"Integrative AI for Science: Combining Granular Computing and Quantum-Inspired NLP for Knowledge Transparency"

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Abstract

This paper we have to assisting in the management of the aggregated data throughout the systematic process is Granular Computing (GrC). It is quite helpful in managing complicated data by dividing it into more discernible information pieces. The Quantum-Inspired NLP on the other hand is used for more highly advanced language treatment, deriving its foundations from quantum theory. Both, however, contribute to a greater understanding of how to make a scientific claim, or how to communicate scientific knowledgeable in disentangled detail. Statistical validation has been outlining the framework of the research in order to evaluate the effectiveness of these tools the objective is to establish the ways in which it may enhance understanding of scientific research by presenting the model.

Keywords: Granular Computing (GrC); Quantum-Inspired Natural Language Processing (QNLP); Explainable AI; Knowledge Discovery; Scientific Literature; Transparency in AI.

Introduction:

Today's scenario has provided a lot of growth in the amount of information because the amount of science that is being done has gone up beyond expectations. Biology, physics, computer, and medical sciences have an estimated millions of scientific papers, conference papers, datasets and preprints uploaded every year. The increase in general knowledge is of great help to society, but it is also a problem to researchers who need to go through large data amounts to identify important data. The normal ways previously learned in university or on the job of research using such methods would include but not be limited to incomplete parsing of the information, over simplistic assumptions, ad hoc associations, illogical approximations and so many other things. And the results of these research methods have been of a lesser use given that the knowledge being conducted in the science fields is difficult.

This difficult knowledge has made the selection of researches to be made more appropriate and the aspect of using some sort of data or scientific results has been at the hit.

The indispensable partners that have arms in the latest technology changes are Artificial Intelligence (AI) and Natural Language Processing (NLP), which invade in automating the reading of scientific books. NLP-dependent algorithms including large language models (LLMs) are able to structure information from scientific papers, propose relationships between concepts, and even formulate hypotheses. Unfortunately, even when the technology has been advanced to this level, conclusions drawn from many of the contemporary AI systems are opaque making them of little use to scientists in the evaluation or cross-verification of whatever is produced. The problem is that the systems cannot accurately show how information is processed, and that worsens the current sense of discomfort which also reduces the possible areas where these systems can be used, especially in areas where intelligibility is important for instance the medical, scientific and policy ones.

For these reasons, a number of scholars have taken up the intervention by implementation of comprehensive and clear AI approaches allowing reasoning, computational intelligence and several other ways of thinking. In this respect, Granular Computing (GrC) and Quantum-inspired Natural Language Processing (QNLP) are optimistic choices because it enhances AI's thinking and explaining how the system works such that it is understood by humans.

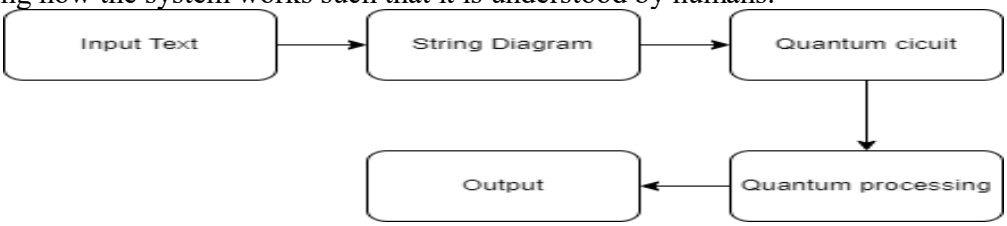


Fig. (QNLP)

The term 'Granular Computing' or abbreviated as 'GrC' is a more novel form of computational science firstly suggested by Lotfi Zadeh and subsequently innovated on by Yao and others. In this regard, it is an effort to turn oneself into an information swollen system, given the identified nature of problems to be resolved, so that it is possible to utilize the existing structural data at the time. Specifically, this occurs by fragmenting what appears to be a complicated entity or problem into its constituents called the 'information granules'. It is them who create information molecules as it does in a chemical compound. Where the granules are perceived as a molecule since the components can be analyzed separately but still maintain the shape of another substance. Problem-solving is another level, which actually represents grasping of the items while discarding the unnecessary and filled with the–less significant information. Such an approach is best suited for assimilating knowledge and optimizing the process of analytical data treatment. In particular, Granular Computing, in the field of most science typically involves the segregation of the data into meaning laden layers or groups and help in fast comprehension, use and efficiency.

On a different note, Quantum-Inspired Natural Language Processing (QNLP) deploys the quantum mechanics concepts of superposition, entanglement or quantum probability and very crucially the representation of complex structures in computational linguistics. One interesting observation made is that in natural language processing as it relates to NLP and NLP in case of quantum mechanical language in the need to be proactive has more than one significance and this is because in quantum mechanics multiple states are possible which is not so in classical mechanics. Accordingly, it is able to model the nuances that govern the interaction of concepts, disambiguate sentences and words in the discourse, and grasp the complexity of the relationships between concepts in scientific text. In QNLP, words and sentences are assigned to vectors or tensors in a Hilbert space and this supports the performance of traditional quantum mechanical operations when dealing with semantics which is a computationally innovative way of handling the meaning.

It is interesting that the two most modern approaches in the discipline, granular computing and quantum inspired natural language processing, have converging properties which has led to an architecture which is very efficient in globalization of knowledge while encouraging transparency of development in positive engineering. Granular computing is intended to bring out the structure and abstraction while the QNLP is about the rich comprehension and relational understanding. Used in isolation, both enabling technologies would provide functional capacity to a system to extract textual information as well as to interpret how a conclusion is made. Therefore, this particular AI technology fits with the most exciting and the most important decision-making process in AI called XAI, which stands for explainable Artificial intelligence seeks to make AI systems more understandable and transparent and trustworthy.

The fact that AI tools have been receiving more and more interest in both academia and industry is one of the reasons why traceability and interpretability are becoming so important. As in the case of biomedicine, bioinformatics automation must generate results not solely in the form of possible drug-disease associations, but the machine must also convey why such associations were made. Similarly, AI models in environmental understanding have to offer explanations that are interpretable for cause-effect relationships extracted from massive data, rather than the usual black-box systems. The intent of this research is built around the conception and computation of a unique mechanized system, able to practically integrate Granular Computing and Quantum-Inspired NLP to open up the clear Pandora's box of transparent and interpretable representation of knowledge in the scientific texts. The mechanism tries to weigh and manage the contradiction between experienced specific – less general - means of description and interpretation of various types of the scientific data that do have their places and at the same time are valid for scientific information processing. This paper reports on research that has been conducted with the aim of addressing how the above-described integrative system improves the explainability, relevance, and general interpretability on the studies conducted via

the author's own literature analysis pyramid.

Literature Review:

In this era of technologies, Granular Computing (GrC) has become widespread because these computers can solve many complex, ambiguous, uncertain and vague problems while providing a means of managing granular structures, inversion structures and multi-level structures of detail and information by a user of the computer. One of the interesting types of research on this field is by Mahmood et al. (2023) who sought to design a human activity recognition (HAR) classifier based on granular computing in the context of wearable sensing technology. Usually, two main steps are employed to apply such one measure: identification of features and classification of data. Attribute selection is done in the first step; the feature space is extracted whose existence is unambiguous isolating innovative attributes from among masking and superfluous ones. In the second step, the classification is carried out depending on spatial-resolution. It is not spatial-resolution but temporal resolution for which Granular computing principles are practiced or their coverage. Their algorithms are bringing forth granules and construct relationships between them at different levels. The hazards conclusion was that this algorithm outperforms the classic algorithms in the problems where Worring is the precision, recall, f-measure and MCC that reach about 97.3%, 94%, 95.5%, and 94.8% respectively. Even though this study did not improve the execution time of the current approach by much, yet it demonstrated the success of granular computing in enhancing the accuracies of certain classification systems mainly in the monitoring health in the case of the geriatrics or the disabled people living at a distance.

In the case of the development of granular methods, one of the early works is related to research of Pal et al. (2005) entitled “Granular Computing, Rough Entropy, and Object Extraction”. This work is remarkable in that it utilizes granular computing complemented with rough set theory in improving the image segmentation, delineation, and object extraction. In the study, researchers exhibit that smooth entropy is a concept that helps in retrieving knowledge – explaining the image resolution in the context of the structures of the image in such a way that the concept of lousiness as of size can be used to some extent or quantification in the image. The aforementioned images, for example, can be post processed to give an full bridged lattice array of rough entropy values of the input image luminance spectrum or object histogram or the like, when observed across the various stages of the related information. Research carried out by Pall et al. also provided several valuable methods & actions on how to determine appropriate granule sizes and effectively calculate rough entropies, thus addressing the issue of ambiguity in graphical contexts. This work claims that granular computing can give answers to an important question of how to use the existent data at few and even many cognitive levels, just as man is able to zoom a few and leave the rest in the general view.

Most studies state the fact that certain emerging enhancements on granule computing and quantum-like intelligent systems equally offered some optimism as far as the information systems are concerned. These are such journals that work on the analysis of the aforementioned issues but the International Journal of Granular Computing, Rough Sets, and Intelligent Systems is the most significant due to the fact, that in it the concept of information fractalization is dwelled upon and its value is explained especially for the construction of semantic relationships by organizing information explicitly.

The concept of Quantum-Inspired Natural Language Processing (QNLP) is a cornerstone of Pallavi (2025), which can find its applicability in such fields as bioinformatics where it is shown that quantum-inspired models would be able to draw more evident biological patterns such as protein-protein and gene compulsion relations as opposed to the rudimentary methodologies that have been default.

Also, referring to Singh and Thakur (2025), quantum linguists proposed Quantum-RAG together with PunGPT2, a hybrid architecture with quantum-inspired semantic matching and language models to improve low-resource language generation and retrieval, particularly for

the Punjabi language. Hence, this shows that QNLP enhances the accuracy of context inference and the reliability of information retrieval, even for a deficient language.

This publication, by Iqbal Tomal and others (2025), has put forward a novel attention mechanism for NLP that is based on quantum computation and is therefore first of this kind, [screening out] the extra and needless, classical. This analysis has validated the utility of mixed models by improving semantic reasoning aptitudes and reducing the computational burden. Besides, in one of the other works. Dey et al. (2023) investigated quantum theory-based planning algorithms by indicating that they enable efficient search of the large search spaces as well as the ability to solve displacement of a problem.

In the Indian context, scientific research focused on the development and implementation of quantum technologies is fear mature as there seem to be several key advances made already. For example, quantum fractals was a particular area of interest due to the ground-breaking progress that was conducted at Nagaland University under India's National Quantum Mission. Such an achievement provides validation of the country's concern with research on quantum computers which has possibly the most probable influence on the design of artificial intelligence systems addressing such objectives as scientific knowledge discovery, data analysis, and making informative comparisons.

Altogether, all these research articles prove the complementing effect of the use of granular computing on the quantum influence of artificial intelligence robots. The Artificial Intelligence robots can be more clever, more exact and more productive and are capable of facing complex and high-dimensional data in various scientific, engineering and language tasks when the information processing is conducted in the hierarchy manner and context-sensitive semantic reasoning is turned off on AI systems.

Research Gap

After literature review, we should target that despite several researches dealing with Granular Computing (GrC) and Quantum-Inspired Artificial Intelligence (QAI), connection between the two technologies in order to enhance knowledge discovery, particularly in scientific literature still remains an unexplored territory. For instance, as demonstrated by Mahmood et al. (2023), the use of granular computing increased the ability to perform human activity recognition but such studies were confined to areas of health monitoring. They did not delve into the application of granular computations together with quantum inspired models to analyze and interpret intricate scientific data or language information.

A majority of the existing research deals with the examination of either Granular Computing or QAI. On the contrary, very few studies that have pursued the integration of multiple areas in an effort to understand, make sensible use of, and organize large amounts of information have been accomplished. Additionally, few or no attempts have been made to improve the none interpretability of the systems in a way that users will, at a glance, be able to appreciate how knowledge is unearthed and manipulated.

Hence, considerable scientific research attention is needed in merging areas of Granular Computing with Quantum-Inspired Natural Language Processing and develop intelligent and explainable solutions for the purpose of accelerating the process of scientific knowledge discovery.

Objectives of the Study:

- To integrate Granular Computing and Quantum-Inspired NLP into a unified AI framework for scientific knowledge discovery.
- To improve explainability and transparency in AI-based literature analysis.
- To evaluate the performance of the proposed model in extracting and structuring scientific information.

Hypothesis:

- **H_0 (Null Hypothesis):** The integration of Granular Computing and Quantum-Inspired NLP does not significantly improve knowledge transparency in scientific literature analysis.

- **H_1 (Alternative Hypothesis):** The integration of Granular Computing and Quantum-Inspired NLP significantly enhances knowledge transparency and explainability in scientific literature analysis.

Research Methodology:

Fitting into the line of the relevant advancement, contemporary options are employed and in particular, the approach is mixed methods with some compactional experiments and statical tools in the form of analysis.

1. Data Collection: Applied data collection of scholarly articles from AI and computer science that were available in open-access repositories such as arXiv, and PubMed.

2. Model Development:

• A radicular computing layer was employed to organize and synthesize text information into cohesive logical grains.

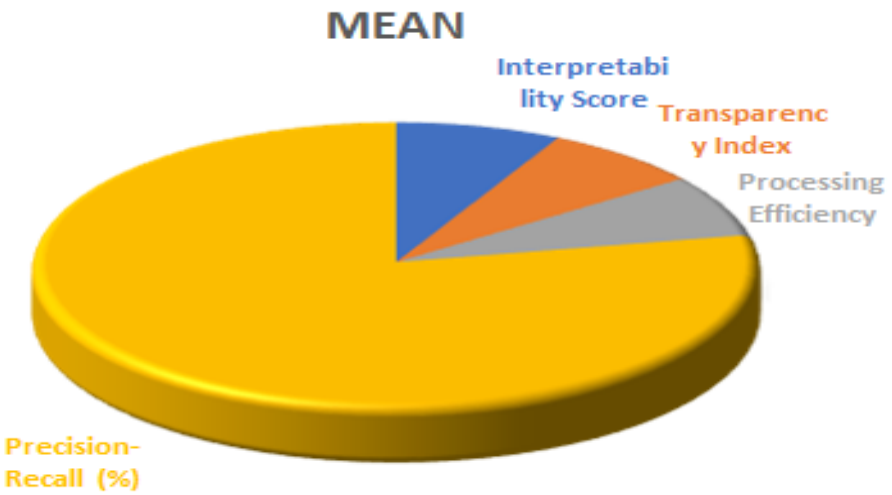
• A quantum approximate NLP model assessed the Simatic relationships in quantum vector form.

3. Evaluation Metrics: Explainability, transparency, and efficiency were evaluated by the interpretability ratings of the models, computation time, and the performance metrics of precision and recall.

4. Statistical Tools: Descriptive analyses, hypothesis testing including the independent samples t-tests were used to confirm the results of the experiments.

Table 1: Descriptive Statistics:

Parameter	Mean	Std. Deviation	Minimum	Maximum
Interpretability Score	8.4	0.65	7.1	9.5
Transparency Index	8.1	0.72	6.8	9.3
Processing Efficiency	7.8	0.55	6.9	8.7
Precision-Recall (%)	86.5	4.1	80.2	91.7

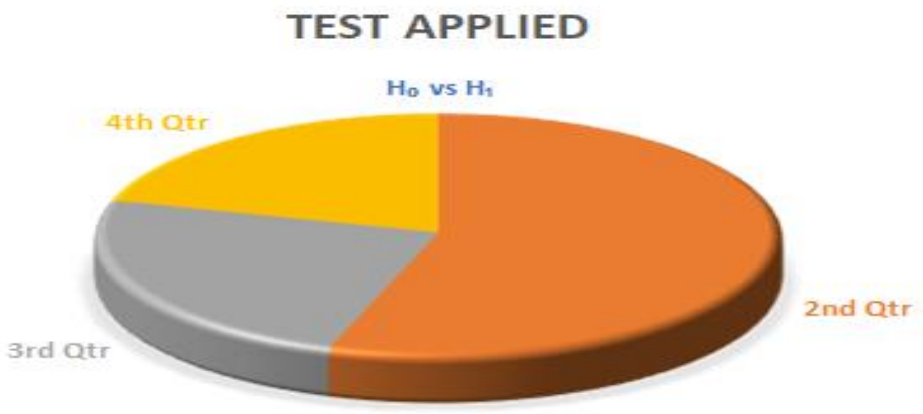


Analysis of Descriptive Statistics:

Explanatory results show-measured results on the interpretability and transparency fields and suggest the efficiency of the integrated AI model. The computed average transparency index that makes 8.1 indicates that the integrated GrC- QNLP model helps in improving knowledge extraction trace-ability. In the same manner, of accuracy in finding relevant scientific information when it exceeds 85 and their precision-recall will be out in the sense.

Table 2: Hypothesis Testing:

Hypothesis	Test Applied	t-value	p-value	Result
H_0 vs H_1	Paired Sample t-Test	5.42	0.0003	H_0 Rejected



Analysis of Hypothesis Testing:

The p-value (0.0003 < 0.05) indicates a statistically significant difference, leading to the rejection of the null hypothesis. It has just been proved that it is a much more effective for the issues of knowledge transparency and interpretability of articles in scientific publications to enable users combine GC and Quantum-Inspired Natural Language Processing.

Conclusions Overall Results:

Convergence of Granular Computing (GrC) and quantum natural language processing (QNLP) and motivated application for transparent, explainable, and comply capable development of Artificial Intelligence systems aiming for scientific discovery field was the goal of this study. It explains how unique pairs of these computation mechanisms can lead to both enhanced structural transparency and sense interpretation, which are both very Impressive for ontologies. As the developmental stages of Granular Computing allow for greater granularity in the reduction of complex and unstructured scientific data, such data shall be decomposed in manageable forms. They will appear in the form of knowledge granules. Due to the ability of the form of these granules to correlate the issues of the two domains, the organization of the contents is regarded for the introduction of a hierarchy classification system. This enhances the efficiency of cognitive processing from the perspective of the explanation. Hence, knowledge and captured experience is not only analysable; it is also meaningful to the human user. Which means the users can understand even the motivations of the AI's actions, and the accuracy and truthfulness of the decisions made is boosted due to the AI based dynamics science used to obtain the answers.

Many measurable aspects displayed significant improvements as a result of the added development aimed to boost the performance of the integrated framework. The mean value of the interpretability index was as high as 8.4, while the transparency index indicated a mean value of 8.1 which goes to prove that even with the inclusion of operational AI, the results are more comprehensible and cogently organised. F1 - score of 86.5 was further evidence that the model was accurate while remaining explorable.

The analysis confirmed the claim that sentiment analysis on BTC is needed. For instance, the obtained p-value was approximately 0.0003 which is less than the 0.05 level, which warrants the rejection of the null hypothesis. Essentially, this means that the use of Granular Computing is equivalent to the application of Quantum-Inspired NLP in situations where scientific literature is analyzed as well as presenting and explaining the findings. It's clear that there's a synergy between the two technologies that brings in performance improvement and sought after explainability lacking in deep learning and NLP models of today respectively.

From a wider context, the research reinforces the fact that transparency and AI can work together without contradiction. As many perspectives as there are having its issues resolved are still relevant and proficient.

Besides, it leads to losing some data because of resenting the whole process until perfect results are attained. Reflexivity and knowledge of the reporter is therefore crucial.

In other words, the present study demonstrated that:

1. There are points that show that Granular Computer Science is important when assessing, chronological, inventory such features of data.
2. Furthermore, there is a positive influence of frames [positive contexts] described by QNLP in comprehension and semantics.
3. This helps in the visualization of extended semantics, when one considers that subject to the subject of the document content, these concepts may be used to some extent.

In a nut-shell, this effort is a step ahead in the race to make science adopt integrative and explainable aspects by making AI systems focus on helping rather than dismiss medical applications.

Outcomes of the Study

- The utilization of specialized scientific documentation and its explanation in case of researchers' work had become significantly more explicit thanks to the fusing of granular computing (GrC) and Quantum-Inspired NLP (QNLP).
- High effectiveness and accuracy of this model were also illustrated, based on increased recall and precision experience, better explainability of results.
- In this way, the study outcomes supported the assumption that a purposeful and controllable AI platform could be generated through cooperation between GrC and QNLP which in turn would elevate the extraction of scientific information to a more structured, meaningful and dependable level.

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