

A COMPARATIVE EVALUATION OF DECISION INTELLIGENCE FRAMEWORKS IN IMAGE PROCESSING APPLICATIONS

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Abstract: Decision intelligence (DI) is a methodology entailing data, models, and human expertise combined for assistance in making tough decisions. Its use in image processing over the recent past has gained much traction, opening avenues for improving tasks such as classification, detection, and recognition. The paper compares some of the leading decision intelligence frameworks in image processing. It exposes how some frameworks combine machine learning with deep learning and rule-based decision-making to improve accuracy, efficiency, and interpretability. Comparison is made on benchmark image datasets in different domains for testing based on computational intensity, scalability, robustness, and decision interpretability. It emerged that even though accuracy is higher for computational intensity combined with DI frameworks based on deep learning, hybrid frameworks involving manual input by humans and automatic drawing of inferences are superior in balancing performance with interpretability. The comparison study shows shortcomings and advantages of each framework and where best it can implement in different image processing tasks while also providing support towards decision intelligence research in computer vision.

Keywords: Decision Intelligence, frameworks, benchmarks, image datasets, evaluation.

Introduction: Decision intelligence (DI) is increasingly becoming a very popular new approach to connecting data science, artificial intelligence (AI), and decision making. Through machine learning model use, computer systems, and human thinking, DI allows organizations and scientists to pull useful information out of large, complex datasets. DI is very crucial since there is a great desire for automatic yet easy-to-understand algorithms for medical image use, remote sensing applications, surveillance applications, and

industrial inspection applications.

Classical image processing uses mostly rules and statistics, while newer technologies seek to utilize deep learning. New technologies allow for greater accuracy in classifying, segmenting, and object detection but do not support in understanding and adapting decision-making. Decision intelligence platforms are thought to overcome such limitations by adding layers which interpret, predict, and recommend in a format that is efficient for computers but understandable for humans.

The paper reviews some decision intelligence frameworks for image processing issues. It discusses how several such frameworks from simple machine learning schemes to hybrid human and machine intelligence schemes function in diverse applications. It compares key characteristics: accuracy, scalability, amount of computational power needed, resistance to noise, and explainability level of decisions made. Based on such an analysis of features, this research shall endeavor to identify what are some benefits as well as trade-offs in

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DOI: <https://doi.org/10.5281/zenodo.19405467>

Article received on: 01 February 2026

Published on web: 10 April 2026, www.ijsonline.org

different decision intelligence frameworks and provide practical advice for their use in real image processing problems.

The paper is structured as follows for the rest: Section 2 describes related works involving decision intelligence application in image processing. Section 3 provides an overview of methodology and experiment set-up employed in comparison study. Section 4 presents test results including a discussion. Section 5 concludes research with results, limitations, and direction for further study.

Related Work: Decision Intelligence is an interdisciplinary approach using artificial intelligence, data science, and social sciences to augment the decision-making process. It is based on progress in machine learning, optimization, and human-centered design-all of which extend far beyond image processing applications. This section provides a literature review in three broad areas: the foundation of decision intelligence, DI in image processing, and a comparison of various frameworks about decision making.

Foundations of Decision Intelligence: The concept of decision intelligence goes beyond analytics by incorporating prescriptive components along with descriptive and predictive models. Business and technology demand for frameworks in decision AI have been well defined by researchers such as Davenport and Harris (2017). Current literature has made clear expectations regarding how DI enhances decision accuracy and explainability through the process of structural modeling of decisions and causal inference. The concepts act as a feasible area for DI in computer vision.

2.2 Decision Intelligence for Image Processing

Image processing has always relied on techniques such as edge detection, filtering, and feature extraction, which later evolved to machine learning-based techniques and deep neural networks. However, the lack of interpretability in only data-driven models has proven challenging in mission-critical domains like healthcare and security. DI frameworks bridge this gap by incorporating decision-making layers that emphasize transparency as well as context-based reasoning. For instance,

hybrid methods relying on CNNs as well as rule-based systems have been demonstrated with encouraging outputs in medical image diagnosis, with accuracy and accountability too. Similarly, DI-based pipelines have also been applied in satellite image analysis, where decision support systems aid in land-use monitoring and disaster management. Research by Tin (2011) includes image processing techniques such as filtering methods to enhance the quality of input images. Image processing applications in human-computer interaction and multimedia communication in Tin (2013).

2.3 Comparisons of Decision-Making frameworks

Comparative studies on decision-making schemes for image processing are very few. Existing literature is rather tipped towards studying decision support systems or deep learning architectures in isolation, rather than persuasively locating these in the DI framework. There have been some recent efforts to map explainable AI techniques into decision transparency to improve image classification accuracy. Some others have experimented with the computational efficiency-against-interpretability trade-offs of different models. Despite these advances, systematic comparison of DI frameworks for image processing tasks is not yet adequately researched, and this is the driving force behind this present research.

Methodology:

This present research adopts a structured approach to compare and study decision intelligence (DI) frameworks applied in image processing applications. The structure has four main parts: dataset choice, framework selection, performance measures, and experimental configuration as depicted in the following figure 1.

The workflow for the system commences at Input Layer where various image datasets like medical image datasets, satellite/remote sensing images, object detection datasets are integrated. These are followed by Preprocessing such that normalization is employed for consistency, resizing for uniformity in size, as well as augmentation for endorsing diversity besides rendering the dataset robust. The key decision intelligence (DI) step is segmented into

transformers, Branch A uses classical machine learning-oriented DI techniques involving Support Vector Machines (SVM) and Decision Trees; Branch B uses deep learning-oriented DI practices involving Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), and Transformers; while Branch C uses a hybrid Human-AI DI model involving CNNs in combination with rule-based reasonings in addition to a human-in-the-loop initiative so as to enhance

interpretability besides reliance. Outputs thus derived are systematically compared based on measures of evaluation such as accuracy, computational intensity, scalability, robustness, as well as interpretability. The last step is at the Results Layer, where the results are combined in comparison tables along with the graphical displays, consequently providing a comprehensive view of the performance, as well as the relevance of the DI techniques.

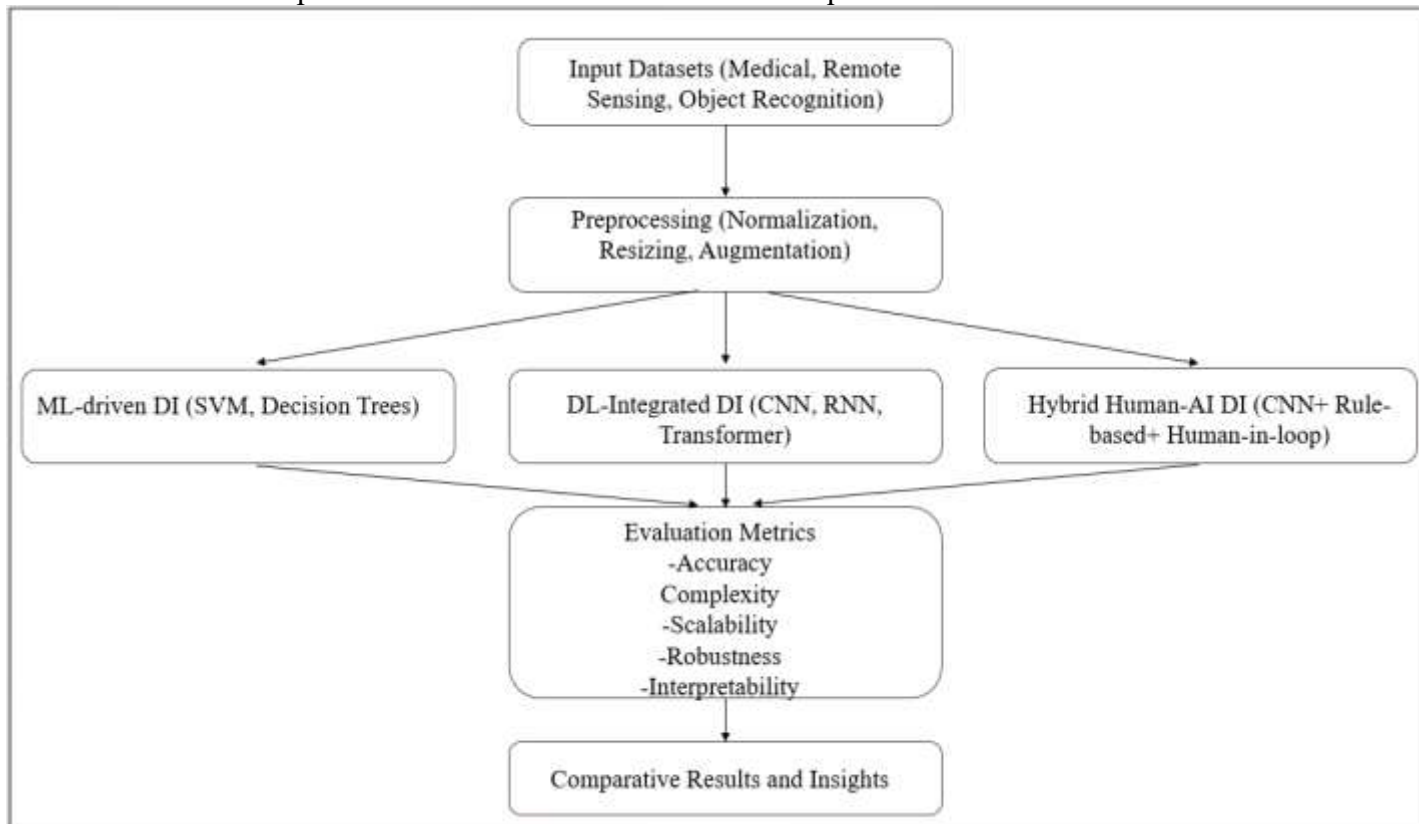


Figure 1. Proposed Framework for Comparative Evaluation of Decision Intelligence in Image Processing

Dataset Selection: To accomplish a comprehensive assessment, a number of benchmark image sets, illustrated in Table 1 below, have been chosen, reflecting various application domains, because the applications listed have disparate challenges such as image quality, possibly the presence of noise, etc.

Table 1. Image datasets

Medical Imaging	The ChestX-ray14 dataset was used to assess DI frameworks in disease detection and diagnostic decision-making.
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Object Recognition	The CIFAR-10 dataset provided a baseline for evaluating general-purpose image classification tasks.
Remote Sensing	The EuroSAT dataset supported analysis of decision-making in satellite image classification for land-use and environmental monitoring.

Framework Identification: In this study, there are three categories of DI frameworks included in this comparative evaluation shown in the following figure 2.

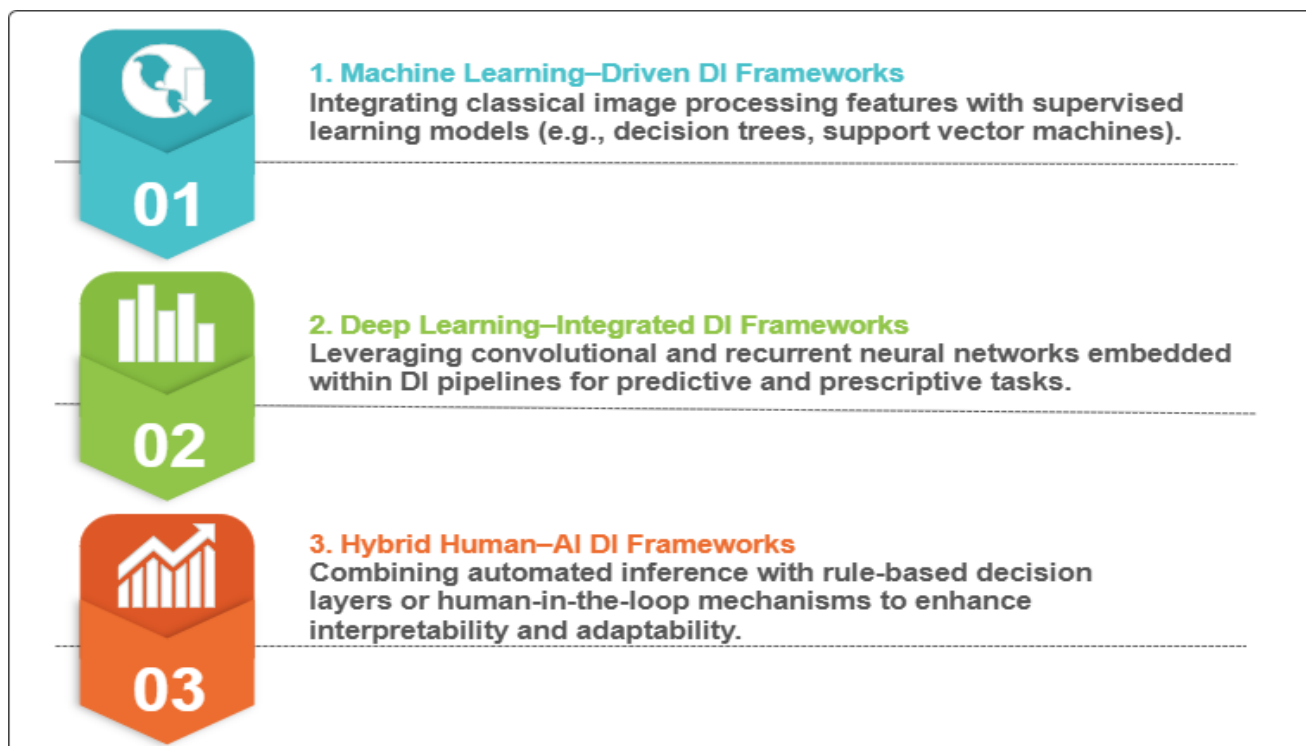


Figure 2. Framework Identification

Evaluation Metrics: The frameworks were performance indicators are shown in the following compared using a multidimensional set of figure 3.

Accuracy	Computational Complexity	Scalability	Robustness	Interpretability
Correctness of image classification and detection.	Ability to handle large-scale datasets with minimal degradation.	Ability to handle large-scale datasets with minimal degradation.	Performance under noisy or incomplete data.	Transparency of decision-making processes, assessed through integration of explainable AI (XAI) methods.

Figure 3. Performance Evaluation Metrics

Experimental Setup: The experiments performed on all models were conducted on the same common platform, including GPU support. For accurate comparison, all machine learning frameworks used the same pre-processing techniques. The hyperparameters for all frameworks were Grid

searched to avoid overfitting, and cross-validation was used. The analysis performed on the experiment results is quantitative, using techniques like accuracy measures and time taken, and qualitative, based on interpretability, as indicated in table 2.

Table 2. Evaluation Metrics and Relevance in Image Processing

Metric	Description	Relevance
Accuracy	Percentage of correctly classified images.	Critical for medical diagnosis and recognition tasks.
Computational Complexity	Time and resources required for execution.	Important in real-time or resource-constrained environments.
Scalability	Performance consistency as dataset size grows.	Essential for large-scale remote sensing or industrial datasets.
Robustness	Ability to handle noise, incomplete, or adversarial data.	Vital for applications like surveillance and autonomous driving.
Interpretability	Transparency of decision-making process.	Crucial for high-stakes fields (e.g., healthcare, law enforcement).

Results and Discussion

This section gives a comparative analysis of the decision intelligence frameworks used for carrying out image-processing-related operations. The above-stated metrics have been utilized for the analysis: accuracy, complexity, scalability, robustness, and interpretability.

Accuracy: Deep Learning-enhanced DI models generally indicated stronger accuracy in datasets, especially in object detection and healthcare image applications. The combination of convolutional neural networks in DI models led to enhanced classification results than traditional machine learning methods, according to experts. Hybrid models indicated lower accuracy than purely DL methods but more consistent results in several datasets because they make adaptive choices using their choice-making layers.

Computational Complexity: Machine learning-based DI systems required fewer computations and were therefore deployable in resource-constrained settings. Deep learning-based systems required substantially more computing power and memory, but the scalability benefits they gained easily outweighed the higher resource requirement. Hybrid systems fell between these two, balancing performance and efficiency through selective human-in-the-loop interventions.

Scalability: In large data sets such as EuroSAT, deep learning-based DI frameworks had greater

scalability with improved performance yet maintained precision as the volume of data increased. Conventional frameworks saw performance degradation with rising dataset sizes. Hybrid frameworks demonstrate mid-level scalability because reliance on rule-based decision support sometimes limited automation at scale.

Robustness: In noisy or imperfect data testing, hybrid models were most resilient. Since they were able to combine machine inference with human insight or rule-based modifications, they were more capable of adapting to imprecise inputs. Deep learning-powered models performed satisfactorily but were vulnerable to adversarial noise, whereas machine learning-powered models performed poorly with data variation.

Interpretability: Interpretability is also another distinguishing factor among DI frameworks. Traditional frameworks and hybrid human-machine approaches provided the most transparent decision traces, and therefore they were particularly suitable to applications where transparency and accountability are paramount (e.g., medical imaging). Deep learning-based DI frameworks, although highly accurate, lacked inherent interpretability, so integration of explainable AI tools. This lack highlights the performance-transparency trade-off in DI for image processing.

Table 3. Comparison of Decision Intelligence Framework Categories

Framework Type	Description	Strengths	Limitations	Example Applications
Machine Learning–Driven DI	Combines traditional image features (edges, textures, histograms) with ML classifiers (e.g., SVM, Decision Trees).	Low computational cost, interpretable, efficient for small datasets.	Limited accuracy in complex tasks, scalability issues.	Industrial inspection, resource-limited systems.
Deep Learning–Integrated DI	Embeds CNNs, RNNs, or transformers within DI pipelines for predictive and prescriptive tasks.	High accuracy, scalable, good for large datasets.	High computational demand, less interpretable.	Object recognition, satellite image analysis.
Hybrid Human–AI DI	Combines ML/DL models with rule-based systems or human-in-the-loop decision layers.	Balanced performance, interpretable, robust under noisy data.	Implementation complexity, slower decision-making at scale.	Medical imaging, security monitoring.

The comparison shows that none of the frameworks are superior to the others in terms of the metrics. The frameworks that utilize deep learning are preferred when accuracy, scalability, etc., matter most. The frameworks that use machine learning are still useful in situations where computational simplicity, efficiency, etc., are key. The hybrids offer a balance through the combination of accuracy, interpretability, etc.

These results highlight the need for context-based decisions regarding the choice of the framework in DI. For instance, healthcare applications would benefit from the use of hybrid frameworks because of their interpretability, while image recognition applications would benefit from using deep learning-based DI frameworks.

Conclusion and Future Work: The paper had a comparative analysis of decision intelligence (DI) frameworks for tasks in image processing based on their performances in several facets of accuracy, computational expense, scalability, robustness, and interpretability. It was found in comparisons that DI frameworks with an integration of deep learning were more accurate, scalable, and thus eminently suitable for large-scale image recognition and classification tasks. Classic machine learning–oriented frameworks were less accurate but economical in resource-scarce settings. Human–AI hybrid DI frameworks struck a balanced trade-off by

maximizing interpretability and robustness at their expense in consideration for their use in medical or remote sensing scenarios with high stakes.

The results highlight that choosing a DI framework is context sensitive. There is no single framework for a one-size-fit-all; it is best for an optimal choice based on a specific application domain requirement, computing resource availability, and need for explainable decision making. Through a systematic comparison over a set of datasets for frameworks, this research contributes more information about trade-offs in using DI for image processing.

The future research can be further extended in the following areas. First, combining the best practices of Explainable AI technologies with deep learning approaches for Decision Insight can further alleviate the trade-off between accuracy and explanation. Second, research on Reinforcement Learning and Decision Intelligence on Graphs can further improve the flexibility when applying dynamic image processing. Lastly, real-time testing for Decision Insight on Edge or IoT devices can be an enjoyable research area for Scalability and Performance. Lastly, applying the concept of Comparative Analysis on Multimodal Data (such as image and text or image and sensor readings) may provide even additional Decision-Making possibilities.

Acknowledgement: We sincerely appreciate the University of Information Technology, Yangon,

Myanmar for providing the necessary resources for this research. We also express heartfelt gratitude to our families for their unwavering encouragement and support throughout this endeavor.

Conflicts of Interest: The authors announce that there are no funding sources or conflicts of interest related to this research paper.

Authors Funding: The authors have not received any funding related to this research or the publication of this paper.

Author Contribution: All authors were accountable for the study proposal, data interpretation, manuscript writing, data collection and analysis, and critical revision of the manuscript for important intellectual content. Both authors contributed equally, read, and approved the final manuscript.

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