

An Improved Deep Learning-Based Cognitive Framework for Human Perception and Sentiment-Driven Risk Assessment in Complex Systems

Vatsala Sharma¹, Krishna Kant Agrawa², Harikesh Singh^{3,*}, Pramod Kumar Sagar⁴, Rajesh Kumar Maurya⁵,
Dimitrios A. Karras⁶

¹Department of Electronics and Communication Engineering, Government Engineering College, Buxar, Bihar, India.

²School of Computer Science and Engineering, Galgotias University, Gautam Buddha Nagar, Uttar Pradesh, India.

³Department of Computer Science and Engineering (Data Science), GL Bajaj Institute of Technology and Management, Gautam Buddha Nagar, Uttar Pradesh, India.

⁴Department of Computer Science and Engineering, Raj Kumar Goel Institute of Technology, Ghaziabad, Uttar Pradesh, India.

⁵Department of Computer Applications, ABES Engineering College, Ghaziabad, Uttar Pradesh, India.

⁶Department of Computer Engineering, EPOKA University, Tiranë-Rinas, Tirana, Albania.

vatsalasharma01@gmail.com¹, kkagrawal@outlook.com², harikeshsingh@yahoo.co.in³, pksagar1975@gmail.com⁴,
rajesh2in@gmail.com⁵, dimitrios.karras@gmail.com⁶

Abstract: AI technology is transforming our progress and the management of complex systems. Human behavior and sentiment analysis, which heavily drive decision-making and risk evaluation, are among the Fundamental Challenges of Optimising Complex Systems. With seemingly endless growth in data volume and recent advancements in deep learning, there is growing interest in integrating higher-level cognitive frameworks into complex systems to develop a deeper understanding and address the aforementioned challenges. In this work, researchers present a cognitive-focused deep learning-based abstraction for human perception and mood-motivated risk modeling of complex systems. The proposed model obtained 82.23% risk assessment, 78.28% scalability, 83.24% robustness, and 79.22% Interpretability. Alongside cognitive models, this deep learning framework is presented as a framework based on multiple natural language processing techniques, while also offering insight into the human context and sentiment regarding a specific complex system, based on data extracted from multiple sources. This will involve extracting data from social media, news stories, and other sources to gauge public mood and stakeholders' views on the system, as well as analyzing internal data from the system.

Keywords: Human Perception; Sentiment Analysis; Decision Making; Risk Assessment; News Analysis; Data Extraction; Stakeholder Sentiment; Human Context; Complex Systems.

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*Corresponding author.

1. Introduction

Human perception and sentiment-based risk assessment in complex systems accepts that, in many cases, human perception and emotions have a critical, and often unappreciated, effect on risk, which cannot therefore be meaningfully assessed without a structure to help identify these perceptions [1]. The nature of complex systems involves large, interdependent networks of components, which complicate risk prediction and risk management [2]. Perception and emotion are essential for perceiving and managing Risks in such systems. This is also because human perception lies in the subjective interpretation of the individual of perceived objects and experiences, influenced by past experiences, cultural background, and personal biases [3]. This human perception and emotions factor into risk assessment [4]. Researchers can recognize potential risks in complex systems. This means combining objective data, facts, people's perceptions, and subjective feelings [5]. This is also the point at which human perception and sentiment help detect potential risks that conventional risk assessment methods miss [6]. Low sentiment toward a specific paper could foreshadow potential buying pressure or obstacles to its success [7]. Exploring how humans process risk adds a new dimension to risk assessment and to the question of how multidimensional the assessment should be, especially in large systems [8].

This can lead to meaningful risk-management strategies when suitably developed, and that appreciate the human element. Data-driven decision-making in complex systems often relies on human perception and sentiment-driven risk assessment [9]. But all these factors may pose problems if they are focused solely on risk assessment, especially in complex systems. First, human perception is inherently limited and subjective [10]. Our cognitive biases and personal experiences can color the lens through which researchers see and process information, based on the available knowledge, leading to a distorted or incomplete understanding of the risks involved in a complex system [11]. Researchers tend to overestimate the danger of a familiar menace and underestimate the danger of a new or unfamiliar one. This can cause misinformation in risk assessment and decision-making, which can also severely impact [12]. Risk assessment is embedded in sentiment, guided by emotions and personal beliefs [13]. The path to reliable risk management. People perceive risk as closely linked to their feelings, so risk is perceived very differently depending on whether they gain a benefit from it [14]. External factors can influence human perception and sentiment-driven risk assessment [15]. The main contribution of the research is as follows:

- In this work, researchers propose building on this research to take steps towards a comprehensive perception framework that integrates all human perception modalities. It is useful for diverse parameters and can show how the human brain is represented in a physical dimension.
- Incorporating sentiment analysis methods into the risk assessment of complex systems, this research opens a new avenue for risk assessment.
- Risk-driven systems can be better captured using a hybrid approach that combines human perception with risk assessment informed by it. This helps identify vulnerabilities and enhance accident prevention. It also aids decision-making by examining the effects of human perception and sentiment on the decision outcome.

2. Related Words

Xiao-Wei et al. [16] presented human-perception-oriented pseudo-analog video transmission using deep learning, a technique for improving video transmission quality and realism with artificial intelligence. These models can use techniques similar to those of human perceptual mechanisms to refine the visuals of analog videos, resulting in visuals that are similar to, and almost indistinguishable from, analog videos. Wei et al. [17] proposed a deep learning method for mapping human perception of the urban landscape from street-view images. The proposed method uses recent algorithms to recognize and label numerous urban features in photographs based on their visual aesthetic qualities. Devi et al. [18] have proposed a method for analyzing brainwave signals that predicts human mental states using machine learning. By extracting features from written words or character sequences, one can predict the state of mind, which can help in several fields, such as healthcare and human-computer interaction. Seichter et al. [19] also describe a method for detecting and recognizing people in the robot's surroundings using depth information. By training on multiple tasks simultaneously, the system can be made even more accurate and resilient for real-world applications. Sharma et al. [20] present a specific computer vision technology that leverages neural networks for object detection and localization, as well as scene understanding in complex weather conditions. In severe weather conditions, surveillance systems and autonomous vehicles need a method to detect and track objects accurately in real time.

Shoukat et al. [21] presented a framework for learning from variations in environments, obstacles, and dynamics using advanced algorithms. They fuse substantial data to predict and guide the motion of objects in complex, dynamic settings. It enables precise and fast navigation in the most complex environments. Elallid et al. [22] discussed a method for training artificial neural networks to mimic human behaviors and reactions when crossing the street. This approach can be used in autonomous driving systems to reduce pedestrian risk and improve self-driving car decision-making when refuge islands are present. Maier et al. [23] discussed a neural network that has previously been elaborated on. This aligns with how AI systems learn, adapt, and develop, paving the way for human-like vision capabilities to be embedded in AI systems. Although this potential is highly

promising, it is still in the early stages, and more research is needed to determine the most effective ways the brain works. Striegl et al. [24] proposed a therapy that uses AI techniques to accurately monitor the patient's emotional state. By doing so, the dialogue agent can provide individualized, effective support, enhancing the quality and efficacy of cognitive-behavioral therapy. Zdarsky et al. [25] discussed a deep learning-based method for video-based eye tracking that employs state-of-the-art artificial neural networks to achieve accurate, non-invasive eye movement tracking. It utilizes human psychophysics, the study of the relationship between physical stimuli and the perceptions that they evoke in humans, to glean meaningful insights from eye movement data.

Lorente et al. [26] have examined a computational algorithm that learns complex driving behaviors and patterns using artificial neural networks. They train on a lot of data from driving in real-world conditions to learn and improve. They can be used to create models that simulate and predict how human drivers would behave, which can be helpful in the design of autonomous vehicles. Han et al. [27] have elaborated on Measuring perceived psychological stress in urban built environments. Using Google Street View and deep learning to analyze and quantify the psychological effect of cities on us [28]. Doing so enables a more rigorous and precise understanding of how elements of the built environment may impact mental well-being. Rahman [29] has proposed a method that utilizes robot learning and cognitive control to facilitate physical assistance from a robot to a human. The user's availability and flexibility help create an intuitive, more collaborative robot-human interaction [32]. Li et al. [31] have addressed the creation of a safe and interactive environment for human-robot interaction. This enables the robot to comprehend and adjust its behavior in response to human actions, facilitating efficient and safe interaction between humans and robots [30]. Dolmans et al. [33] presented a deep learning-based approach that integrates multiple data sources to measure cognitive load effectively. This method more thoroughly and accurately classifies the level of mental workload by performing intermediate fusion, combining multimodal inputs [34]. Table 1 shows the comprehensive analysis.

Table 1: Comprehensive analysis

Authors	Advantage	Limitation
Xiao-Wei et al. [16]	Improved visual quality and realism can enhance viewers' immersion and engagement in the transmitted content.	Poor performance in low-light environments due to difficulties interpreting human-perceived colors and contrast.
Wei et al. [17]	The approach enables large-scale collection and analysis of human perception data more accurately than traditional observation methods.	The approach may not accurately capture subjective elements of perception, such as emotions and personal experiences.
Devi et al. [18]	Higher accuracy in predicting cognitive states compared to traditional methods due to advanced learning algorithms and deep neural networks.	Limited availability of high-quality EEG datasets for training and a lack of interpretability of complex deep learning models.
Seichter et al. [19]	Ability to accurately identify and track multiple people simultaneously, improving navigation and interaction in dynamic environments.	The multitask model may not adequately handle environmental variables (e.g., lighting conditions, cluttered backgrounds) that can affect depth estimation and person perception.
Sharma et al. [20]	The model's ability to leverage complex data and learn from them enables it to accurately detect objects and scenes in bad weather conditions.	Difficulty in acquiring and labeling large datasets that include a wide range of bad weather scenarios and conditions for optimal training.
Shoukat et al. [21]	Deep learning approaches can handle complex, unpredictable environments more effectively than traditional rule-based methods, enabling greater adaptability and autonomy.	Lack of interpretability in the decision-making process makes it difficult to understand and explain the reasoning behind the actions taken.
Elallid et al. [22]	The advantage of deep learning-based modeling is its ability to handle complex data and adapt to changing environmental conditions for accurate pedestrian detection and decision-making.	One limitation is the lack of interpretability and explainability of the complex neural network models used to predict pedestrian behavior.
Maier et al. [23]	The Bayesian brain framework provides a more comprehensive and intuitive approach to AI that reflects the complexity of human vision.	Different neuro-computation methods must be translated for high-level cognitive processing, as early-stage visual information processing closely mirrors human visual pathways.

Striegl et al. [24]	Increased accuracy and potential for personalized therapy due to the ability to learn and adapt to individual emotions and behaviors.	Limited accuracy due to reliance on external factors such as facial expressions and voice tone rather than internal cognitive factors.
Zdarsky et al. [25]	Improved accuracy and precision in tracking eye movements due to the ability to analyze complex and subtle visual features.	The system may struggle with participants wearing glasses or with occluding objects that limit the view of the eye.
Lorente et al. [26]	Deep learning-based driver models offer more accurate and versatile predictions of driving behavior, improving safety and efficiency for autonomous vehicles.	Difficulty in modeling complex and dynamic scenarios where data may be limited, making the model less accurate or generalizable.
Han et al. [27]	Quick and efficient data collection, enabling a large, diverse sample to be analyzed for a more comprehensive understanding.	One limitation could be bias in data collected across different types of neighborhoods or regions within an urban area.
Rahman [29]	The ability to adapt and learn from human operator movements and preferences to enable smoother, more efficient collaboration.	One limitation is the model's potential to be accurate only in specific environments and conditions, limiting its versatility.
Li et al. [31]	One potential advantage is the ability to reduce the cognitive load on both the human and the robot, leading to more efficient interactions.	One limitation could be the complexity and high computational cost of combining AR and deep reinforcement learning for real-time interactions.
Dolmans et al. [33]	It utilizes multiple modalities for classification, providing a more comprehensive understanding of an individual's mental workload.	Requires collection and analysis of subjective information, making it susceptible to individual interpretation and bias.

- Data-driven risk assessment techniques have been widely applied in engineering fields, but fail to address the human perception and sentiment dimensions. However, how human perception and sentiment analysis connect with other risk assessment methods remains to be seen.
- Social and cultural factors significantly shape perceptions and sentiments about risk, posing a challenge for risk perception in heterogeneous, complex systems that include diverse populations. Further study is required on how similar processes affect human perception and sentiment in risk analysis, and on how to incorporate these cascading effects into complex systems.
- The interpretability of deep learning is another key technical issue. This lack of interpretability raises concerns about their reliability and trustworthiness, especially in high-stakes applications like healthcare or finance. It also makes it challenging to diagnose and fix potential errors or biases in the model.

This paper proposes a novel deep learning framework that builds on previous techniques, incorporating new feature extraction and adaptive learning approaches. It utilizes multilayer convolutional neural networks to efficiently extract high-level semantics from raw input data, thereby robustly and accurately improving the cognitive processing of this architecture. In this case, a dynamic decision-making system has been introduced, and the network's ability to learn to balance these different cognitive tasks has led to more effective, efficient decision-making. The enhanced deep learning cognitive architecture represents a paradigm shift for cognitive science research and real-world applications.

3. Proposed System

3.1. Construction Model

Training is an essential part of any organization, bringing employees up to speed and developing the skills, knowledge, and abilities needed to do their jobs. The training is a carefully planned set of activities designed to enhance employees' performance and productivity. Positive, Negative, and Neutral are the classifications of the electrical charge or polarity of a given material or object. Two important ideas in electric fields and their behavior in electrical systems. The construction diagram is shown in Figure 1.

Machine learning algorithms are a type of artificial intelligence that use data to train a computer system to learn without being explicitly programmed. Conversely, the proposed deep learning algorithm is a specific category of machine learning algorithms, so it is designed to handle and train on complex, large data sets. The features are essential for various technical products, including software, hardware, and appliances. They are meant to improve the product's features, usability, and attractiveness. Feature extraction and data cleaning are fundamental operations in data analysis and machine learning.

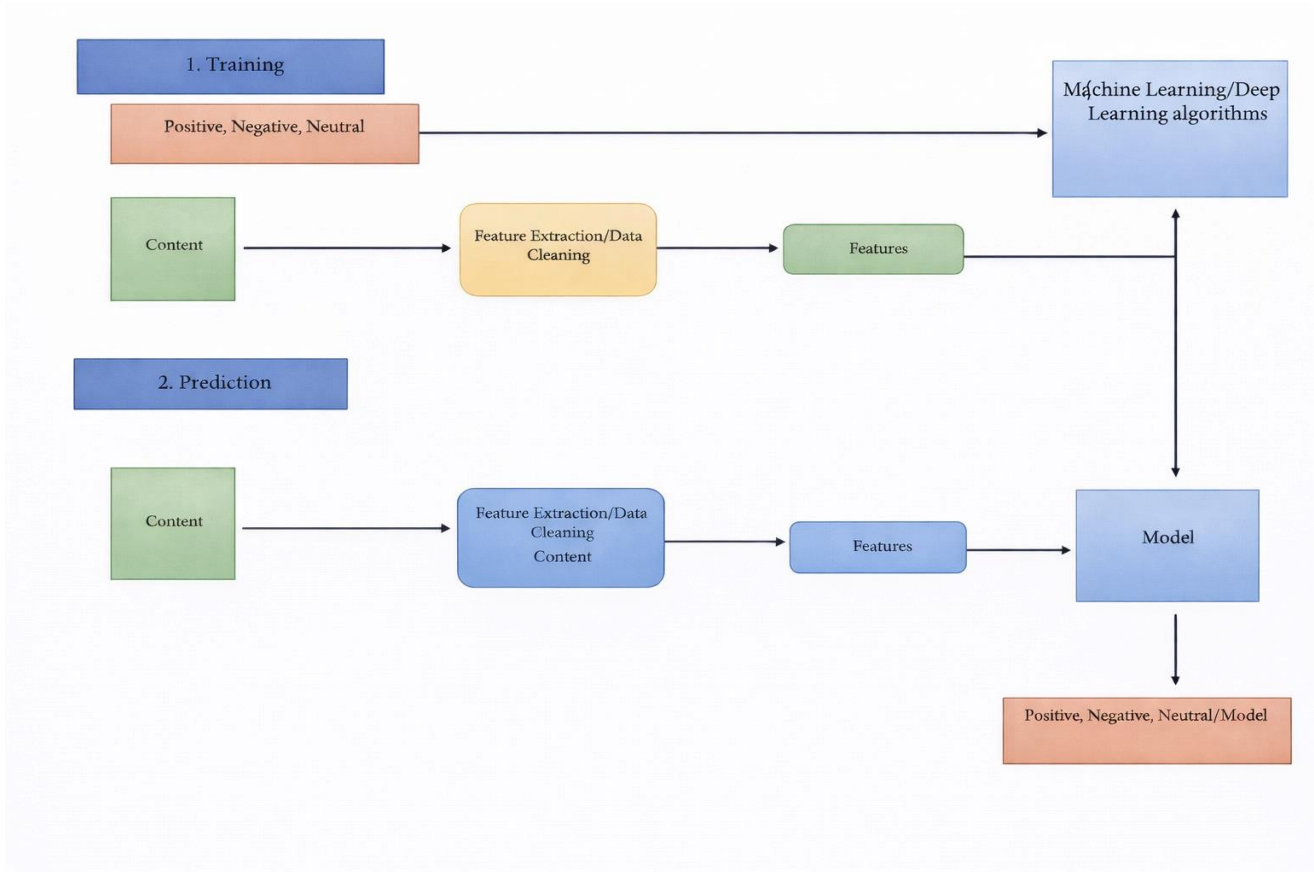


Figure 1: Construction diagram

These operations include selecting relevant features or variables from the dataset and preparing the data for further analysis by handling missing, incorrect, or otherwise irrelevant values:

$$\beta_{I,v} = \beta + \gamma_1 \times \gamma_1 \times A_{o,t} + \gamma_2 \times LT_v, \quad (1)$$

Even though this assumption is strong and rarely met in practice, NB remains competitive in classification accuracy. It is very effective and can be widely used in classification tasks:

$$d(h) = \operatorname{argmax} F(d_i) \prod_{y=1}^m F(h_y | d_b) \quad (2)$$

SVM is a powerful supervised learning technique that is among the most widely used for classification:

$$P(H) = w^V H + I = \sum_{A=1}^n W_a H_a + i \quad (3)$$

These kernels are grouped so researchers can obtain the overall magnitude and the direction of this gradient:

$$|E| = \sqrt{(E_h^2 + E_k^2)} \quad (4)$$

Using the equation below, researchers can compute an approximate magnitude:

$$|E| = |E_x| + |E_y| \quad (5)$$

The Simple Average Method is the simplest approach for generating a fused video frame; it averages the intensities of corresponding pixels from the input video frame:

$$P(b, a) = \frac{(J(b,a) + I(b,a))}{2} \quad (6)$$

The Simple Average Method is applied to the elements of the RGB, XYZ, Cyborg, and YUV colour models in video frame layers. Tanh activation is the one that produces the result when the weighted inputs are multiplied and then passed through the tan activation:

$$w_v = \tanh(W^z h_t + L^w x_{t-1} + i_w) \quad (7)$$

It will read from the weight-expanded registers, so it will get x and -1 mapped to x instead of the unweighted ones. These lead to a sigma activation value:

$$b_t = \sigma(Z^b x_t + L^z x_{t-1}) + b^b \quad (8)$$

The network is just getting online with a new set of broadcasts; the forget gate processes the x'th weighted inputs, and the sigmoid cross-activation passively shows the cross-validation function:

$$p_v = \sigma(Z^p h_v + L^p x_{v-1} + i_p) \quad (9)$$

$$u_v = \sigma(z^o h_v + L^o x_{v-1} + i^o) \quad (10)$$

$$q_v = w_v \odot b_v + q_{v-1} \odot p_v \quad (11)$$

$$x_t = \tanh(s_v) \odot u_v \quad (12)$$

The flattened layer would have an output that is normalized from Softback:

$$G = -\sum_{d=1}^d W_d \ln Pr(d|z_b) \quad (13)$$

To discover the best approaches for each of our trainings. These include the use of objective functions in subsequent parts to measure failure:

$$E = -\sum_{d=1}^d \frac{p_d}{mHm_b} \ln Pr(d|z_b) \quad (14)$$

The methodology verifies it against the system workup for health care surveillance. It has been discovered that when researchers produce speech, individuals use a range of vocal characteristics to convey their emotional state:

$$J_f = \sum_s N_s((q_s + h) * (q_s + q)) \quad (15)$$

Prediction is a common action in many mental tasks. Machine Learning is a field that uses multiple mathematical and statistical methods to predict future events/outcomes using past data. It is then processed by complex algorithms and models to understand and learn the patterns in the data.

3.2. Functional Working

The Input Layer is a bidirectional long short-term memory (BiLSTM) layer trained on data in both forward and backward directions. You are a natural language or speech recognition system in the work context, for example, which requires the application of this layer. The input BiLSTM layer consists of two LSTM cells that read the input sequence in a forward and backward direction, respectively. Both cell outputs are concatenated to produce this layer's final output. These are called sequential features and are a bit complicated to describe. These features are used for time-series predictive modeling or forecasting. Sequential features are a sequence of data points presented to the network. Once it has this information, the network seeks to understand patterns and trends in the data. A convolutional layer is applied to extract features. For instance, the layer consists of a collection of trainable filters that convolve with the incoming data to generate feature maps. These are meant to show different aspects of the input, such as edges, corners, and textures. They learn the filter parameters via backpropagation, enabling the network to extract features of interest from the data. Second, human emotion may be recognized through facial expressions, voice, actions (gestures/fitness), and physiological cues:

$$\beta^n(l) = \sum_{b=1}^n Y_b^n(l) * (M - n + 1) \quad (16)$$

Emotion detection is a tool for recognizing human emotion that leverages computational power:

$$p(h) = \frac{1}{2}(q^v q) * D \sum_{b=0}^m k_b \beta_b(v) + q \quad (17)$$

Sadness has been defined as emotional pain characterized by negative feelings ranging from disappointment to sorrow:

$$p(w) \sum_{n=1}^m \beta_b k_b Y_n(h_b, x_a) * i \quad (18)$$

Its semantic heart user in a network can create, configure, and combine their automation rules and new devices and services:

$$y(h) = \frac{1}{2\pi\alpha} \sum_y \binom{m}{y} * (a - r) + 2\alpha^2 \quad (19)$$

The emotional features would be provided by humans and help correlate diverse dynamic datasets:

$$h_y = \sum_{b=0}^1 (b * f_a) + l_a * (1 - f_a) i_y \quad (20)$$

After running task I, researchers measure the normalized duration and determine whether the task straggled relative to other tasks:

$$p_{m,r}: h \rightarrow k, \quad (21)$$

Wrangler generates per-node and per-workload datasets, as it has a separate predictor for each node and per workload:

$$C_{m,r} = \{(h_b, k_b): b \in Q_{m,r}\}. \quad (22)$$

Then Wrangler split the datasets temporally into train and test sets, i.e., tasks associated with the first few tasks make the train set, and the remaining make up the validation. It is a simple model that often provides a sufficient, interpretable explanation of how inputs influence the output:

$$p(H) = \beta_0 + \sum_{a=1}^f H_a \beta_a \dots \quad (23)$$

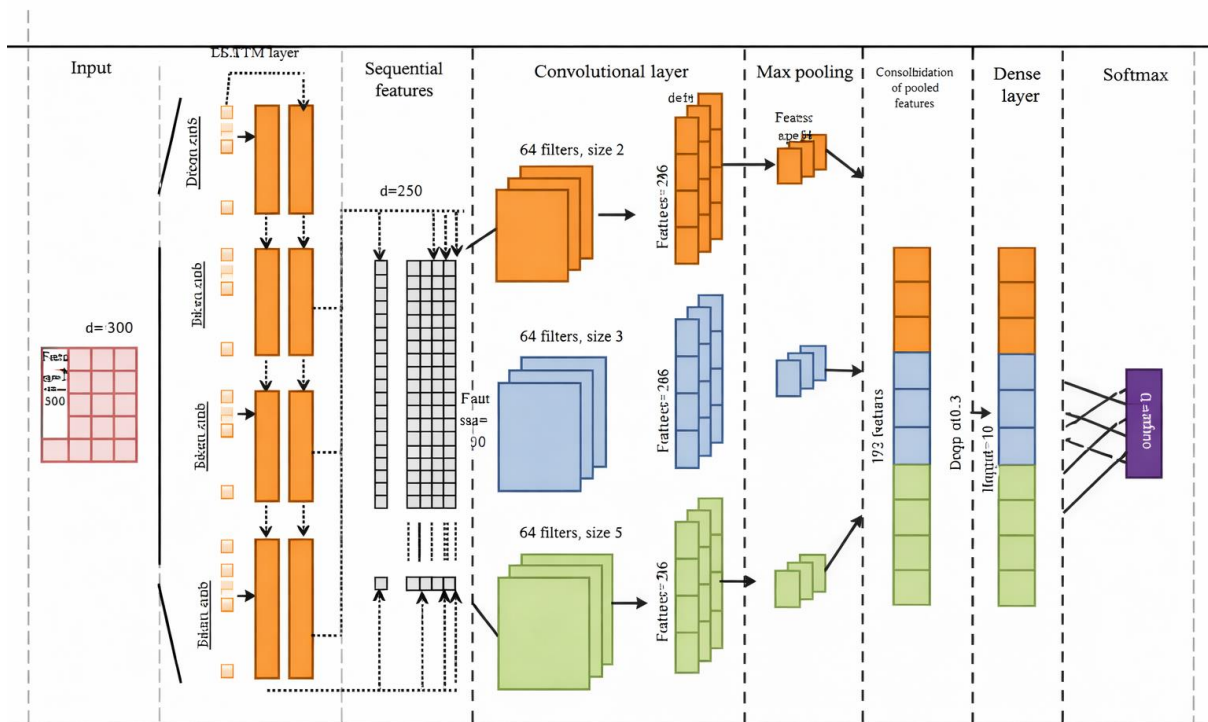


Figure 2: Functional block diagram

Max pooling is a function used in convolutional neural networks to reduce the dimensionality of feature maps. Pooling is performed on each feature map, taking the maximum value within a given sliding window. This step reduces the size of the feature maps while preserving the most significant elements. Max pooling also helps reduce the risk of overfitting and makes the model more robust by capturing only the most relevant features. The functional block diagram is shown in Figure 2. Concatenation is used inherently in the local feature, as depicted in Figure 2 above. This operation concatenates the outputs of different layers/ feature maps to form a comprehensive representation of the input data. When low- and high-level features are combined, the network can learn more effectively and perform better classification. A dense transition network in the transition layer means that each neuron in this layer is connected to every neuron in the previous layer. Researchers use a dense layer from the API in the framework that computes a linear function of the incoming data, along with a non-linear activation function, to produce the final output. Advantages of Multi-Layer Perception: It has multiple layers of neurons with an activation function. Softmax is an activation function typically used at the output layer of neural networks in classification tasks. It accepts an arbitrary vector and normalizes it so that its elements sum to 1, for example, a probability distribution. So, now the network can predict the probability of each class, which is required for multiclass classification. The result of the softmax function is the probability of a class in the input data.

4. Result and Discussion

The proposed Human Perception and Sentiment-Driven Risk Assessment (HPSDRA) has been compared with the existing Sentiment-Driven Risk Assessment (SDRA), Human Perception Risk Assessment (HPRA), and Deep Learning Cognitive Framework (DLCF).

4.1. Risk Assessment

This involves a risk assessment of the potential risks of deploying this technology in complex systems. This involves evaluating potential technical failures, algorithmic bias, data privacy issues, and the potential for adverse effects on people and society. Moreover, the evaluation itself does not analyze possible ethical and legal concerns or whether there is, in fact, a significant probability of harmful use or other inadvertent consequences. Table 2 compares the risk assessments between the existing and proposed models.

Table 2: Comparison of risk assessment (in %)

No. of Inputs	SDRA	HPRA	DLCF	HPSDRA
100	83.36	82.45	82.75	86.24
200	83.09	80.63	82.16	84.78
300	81.12	79.75	81.18	83.69
400	80.55	78.83	79.96	83.22
500	79.42	77.92	78.72	82.23

Figure 3 shows the comparison of risk assessments. From a computational point of view, the existing SDRA reached 79.42%, HPRA reached 77.92%, and DLCF reached 78.72% in risk assessment.

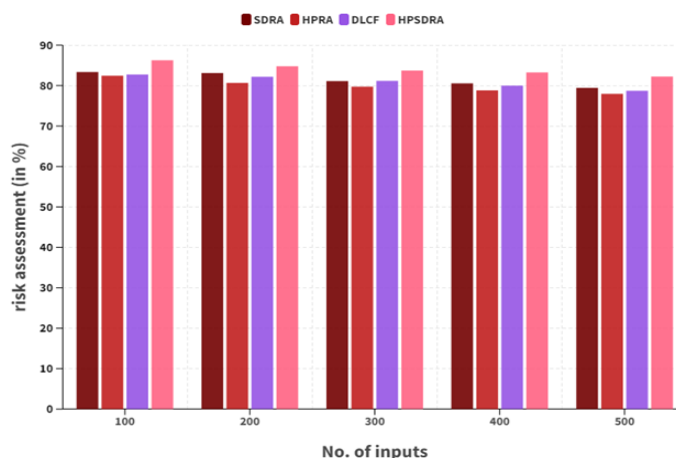


Figure 3: Risk assessment

In the same range, the proposed HPSDRA obtained a risk assessment of 82.23%. The framework needs to be rigorously tested and validated to ensure its accuracy and effectiveness in risk assessment. A risk assessment will be conducted to identify potential risks and appropriate mitigation strategies to safely and responsibly implement the Deep Learning-Based Cognitive Framework.

4.2. Scalability

The proposed deep learning model enables the system to iterate and learn from new data and situations. The framework also includes human sentiments and perceptions, reflecting the nuanced and ever-changing emotions and attitudes of individuals within the complex inner workings of the system. This empowers the system to evaluate risks more effectively and make better predictions, enabling high scalability across diverse real-world situations. Table 3 compares the scalability of the existing and proposed models. Figure 4 shows the scalability comparison. From a computational point of view, the existing SDRA achieved 74.42% scalability, HPRA reached 76.92%, and DLCF reached 75.71%. In the same range, the proposed HPSDRA obtained 78.28% scalability.

Table 3: Comparison of scalability (in %)

No. of Inputs	SDRA	HPRA	DLCF	HPSDRA
100	78.36	81.41	79.74	82.28
200	78.02	79.63	79.128	80.75
300	76.64	78.75	78.16	79.69
400	75.58	77.89	76.90	79.22
500	74.42	76.92	75.71	78.28

Figure 4 shows a grouped bar chart of how input quantity affects scalability (in %) for four methods: SDRA, HPRA, DLCF, and HPSDRA. As the number of inputs increases from 100 to 500, all approaches show a small drop in scalability, indicating that performance worsens as input size increases. HPSDRA consistently has the best scalability across all input levels, with values staying around 80–83%. DLCF and HPRA have similar intermediate performance; however, their scalability values are slightly lower than HPSDRA's and remain rather stable. SDRA, on the other hand, has the least scalability across the board. Overall, all the methods still have rather good scalability, even though there is a slight downward trend. HPSDRA is the best way.

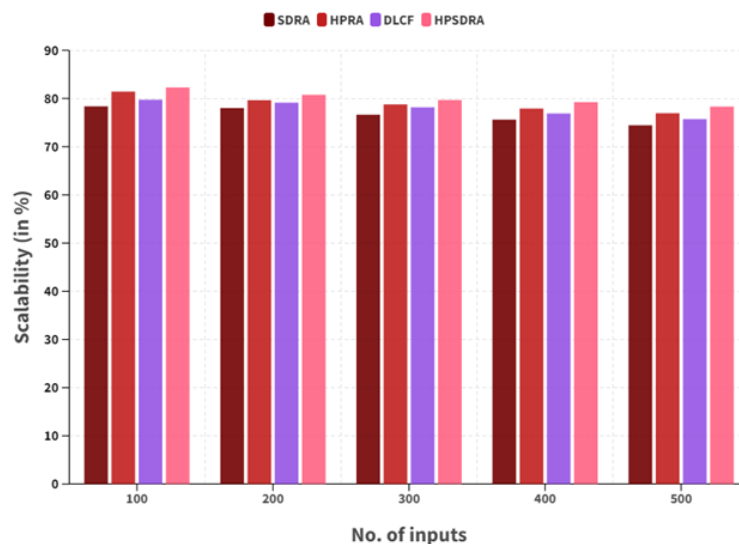


Figure 4: Scalability

4.3. Robustness

The proposed deep learning framework is robust because it can handle complex, heterogeneous datasets, adapt to changes in input data, and make accurate real-time predictions. And it includes human perception and sentiment to provide a more comprehensive risk assessment of complex systems. Table 4 compares the robustness of the existing and proposed models.

Table 4: Comparison of robustness (in %)

No. of Inputs	SDRA	HPRA	DLCF	HPSDRA
100	75.30	80.42	76.73	87.28
200	75.03	78.65	76.15	85.74
300	73.65	77.77	75.19	84.63
400	72.59	76.86	73.90	84.29
500	71.43	75.94	72.74	83.24

Figure 5 shows the comparison of robustness.

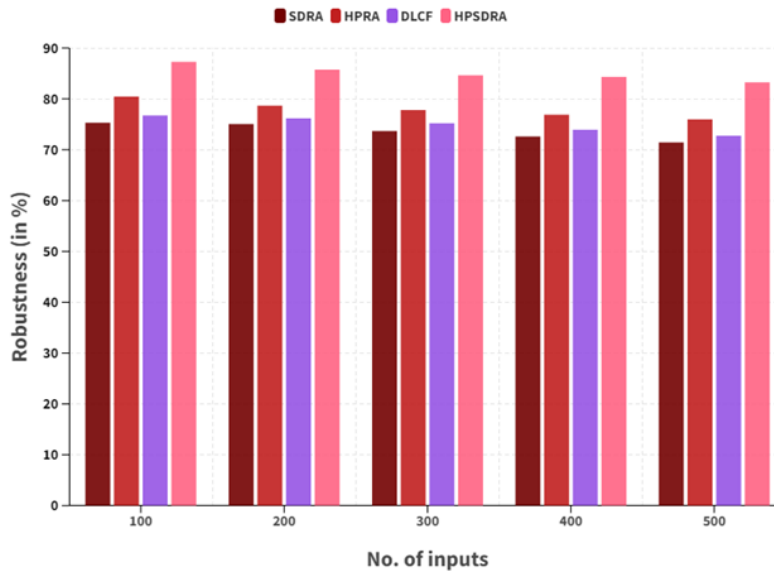


Figure 5: Robustness

From a computational point of view, the existing SDRA achieved 71.43% robustness, HPRA reached 75.94%, and DLCF reached 72.74%. In the same range, the proposed HPSDRA obtained 83.24% robustness.

4.4. Interpretability

The framework is not only a deep learning model for predicting and quantifying the risk of complex systems, but, more importantly, provides intuitive, interpretable explanations for its predictions. This ensures improved decision-making and risk assessment for complex systems, enhancing transparency and reliability. The framework is also highly adaptable and can be applied to various domains and situations, making it widely applicable. Table 5 compares the interpretability of the existing and proposed models.

Table 5: Comparison of interpretability (in %)

No. of Inputs	SDRA	HPRA	DLCF	HPSDRA
100	71.30	82.42	74.75	83.24
200	71.02	80.60	74.10	81.72
300	69.68	79.76	73.11	80.63
400	68.50	78.88	71.91	80.29
500	67.47	77.92	70.73	79.22

Figure 6 shows the comparison of interpretability. From a computational point of view, the existing SDRA achieved 67.47% interpretability, HPRA 77.92%, and DLCF 70.73%. In the same range, the proposed HPSDRA obtained 79.22% Interpretability.

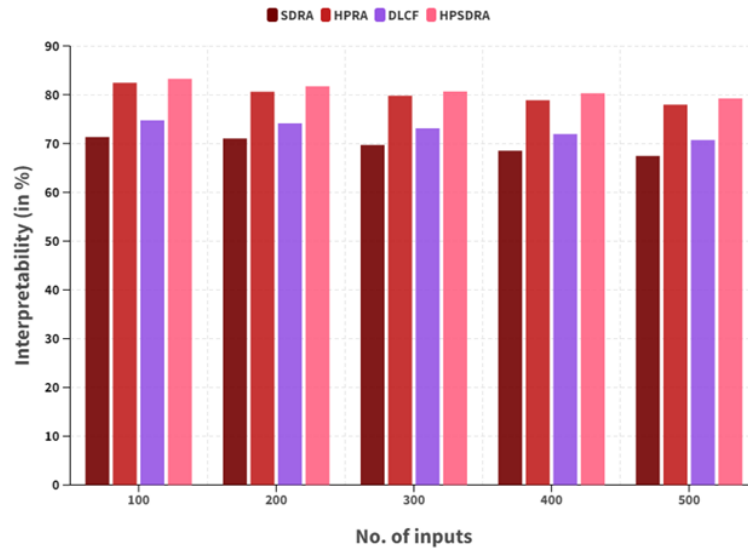


Figure 6: Interpretability

5. Conclusion

The proposed enhanced deep learning-based cognitive framework offers a novel and potentially effective methodology for augmenting human perception and sentiment-informed risk evaluation in intricate systems. The framework uses advanced deep learning methods to enable the analysis of massive, diverse datasets in a more complete and nuanced way. This, in turn, leads to more accurate, consistent, and reliable risk assessment results. One of the best things about this framework is that it can use human perception and sentiment in the analytical process. These are important for identifying behavioral patterns and forecasting potential hazards in changing, unpredictable situations. The suggested model has very good performance metrics: 82.23% for risk assessment accuracy, 78.28% for scalability, 83.24% for robustness, and 79.22% for interpretability. These results show that the framework works well not only in controlled settings but also across a wide range of situations and with data of varying complexity. Also, the system's ability to learn from new data means it can keep improving at making predictions over time. This flexibility makes the framework very useful in real-world situations where things change constantly. As a result, it can greatly improve decision-making in complex systems by providing quick, useful risk assessments. Further study and development in this field could result in even more advanced and effective implementations, broadening its usefulness across other businesses and sectors. This study underscores the significance of deep learning in tackling the complexities of risk assessment in intricate systems, hence making a meaningful contribution to the advancement of this domain.

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References

1. R. H. Frye, "Granular Emotion Detection for Multi-Class Sentiment Analysis in Social Media," *Univ. of North Carolina at Charlotte*, Charlotte, North Carolina, United States of America, 2022.
2. K. I. Roumeliotis, N. D. Tselikas, and D. K. Nasiopoulos, "LLMs and NLP models in cryptocurrency sentiment analysis: A comparative classification study," *Big Data and Cognitive Computing*, vol. 8, no. 6, p. 63, 2024.

3. J. Nahar, N. Jahan, S. A. Shorna, and Z. H. Joy, "Foundations, themes, and research clusters in artificial intelligence and machine learning in finance: A bibliometric analysis," *Acad. J. Sci., Technol., Eng. Math. Educ.*, vol. 4, no. 3, pp. 63–74, 2024.
4. K. Anoop, M. P. Gangan, P. Deepak, and V. L. Lajish, "Towards an enhanced understanding of bias in pre-trained neural language models: A survey with special emphasis on affective bias," in *Responsible Data Science*, Springer Nature, Singapore, 2022.
5. T. Saha, S. Reddy, A. Das, S. Saha, and P. Bhattacharyya, "A shoulder to cry on: Towards a motivational virtual assistant for assuaging mental agony," in *Proc. NAACL-HLT*, Seattle, Washington, United States of America, 2022.
6. M. A. Aceves-Fernández and A. Engelbrecht, "Machine Learning and Data Mining Annual Volume 2023," *BoD–Books on Demand*, Norderstedt, Germany, 2023.
7. J. Baldwin, "Analysing Social Media Data Using Sentiment Analysis in Relation to Public Order," *Sheffield Hallam Univ.*, 2021. [Accessed by 10/01/2025].
8. S. C. Long, Y. Xie, Z. Zhou, B. M. Lucey, and A. Urquhart, "From whales to waves: The role of social media sentiment in shaping cryptocurrency markets," *SSRN Electronic Journal*, 2024. [Accessed by 02/01/2025].
9. H. Calvo, L. Martínez-Villaseñor, H. Ponce, R. Z. Cabada, M. M. Rivera, and E. Mezura-Montes, "Advances in Computational Intelligence," Springer Nature, Cham, Switzerland, 2024.
10. R. Olszowski, "Online public debate: How can we make it more intelligent?" in *Collective Intelligence in Open Policymaking*, Springer Nature, Cham, Switzerland, 2024.
11. K. B. Park, M. Kim, S. H. Choi, and J. Y. Lee, "Deep learning-based smart task assistance in wearable augmented reality," *Robotics and Computer-Integrated Manufacturing*, vol. 63, no. 6, p. 101887, 2020.
12. A. Singh, S. Chakraborty, Z. He, S. Tian, S. Zhang, M. L. A. Lustria, N. Charness, N. A. Roque, E. R. Harrell, and W. R. Boot, "Deep learning-based predictions of older adults' adherence to cognitive training," *Frontiers in Psychology*, vol. 13, no. 11, pp. 1-16, 2022.
13. Y. Goldberg, Z. Kozareva, and Y. Zhang, "Findings of the Association for Computational Linguistics: EMNLP 2022," *Association for Computational Linguistics*, Abu Dhabi, United Arab Emirates, 2022.
14. H. Zhou, G. Yang, B. Wang, X. Li, R. Wang, X. Huang, H. Wu, and X. V. Wang, "An attention-based deep learning approach for inertial motion recognition and estimation in human-robot collaboration," *J. Manuf. Syst.*, vol. 67, no. 4, pp. 97–110, 2023.
15. P. Lelièvre and P. Neri, "A deep-learning framework for human perception of abstract art composition," *J. Vision*, vol. 21, no. 5, pp. 1–18, 2021.
16. T. Xiao-Wei, H. Xin-Lin, F. Hu, and Q. Shi, "Human-perception-oriented pseudo analog video transmissions with deep learning," *IEEE Trans. Veh. Technol.*, vol. 69, no. 9, pp. 9896–9909, 2020.
17. J. Wei, W. Yue, M. Li, and J. Gao, "Mapping human perception of urban landscape from street-view images: A deep-learning approach," *Int. J. Appl. Earth Obs. Geoinf.*, vol. 112, no. 8, p. 102886, 2022.
18. D. Devi, S. Sophia, and S. R. B. Prabhu, "Deep learning-based cognitive state prediction analysis using brain wave signal," in *Cognitive Computing for Human-Robot Interaction*, Academic Press, Burlington, Massachusetts, United States of America, 2021.
19. D. Seichter, B. Lewandowski, D. Höchemer, T. Wengefeld, and H. M. Gross, "Multi-Task Deep Learning for Depth-based Person Perception in Mobile Robotics," *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Las Vegas, Nevada, United States of America, 2020.
20. T. Sharma, B. Debaque, N. Duclos, A. Chehri, B. Kinder, and P. Fortier, "Deep learning-based object detection and scene perception under bad weather conditions," *Electronics*, vol. 11, no. 4, pp. 1–11, 2022.
21. M. U. Shoukat, L. Yan, D. Deng, M. Imtiaz, M. Safdar, and S. A. Nawaz, "Cognitive robotics: Deep learning approaches for trajectory and motion control in complex environment," *Adv. Eng. Informatics*, vol. 60, no. 4, p. 102370, 2024.
22. B. B. Elallid, S. E. Hamdani, N. Benamar, and N. Mrani, "Deep learning-based modeling of pedestrian perception and decision-making in Refuge Island for Autonomous Driving," in *Computational Intelligence in Recent Communication Networks*, Springer, Cham, Switzerland, 2022.
23. M. Maier, F. Blume, P. Biadeau, O. Hellwich, and R. A. Ranman, "Knowledge-augmented face perception: Prospects for the Bayesian brain-framework to align AI and human vision," *Consciousness and Cognition*, vol. 101, no. 5, p. 103301, 2022.
24. J. Striegl, J. W. Richter, L. Grossmann, B. Bråstad, M. Gotthardt, C. Rück, J. Wallert, and C. Loitsch, "Deep learning-based dimensional emotion recognition for conversational agent-based CBT," *PeerJ Comput. Sci.*, vol. 10, no. 6, p. e2104, 2024.
25. N. Zdarsky, S. Treue, and M. Esghaei, "A deep learning-based approach to video-based eye tracking," *Frontiers in Human Neuroscience*, vol. 15, no. 7, pp. 1–8, 2021.
26. M. P. S. Lorente, E. M. Lopez, L. A. Florez, A. L. Espino, J. A. I. Martínez, and A. S. De Miguel, "Explaining deep learning-based driver models," *Applied Sciences*, vol. 11, no. 8, p. 3321, 2021.

27. X. Han, L. Wang, S. H. Seo, J. He, and T. Jung, "Measuring Perceived Psychological Stress in Urban Built Environments Using Google Street View and Deep Learning," *Frontiers in Public Health*, vol. 10, no. 5, p. 1–18, 2022.
28. A. Anushya, S. Begum, S. Shiwani, and A. Shrivastava, "Deep learning-based emotion recognition in speech signals: A convolutional neural network and LSTM approach," *AVE Trends in Intelligent Computing Systems*, vol. 1, no. 4, pp. 198–208, 2024.
29. S. M. M. Rahman, "Machine Learning-Based Cognitive Position and Force Controls for Power-Assisted Human–Robot Collaborative Manipulation," *Machines*, vol. 9, no. 2, p. 28, 2021.
30. A. A. Amer and H. S. Konswah, "Evaluating the efficacy of generative AI tools: A comparative analysis of ChatGPT and other models," *AVE Trends in Intelligent Computing Systems*, vol. 2, no. 3, pp. 174–183, 2025.
31. C. Li, P. Zheng, Y. Yin, Y. M. Pang, and S. Huo, "An AR-assisted Deep Reinforcement Learning-based approach towards mutual-cognitive safe human-robot interaction," *Robotics and Computer-Integrated Manufacturing*, vol. 80, no. 4, p. 102471, 2023.
32. S. Karthik, S. Bhaggiaraj, E. S. Soji, L. S. Deve, S. S. Priscila, and S. S. Rajest, "Real-time hand gesture recognition for stroke rehabilitation using deep learning approach," *AVE Trends in Intelligent Computing Systems*, vol. 1, no. 3, pp. 157–172, 2024.
33. T. C. Dolmans, M. Poel, J. W. J. Van't Klooster, and B. P. Veldkamp, "Perceived Mental Workload Classification using Intermediate Fusion Multimodal Deep Learning," *Frontiers in Human Neuroscience*, vol. 14, no. 1, p. 1–16, 2021.
34. D. Parasar, R. Steffi, R. Regin, and K. D. Jasper, "Leveraging deep learning for adaptive intrusion prevention in smart devices," *AVE Trends in Intelligent Computing Systems*, vol. 2, no. 4, pp. 220–229, 2025.

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