then they represent the same relationship. Therefore, based on the previous problem analysis, we can define the relationships accordingly.

- The relationship between the HFT definition and legislative interpretation details is as follows:

$$R_{hd} = (V_h, V_d) \quad (16)$$

In the preceding equation, the relational link R_{hd} signifies the association between the definition of HFT and the specific interpretation of its regulatory content, thereby ensuring completeness and consistency for stakeholders within the Concept Space.

- The relationship between regulatory boundaries and legislative interpretation details is as follows:

$$R_{bd} = (V_b, V_d) \tag{17}$$

In the previous equation, the relational link R_{bd} signifies the association between each regulatory boundary and the specific interpretation of legislative content, ensuring stakeholders' understanding of the precision and correctness of regulations within the Concept Space.

4.1.4. Operation

The operation of Concept Space involves a series of actions performed within the Concept Space to query, add, or modify concepts and their relations.

- **Query operation:** The querying operation involves retrieving a relevant set of concepts within the Concept Space based on query conditions q (such as specific attributes or relations). It can be expressed as follows:

$$Query(V_{ConC}, E_{ConC}, q) \rightarrow \{v_1, v_2, \ldots, v_m\} \tag{18}$$

where V_{ConC} and E_{ConC} were defined in Section 4.1.1. We can utilize the aforementioned equation to query all concepts related to HFT, for instance, retrieving all companies employing HFT within a certain order-to-trade ratio range.

- **Add operation:** We can add a new concept v to the concept set V_c using the following equation:

$$Add(V_{ConC}, v) \tag{19}$$

For example, due to the addition of a new regulation, we need to add the interpretation of this regulation to the corresponding concept set.

- **Modify operation:** Furthermore, we can maintain the relevant attributes of existing concepts through the following operation:

$$Update(V_{ConC}, v, A(v)). \tag{20}$$

For example, due to changes in the thresholds for HFT stipulated in the regulations, we need to modify the threshold attribute in the HFT definition clause to update the Concept Space.

Through the above formal representation, HFT firms can more clearly identify and understand the specific impacts of the Dodd–Frank Act on their businesses, particularly in terms of definition misunderstandings, regulatory ambiguity, inconsistent enforcement, and missing details in the act's description. This aids companies in formulating more effective strategies to ensure compliance while optimizing their trading strategies and operational efficiency.

4.2. Cognitive Space

The Cognitive Space (ConN) provides a framework for describing and analyzing cognitive processes, namely how input data or information is transformed into understanding, decision-making, or action. This concept is particularly crucial in handling data, information, knowledge, wisdom, and purpose (DIKWP) as it reveals how individuals or systems understand and respond to the external world through unique cognitive processing. Below is a formal description of the definition and processing of Cognitive Space.

4.2.1. Definition

Function set:

$$R = \{f_{ConN_1}, f_{ConN_2}, \ldots, f_{ConN_n}\} \tag{21}$$

where each function $f_{ConN_i} : Input_i \rightarrow Output_i$ represents a specific cognitive processing process, where $Input_i$ is the input space and $Output_i$ is the output space.

Therefore, the processing functions for the cognitive content understanding and execution of n financial companies are represented as follows:

$$R = \{f_{ConN_{u1}}, f_{ConN_{u2}}, \ldots, f_{ConN_{un}}\} \tag{22}$$

4.2.2. Input and Output Space

The relationship between the input space and output space of the Cognitive Space is depicted in Figure 3, where cognitive processing within each function $\{f_{ConN_1}, f_{ConN_2}, \ldots, f_{ConN_i}\}$ process graphically represented DIKWP as DIKWP cognitive input denoted as $Input_{DIKWPG}$. Following the output of each cognitive processing function as the DIKWP cognitive output denoted as $Output_{DIKWPG}$, it serves as input into the subsequent processing function and is merged into the output space of the new Cognitive Space, denoted as $ConN'$ below Figure 3. After i iterations, all DIKWP cognitive inputs and outputs, respectively, constitute their own DIKWP cognitive input space and DIKWP cognitive output space.

- **Input space** $Input_i$ represents the collection of perceived data or information in Figure 3, which can originate from observations from the external world, signals received from other systems, or internally generated data. For the cognitive content input space of n financial companies, there is only one, denoted as $Input_{u1}$, representing the input of legislative content.
- **Output space** $Output_i$ represents the collection of processed understandings or decisions in Figure 3, which may include categorization of information, formation of concepts, determination of purpose, or establishment of action plans. For the cognitive content output space of n financial companies, there are n spaces, denoted as

$$Output_u = \{Output_{u1}, Output_{u2}, \ldots, Output_{un}\}. \tag{23}$$

In Equation (23), from $Output_{u1}$ to $Output_{un}$ represent the cognitive output spaces that each company may execute for the same legislative content input. The cognitive output space for each company may vary, and we denote the collection of cognitive output spaces for each company as $Output_u$.

4.2.3. Cognitive Processing

Each cognitive processing function f_{ConN_i} can be further refined into a series of substeps, including data preprocessing, feature extraction, pattern recognition, logical reasoning, and decision making. These substeps collectively constitute a complete cognitive pathway from raw data to the final output.
The representation of substeps, for each f_{ConN_i}, can be represented as follows:

$$f_{ConN_i} = f_{ConN_{i(5)}} \circ f_{ConN_{i(4)}} \circ \cdots \circ f_{ConN_{i(1)}} = (Input_i) \tag{24}$$

where $f_{ConN_{i(j)}}$ with j representing the jth substep processing function, and the "∘" denotes function composition. Therefore, for each financial company, with the same legislative content composing the input space, the inconsistency in cognitive processing leads to inconsistency in the output space. This can explain the deviation in understanding the legislation among financial companies, resulting in the erroneous adjustment or cessation of certain legitimate trading strategies, or the oversight of activities subject to regulation.

In the DIKWP model, the Cognitive Space transforms data, information, knowledge, wisdom, and purpose into specific understanding and actions through the unique cognitive processes of individuals or systems. By employing different cognitive processing functions, the system can implement the most appropriate processing strategies for different types of inputs, achieving efficient and accurate decision-making.

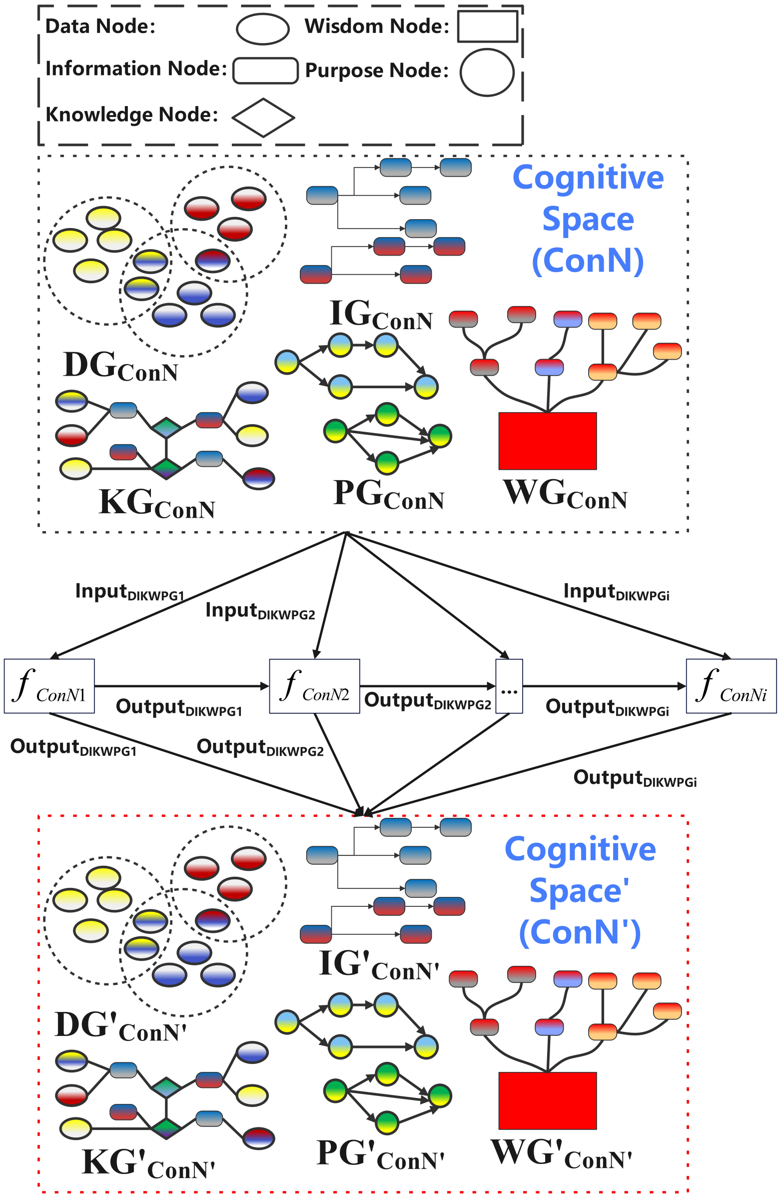

Figure 3. Input and output of Cognitive Space.

4.3. Semantic Space

The Semantic Space (SemA) is a collection of semantic units interconnected through specific associations and dependency relationships, collectively constituting an objective representation of information and knowledge. Widely accepted concepts and linguistic rules within the Semantic Space facilitate the transmission and exchange of meaning. In Figure 4, we extend upon Figure 2, supplementing semantic relationship content, completing concept mappings, and constructing a Semantic Space. We provide an example identified by an HFT firm. In situations where the discretionary boundaries retained in the legislation remain ambiguous, enforcers, regarding the concepts X and Y within the Concept Space depicted in Figure 2, may transform their own cognitions into corresponding semantic relationships. These relationships are utilized as inputs in the DIKWP framework for determination, potentially leading to investigations against financial firms meeting such criteria.

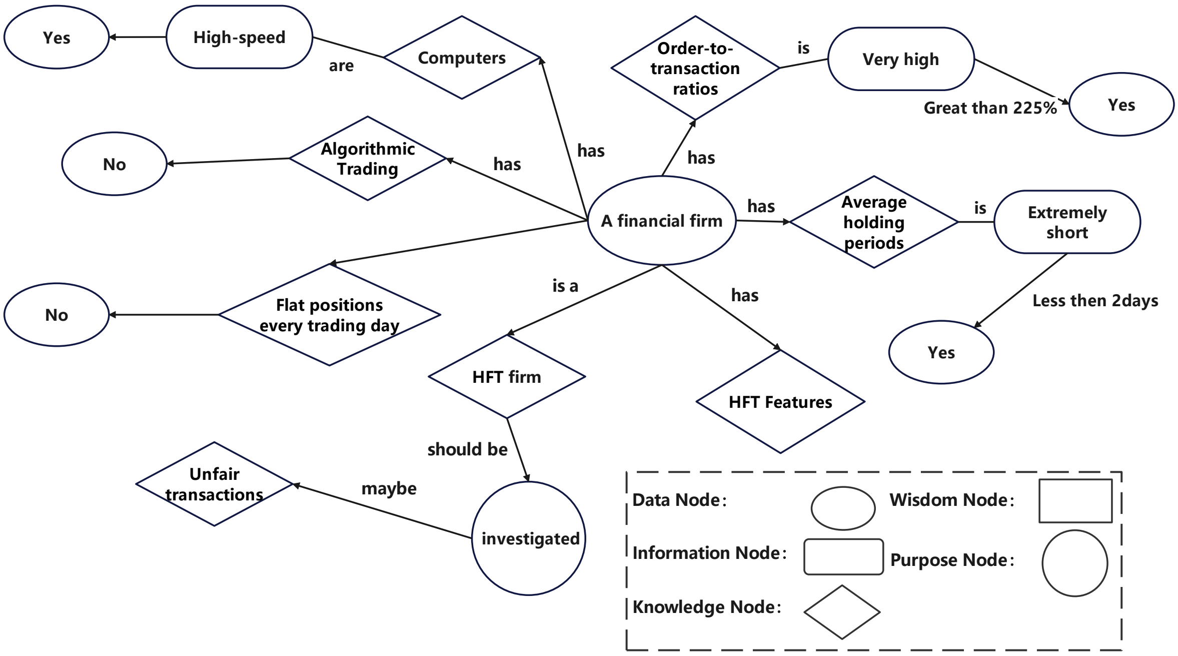

Figure 4. A case of Semantic Space for identification of an HFT firm.

4.3.1. Definition

We represent a semantic graph in Semantic Space using a graph denoted as $Graph_{SemA}$:

$$Graph_{SemA} = (V_{SemA}, E_{SemA}) \tag{25}$$

where V_{SemA} represents semantic units (words, sentences, etc.), and E_{SemA} represents the associations and dependency relationships between semantic units.

4.3.2. Semantic Units and Relations

In the Semantic Space, a series of operations correspond to querying, adding, or modifying semantic units and their relationships.

- **Query operation:**

$$Query(V_{SemA}, E_{SemA}, q) \tag{26}$$

The previous equation returns a set of semantic units that satisfy the query condition q.

- **Add operation:** $Add(V_{SemA}, v)$, adds a new semantic unit vs. to the set V_{SemA}.
- **Update operation:** $Update(E_{SemA}, v, v', e)$ updates or adds the relationship e between semantic units v and v'.

4.3.3. Operation and Application

Based on the relevant definitions and concepts of the Semantic Space, we attempt to analyze and address the issues faced by financial firms in executing the legislation regarding HFT mapped into the Semantic Space as discussed in the previous section. Here, we focus on analyzing the issue of "inconsistency in execution due to content interpretation bias" within the Semantic Space.

- We define a semantic unit $v_{SEmALawUB}$ to represent interpretation bias, and $E_{SemAlaw}$ represents the associations and dependency relationships between the semantic unit, which belong to the legal Semantic Space denoted as $Graph_{SemALaw}$:

$$Graph_{SemALaw} = (V_{SemALaw}, E_{SemAlaw}) \tag{27}$$

- We can use query operations to retrieve units of inconsistency in the execution process:

$$Query(V_{SemALaw}, E_{SemAlaw}, q_{UBias}) \rightarrow \{v_{SEmALawUB}\} \quad (28)$$

where condition q is interpretation bias in law.

- The addition operation can be utilized to enrich the Semantic Space of legal understanding:

$$Add(V_{SemALaw}, v_{SEmALawUC}) \quad (29)$$

where $v_{SEmALawUC}$ represents semantic units reflecting accurate legal comprehension.

- Furthermore, the Semantic Space can also be refined through update operations, as illustrated by the following equation.

$$Update(V_{SemALaw}, v_{SEmALawUC}, v_{SEmALawUB1}, e_{UBias}) \quad (30)$$

where e_{UBias} is comprehending bias and the purpose of this operation is to establish new semantic units, $v_{SEmALawUB1}$, representing the understanding biases existing alongside the accurate legal comprehension $v_{SEmALawUC}$.

The Semantic Space not only aids in identifying and resolving issues encountered in the execution of the Dodd–Frank Act but also provides a methodological approach to clarify the interpretation and application of the act through precise semantic operations. This allows for the identification of misunderstandings, ambiguities, and semantic units in execution, and facilitates continuous optimization and updates through new understandings, enriching the Semantic Space. Such an approach not only helps clarify ambiguous sections of the act but also fosters effective communication among different stakeholders regarding the interpretation and implementation of the act, ensuring regulatory compliance and transparency.

4.4. Crossing-Space Processing of DIKWP

At the bottom of Figure 1, the cross-space processing by DIKWP is driven by purpose, where $T_{A \rightarrow B}$ denotes the transformation function from space A to space B under the impetus of purpose, signifying the processing pathway of stakeholders from Cognitive Space to Concept Space and then to Semantic Space.

4.4.1. Mapping from Concept Space to Cognitive Space

- **Definition:** The concepts in the Concept Space are combined through the intrinsic cognitive mechanisms of individuals or systems, along with personal experience and knowledge, to form unique understandings and interpretations.

$$T_{ConC \rightarrow ConN} : ConC \rightarrow ConN \quad (31)$$

Equation (31) represents the process from the concept $c \in ConC$ to cognitive processing $r \in ConN$, reflecting how individuals understand and interpret concepts.

- **Application:** For instance, financial firms adjust parameters related to high-frequency trading based on their trading and system development experience, ensuring compliance with the concept attributes $A(v) = \{a_{b1}, a_{b2}, a_{b3}, a_{b4}, a_{b5}\}$ of the regulatory boundary V_b. Hence, this process can be regarded as a mapping from the Concept Space to the Cognitive Space.

4.4.2. Mapping from Cognitive Space to Semantic Space

- **Definition:** Transforming internal understanding within the Cognitive Space into semantic expressions that can be comprehended and accepted by the external world.

$$T_{ConN \rightarrow SemA} : ConN \rightarrow SemA \quad (32)$$

Equation (32) represents the transformation from cognitive processing to semantic expression, encompassing the selection and organization of language and symbols to accurately articulate cognitive content.

- **Application:** For instance, in situations where regulatory boundaries are ambiguous, some provisions merely describe illegal boundaries descriptively rather than quantitatively. However, as current computer systems require qualitative analysis of inputs to ensure the accuracy of outputs, it is necessary not only to represent these fuzzy boundaries in the Semantic Space and input them but also to first convert the expression of fuzziness into concepts in the Cognitive Space before processing them into parameters of the trading system to ensure compliance with legal standards. In the aforementioned process, we can interpret and express the mapping and processing from Cognitive Space to Semantic Space using Equation (32).

4.4.3. Feedback from Semantic Space to Concept Space and Cognitive Space

- **Definition:** Feedback from the external world to semantic expression is transmitted through the Semantic Space, thereby influencing Concept Space and Cognitive Space, forming a closed-loop process of cognitive updating and learning.

$$T_{SemA \to ConC} : SemA \to ConC \tag{33}$$

$$T_{SemA \to ConN} : SemA \to ConN \tag{34}$$

Equations (33) and (34), respectively, represent the feedback process from semantic expression to concept updating and cognitive updating, achieving dynamic adjustments and learning of internal understanding and concepts in response to external feedback.

- **Application:** For instance, when a financial company faces penalties, it generates new semantic content and expressions regarding the regulatory boundaries of the legislation. The penalties prompt the company to develop new conceptual attributes regarding the legislation and to perform corresponding operations on its previously vague Concept Space. As the Concept Space changes, the mapping function $T_{ConC \to ConN}$ from Concept Space to Cognitive Space varies accordingly, resulting in new cognition that is reflected in concrete actions. This refers to the process of handling the "4-N" problems under the acceptance of external feedback and Purpose-Driven circumstances, as outlined in the definition: this process constitutes a closed-loop cognitive updating and learning process.

In summary, we integrate the mapping and feedback processes to form a dynamic and interactive DIKWP model framework, where Cognitive Space, Concept Space, and Semantic Space interact and influence each other, presenting the complete process from subjective understanding to objective semantic processing.

5. Conclusions

Through the application of the DIKWP model, we conducted an in-depth analysis of the complex challenges faced by HFT firms in adapting to and complying with the Dodd–Frank Act. These challenges encompass various dimensions, including the ambiguity of legal definitions, the vagueness of regulatory requirements, the inconsistency in enforcement standards, and the lack of detail in the act, which we categorized into the "4-N" problems for analysis. We provided a comprehensive analytical framework involving Cognitive Space, Concept Space, and Semantic Space, followed by a case study analysis and practical application. This not only revealed effective strategies for identifying and addressing these challenges faced by HFT firms but also demonstrated how to enhance operational efficiency while ensuring regulatory compliance. While acknowledging the practicality and efficacy of the DIKWP model in addressing financial uncertainties, it is crucial to recognize the study's limitations, primarily its focus on the HFT sector, potentially limiting broader applicability across the financial realm, and the static assumption of the regulatory landscape, overlooking the dynamic evolution of regulations over time.

Future inquiries should broaden the scope to evaluate the DIKWP model's utility across diverse financial transactions, develop dynamic models responsive to shifting regulatory contexts, undertake longitudinal studies to gauge the long-term impacts of the model and integrate cutting-edge technologies, such as artificial intelligence, to augment the model's performance and relevance. In summary, our proposed methodology not only holds significant practical value for management and compliance professionals in HFT firms but also offers profound insights and theoretical support for financial regulators, policymakers, and researchers in financial technology.

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