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(57) Abstract:

Disclosed is a system (100) for adaptive image enhancement using a coordinated multi-logic processing framework. The system (100) comprises an input acquisition module (102) operatively coupled to a pre-processing module (104) for conditioning image data. A gradient analysis unit (106), a gradient normalization module (108), and a clarity score computation unit (110) are configured to extract structural features. A neutrosophic transformation engine (112) with a neutrosophic parameter estimation unit (114) generates uncertainty-aware representations. A heptagonal fuzzy valuation module (116), a fuzzy membership function generator (118), and a linguistic weight assignment module (120) assign non-linear clarity levels. A decision fusion engine (122) with a fusion weight optimization unit (124) integrates multi-logic outputs. An enhancement confidence computation unit (126) and an intensity adjustment module (128) perform adaptive pixel modification, regulated by a noise suppression controller (130) and an edge preservation controller (132).

FORM 2

THE PATENT ACT 1970

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PROVISIONAL OR COMPLETE SPECIFICATION

(See Section 10 and rule 13)

TITLE OF THE INVENTION:

A SYSTEM AND A METHOD FOR ADAPTIVE MULTI-LOGIC BASED IMAGE CLARITY ENHANCEMENT

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2. PREAMBLE TO THE DESCRIPTION

COMPLETE SPECIFICATION

The following complete specification particularly describes the invention and the manner in which it is to be performed.

A SYSTEM AND A METHOD FOR ADAPTIVE MULTI-LOGIC BASED IMAGE CLARITY ENHANCEMENT

TECHNICAL FIELD OF THE INVENTION

The present disclosure generally relates to a digital image processing and computational vision framework, and more particularly relates to a system and a method for enhancing image clarity using integrated gradient-based analysis, neutrosophic uncertainty modelling, and heptagonal fuzzy valuation, in accordance with an aspect of the present disclosure.

BACKGROUND

Prior to the advent of the present invention, the domain of image enhancement was characterized by several inherent technical limitations that constrained the effectiveness and reliability of existing solutions. Conventional techniques, including histogram equalization, linear contrast adjustment, and sharpening filters, operated predominantly on global image characteristics and lacked sensitivity to localized variations. This resulted in non-uniform enhancement, frequent over-processing, and degradation of fine structural details, particularly in images affected by noise, low illumination, or macro-scale depth variations.

Further, edge-focused or gradient-based methods, although capable of identifying structural transitions, were limited in scope as they did not incorporate mechanisms to distinguish between true image features and noise-induced variations. Consequently, such approaches often amplified noise along with edges, leading to distorted visual outputs and reduced interpretability.

Attempts to address uncertainty through neutrosophic logic introduced the concept of representing pixel information using truth, indeterminacy, and falsity measures. However, these models were constrained by simplified formulations that did not adequately capture complex and non-linear ambiguity patterns present in real-world images. As a result, their ability to accurately model uncertainty in heterogeneous imaging conditions remained limited.

Similarly, fuzzy logic-based enhancement techniques were developed to provide a linguistic interpretation of image clarity. Nevertheless, the use of basic membership functions, such as triangular or trapezoidal models, restricted the system's ability to represent gradual and asymmetric transitions in clarity levels. This limitation was particularly evident in macro imaging and low-contrast scenarios, where clarity variations are inherently non-linear.

Moreover, a significant drawback in the prior art was the absence of an integrated analytical framework. Existing systems typically employed gradient analysis, uncertainty modelling, or fuzzy logic independently, without any coordinated interaction between these paradigms. This lack of multi-logic integration resulted in fragmented decision-making processes and suboptimal enhancement outcomes.

Accordingly, prior art systems were unable to simultaneously address pixel-level uncertainty, non-linear clarity transitions, and context-aware enhancement, thereby necessitating the development of a unified, multi-logic computational framework capable of delivering improved image clarity while preserving structural integrity.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description of the preferred embodiments of the present disclosure will be better understood when read in conjunction with the appended drawings. The present disclosure is illustrated by way of example, and not limited by the accompanying figures, in which like references indicate similar elements.

Fig. 1 illustrates a block diagram of a system for adaptive multi-logic based image clarity enhancement, in accordance with an aspect of the present disclosure;

Fig. 2 illustrates a flow chart of a method for adaptive multi-logic based image clarity enhancement, in accordance with an aspect of the present disclosure.

SUMMARY

In an aspect of the present disclosure, the system (100) enables adaptive image enhancement by integrating gradient-based analysis, neutrosophic modelling, and heptagonal fuzzy valuation through a coordinated multi-logic fusion framework to achieve pixel-wise, non-linear enhancement with improved clarity and reduced ambiguity.

In some aspects of the present disclosure, the gradient analysis unit (106) computes gradient magnitudes using predefined operators and the gradient normalization module (108) standardizes the computed gradients for consistent processing.

In some aspects of the present disclosure, the clarity score computation unit (110) derives gradient-based clarity scores based on local magnitude variations and sensitivity to contrast.

In some aspects of the present disclosure, the neutrosophic transformation engine (112) computes truth, indeterminacy, and falsity values using normalized intensity and statistical deviation measures.

In some aspects of the present disclosure, the neutrosophic parameter estimation unit (114) determines local statistical parameters including mean, deviation, and contrast within a neighborhood window.

In some aspects of the present disclosure, the heptagonal fuzzy valuation module (116) assigns multi-level clarity categories using a seven-parameter fuzzy membership structure.

In some aspects of the present disclosure, the decision fusion engine (122) generates enhancement confidence using weighted combination of gradient clarity, neutrosophic truth value, fuzzy clarity value, and indeterminacy penalty.

In some aspects of the present disclosure, the fusion weight optimization unit (124) determines fusion weights based on user-defined inputs or automated optimization strategies.

In some aspects of the present disclosure, the intensity adjustment module (128) modifies pixel intensities based on enhancement confidence while the noise suppression controller (130) and the edge preservation controller (132) regulate noise reduction and structural preservation.

In an aspect of the present disclosure, the method (200) performs adaptive image enhancement through sequential steps of acquisition, preprocessing, gradient analysis, neutrosophic transformation, fuzzy valuation, multi-logic fusion, confidence computation, intensity adjustment, parameter control, and output generation to produce an enhanced image with improved clarity and reduced noise.

DETAILED DESCRIPTION

The present invention is directed towards an intelligent computational framework for image enhancement, developed based on a multi-logic analytical paradigm for improving image clarity under challenging visual conditions. The invention is founded on the integration of gradient-based feature evaluation, neutrosophic uncertainty modelling, and heptagonal fuzzy valuation into a unified processing architecture. In operation, the invention analyzes an input image at a pixel level by first identifying structural variations through gradient intensity assessment, followed by transforming pixel information into a neutrosophic domain to quantify certainty, ambiguity, and noise characteristics. Thereafter, a heptagonal fuzzy membership structure is employed to classify clarity levels across multiple non-linear linguistic categories. These analytical outputs are subsequently combined through a decision fusion mechanism to derive an enhancement confidence, which governs adaptive adjustment of pixel intensities. Accordingly, the invention provides a context-aware and non-linear image enhancement solution that improves contrast and visibility while suppressing noise and preserving fine structural details across diverse imaging scenarios.

The system (100) is an intelligent computational framework configured to perform adaptive image enhancement by processing an input image through a coordinated multi-logic analytical approach. The system (100) operates at a pixel level to evaluate image characteristics, quantify uncertainty, and determine clarity variations in a context-aware manner. It is designed to integrate multiple analytical paradigms into a unified decision structure, enabling controlled enhancement of image quality without introducing artefacts or distortion. The system (100) is further configured to generate an enhanced output image with improved contrast, reduced noise influence, and preservation of fine structural details, thereby ensuring robust performance across diverse imaging conditions including low-light, macro, and noise-affected environments.

The system (100) may include an input acquisition module (102), a preprocessing module (104), a gradient analysis unit (106), a gradient normalization module (108), a clarity score computation unit (110), a neutrosophic transformation engine (112), a neutrosophic parameter estimation unit (114), a heptagonal fuzzy valuation module (116), a fuzzy membership function generator (118), a linguistic weight assignment module (120), a decision fusion engine (122), a fusion weight optimization unit (124), an enhancement confidence computation unit (126), an intensity adjustment module (128), a noise suppression controller (130), an edge preservation controller (132), an adaptive parameter controller (134), and an output module (136).

The input acquisition module (102) is configured to receive an input image from one or more sources and to generate corresponding digital image data for further processing within the system (100). In some aspects of the present disclosure, the input acquisition module (102) is operatively coupled to at least one of an image capture device, a storage medium, or a communication interface, thereby enabling acquisition of images from cameras, mobile devices, databases, or remote servers. The input acquisition module (102) may be configured to receive images captured under varying conditions, including low-light environments, macro-scale imaging, and noise-affected scenarios.

In some aspects of the present disclosure, the input acquisition module (102) is configured to convert the received image into a standardized digital representation comprising pixel intensity values defined over spatial coordinates. In cases where the input image comprises multiple color channels, the input acquisition module (102) may be configured to extract a luminance component or convert the image into a grayscale intensity map using a predefined transformation, thereby enabling consistent downstream processing.

In some aspects of the present disclosure, the input acquisition module (102) may further normalize image attributes including resolution, scale, and format to ensure compatibility with subsequent processing modules. Additionally, the input acquisition module (102) may be configured to associate auxiliary metadata with the image data, including acquisition parameters such as exposure level, illumination conditions, timestamp, or sensor characteristics, which may be utilized for adaptive processing.

Accordingly, the input acquisition module (102) provides a structured and standardized input interface, ensuring that the image data is suitably conditioned for subsequent gradient analysis, neutrosophic transformation, and fuzzy valuation within the system (100).

The preprocessing module (104) is coupled to the input acquisition module (102) and is configured to receive the image data generated by the input acquisition module (102) for further conditioning prior to analytical processing. In some aspects of the present disclosure, the preprocessing module (104) is configured to normalize pixel intensity values to a predefined range to ensure consistency in subsequent computations. The preprocessing module (104) may further be configured to perform operations including noise smoothing, intensity scaling, contrast normalization, and spatial filtering to improve the quality and stability of the image data.

In some aspects of the present disclosure, the preprocessing module (104) is configured to convert the received image data into a suitable representation, including a grayscale or luminance-based intensity map, thereby reducing computational complexity for downstream modules. The preprocessing module (104) may also be configured to standardize image dimensions, resolution, and format to ensure compatibility with subsequent processing stages.

Further, in some aspects of the present disclosure, the preprocessing module (104) may perform correction operations to address variations in illumination, sensor inconsistencies, or acquisition artefacts, thereby enhancing the reliability of feature extraction in subsequent modules. Accordingly, the preprocessing module (104) ensures that the image data is conditioned, normalized, and optimized to facilitate accurate gradient analysis, neutrosophic transformation, and fuzzy valuation within the system (100).

The gradient analysis unit (106) is coupled to the preprocessing module (104) and is configured to receive the preprocessed image data for detecting structural variations within the image. In some aspects of the present disclosure, the gradient analysis unit (106) is configured to compute pixel-wise gradient components along horizontal and vertical directions using one or more gradient operators, including but not limited to Sobel, Scharr, or central-difference operators. The gradient analysis unit (106) may further be configured to determine gradient magnitude values for each pixel based on the computed directional gradients, thereby identifying edge strength and local intensity transitions.

In some aspects of the present disclosure, the gradient analysis unit (106) is configured to highlight regions exhibiting high spatial variation corresponding to edges, contours, and structural details, while distinguishing such regions from relatively uniform or low-contrast areas. The gradient analysis unit (106) may also be configured to generate a gradient map representing the distribution of structural information across the image.

Further, in some aspects of the present disclosure, the gradient analysis unit (106) enables localized assessment of image clarity by capturing fine-grained variations in pixel intensities, thereby supporting subsequent computation of clarity scores and decision-making processes. Accordingly, the gradient analysis unit (106) facilitates extraction of meaningful structural features from the image data, which are utilized by downstream modules within the system (100) for adaptive enhancement.

The gradient normalization module (108) is operatively associated with the gradient analysis unit (106) and is configured to receive the gradient magnitude values computed by the gradient analysis unit (106) for normalization. In some aspects of the present disclosure, the gradient normalization module (108) is configured to scale the gradient magnitudes to a predefined range to ensure uniformity and numerical stability in subsequent processing stages. The normalization may be performed using linear scaling, non-linear mapping, or adaptive normalization techniques based on the distribution of gradient values.

In some aspects of the present disclosure, the gradient normalization module (108) is configured to mitigate the effects of extreme gradient values, noise-induced spikes, or illumination variations by constraining the gradient magnitudes within a bounded interval. This normalization enables consistent interpretation of structural variations across different regions of the image.

Further, in some aspects of the present disclosure, the gradient normalization module (108) may generate a normalized gradient map that facilitates reliable computation of clarity scores and integration with other analytical measures. Accordingly, the gradient normalization module (108) ensures that the gradient-based features are standardized and suitable for coordinated multi-logic processing within the system (100).

The clarity score computation unit (110) is operatively coupled to the gradient analysis unit (106) and the gradient normalization module (108) and is configured to receive the normalized gradient data for deriving a pixel-wise clarity score. In some aspects of the present disclosure, the clarity score computation unit (110) is configured to compute a quantitative measure of clarity for each pixel based on variations in gradient magnitude, thereby indicating the degree of structural significance associated with the pixel.

In some aspects of the present disclosure, the clarity score computation unit (110) may apply a mathematical mapping function to the normalized gradient values to generate clarity scores within a predefined range, wherein the mapping function may incorporate one or more sensitivity parameters to control responsiveness to contrast variations. The clarity score computation unit (110) may further be configured to distinguish between high-clarity regions corresponding to edges and fine details, and low-clarity regions corresponding to blurred or uniform areas.

Further, in some aspects of the present disclosure, the clarity score computation unit (110) may generate a clarity map representing spatial distribution of clarity across the image, which is subsequently utilized by downstream modules for multi-logic decision fusion. Accordingly, the clarity score computation unit (110) provides a structured representation of pixel-level clarity that supports adaptive enhancement within the system (100).

The neutrosophic transformation engine (112) is operatively coupled to the preprocessing module (104) and is configured to receive the preprocessed image data for transforming each pixel into a neutrosophic domain representation. In some aspects of the present disclosure, the neutrosophic transformation engine (112) is configured to map each pixel into a triad comprising a truth value, an indeterminacy value, and a falsity value, thereby enabling explicit quantification of clarity certainty, ambiguity, and noise presence at a pixel level.

In some aspects of the present disclosure, the neutrosophic transformation engine (112) is configured to compute the truth value based on normalized pixel intensity, the indeterminacy value based on a measure of deviation or local variation, and the falsity value as a complementary or derived function indicative of noise likelihood. The neutrosophic transformation engine (112) may further incorporate local neighborhood statistics to ensure that the computed values reflect contextual variations in intensity and structure.

Further, in some aspects of the present disclosure, the neutrosophic transformation engine (112) generates a neutrosophic map comprising the triad values for each pixel, thereby providing a structured representation of uncertainty and ambiguity across the image. Accordingly, the neutrosophic transformation engine (112) enables separation of meaningful image features from uncertain or noisy regions, thereby supporting informed decision-making in subsequent modules within the system (100).

The neutrosophic parameter estimation unit (114) is operatively associated with the neutrosophic transformation engine (112) and is configured to derive statistical parameters required for generating the neutrosophic representation of each pixel. In some aspects of the present disclosure, the neutrosophic parameter estimation unit (114) is configured to compute local statistical measures including mean intensity, variance, deviation, or contrast within a predefined neighborhood window surrounding each pixel.

In some aspects of the present disclosure, the neutrosophic parameter estimation unit (114) is configured to determine scaling parameters and deviation factors that influence the computation of indeterminacy values, thereby enabling accurate modelling of uncertainty and ambiguity in the image data. The neutrosophic parameter estimation unit (114) may further adapt the size of the neighborhood window or the statistical computation method based on image characteristics such as resolution, noise level, or texture distribution.

Further, in some aspects of the present disclosure, the neutrosophic parameter estimation unit (114) provides the computed statistical parameters to the neutrosophic transformation engine (112) to ensure that the truth, indeterminacy, and falsity values are derived in a context-aware and adaptive manner. Accordingly, the neutrosophic parameter estimation unit (114) enhances the robustness and accuracy of the neutrosophic modelling process within the system (100).

The heptagonal fuzzy valuation module (116) is operatively coupled to the neutrosophic transformation engine (112) and is configured to receive the neutrosophic representation for assigning clarity levels to image pixels using a heptagonal fuzzy framework. In some aspects of the present disclosure, the heptagonal fuzzy valuation module (116) is configured to classify pixel clarity into multiple linguistic categories based on a seven-parameter membership structure, thereby enabling representation of gradual, asymmetric, and non-linear transitions in image clarity.

In some aspects of the present disclosure, the heptagonal fuzzy valuation module (116) is configured to assign clarity categories including very low, low, slightly low, moderate, slightly high, high, and very high, based on the pixel characteristics represented through the neutrosophic domain and associated analytical measures. The heptagonal fuzzy valuation module (116) may further be configured to determine a fuzzy clarity value corresponding to each pixel by evaluating the degree of membership of the pixel in one or more of the linguistic categories.

Further, in some aspects of the present disclosure, the heptagonal fuzzy valuation module (116) enables modelling of complex clarity behaviour that cannot be adequately represented by conventional triangular or trapezoidal fuzzy structures. Accordingly, the heptagonal fuzzy valuation module (116) provides a more expressive and context-sensitive valuation of pixel-level clarity, thereby supporting accurate multi-logic fusion and adaptive enhancement within the system (100).

The fuzzy membership function generator (118) is operatively associated with the heptagonal fuzzy valuation module (116) and is configured to generate heptagonal fuzzy membership functions for evaluating pixel-level clarity. In some aspects of the present disclosure, the fuzzy membership function generator (118) is configured to define a seven-parameter membership structure for each linguistic clarity category, wherein the parameters correspond to transition points that collectively model the ascent, plateau, and descent characteristics of the membership function.

In some aspects of the present disclosure, the fuzzy membership function generator (118) is configured to construct non-linear and asymmetric membership curves that accurately capture gradual variations in clarity across different intensity ranges. The fuzzy membership function generator (118) may further be configured to assign distinct parameter sets for each clarity category, including very low, low, slightly low, moderate, slightly high, high, and very high, thereby ensuring full coverage of the clarity spectrum.

Further, in some aspects of the present disclosure, the fuzzy membership function generator (118) may dynamically adjust the membership parameters based on image characteristics or predefined configurations, thereby enabling adaptive fuzzy modelling. Accordingly, the fuzzy membership function generator (118) facilitates precise and flexible representation of clarity transitions, thereby enhancing the effectiveness of the heptagonal fuzzy valuation module (116) within the system (100).

The linguistic weight assignment module (120) is operatively coupled to the heptagonal fuzzy valuation module (116) and is configured to assign quantitative weights to the linguistic clarity levels generated by the heptagonal fuzzy valuation module (116). In some aspects of the present disclosure, the linguistic weight assignment module (120) is configured to associate each clarity category, including very low, low, slightly low, moderate, slightly high, high, and very high, with a corresponding numerical weight that represents its relative significance in the enhancement process.

In some aspects of the present disclosure, the linguistic weight assignment module (120) may be configured to assign the weights based on predefined mappings, user-defined configurations, or adaptive criteria derived from image characteristics. The linguistic weight assignment module (120) may further be configured to convert the assigned linguistic clarity levels into corresponding numerical values, thereby enabling integration with gradient-based clarity scores and neutrosophic representations during multi-logic fusion.

Further, in some aspects of the present disclosure, the linguistic weight assignment module (120) ensures consistent mapping between fuzzy linguistic interpretations and quantitative measures, thereby facilitating effective aggregation of multi-logic outputs within the system (100).

The decision fusion engine (122) is operatively coupled to the clarity score computation unit (110), the neutrosophic transformation engine (112), and the heptagonal fuzzy valuation module (116), and is configured to receive the respective outputs for integrated processing. In some aspects of the present disclosure, the decision fusion engine (122) is configured to combine the gradient-based clarity score, the neutrosophic representation comprising truth, indeterminacy, and falsity values, and the fuzzy clarity values derived from the heptagonal fuzzy valuation module (116), to generate a unified decision signal for each pixel.

In some aspects of the present disclosure, the decision fusion engine (122) is configured to perform weighted multi-logic fusion, wherein each analytical input is assigned a corresponding weight and aggregated using a predefined or adaptive fusion rule. The decision fusion engine (122) may further incorporate penalty or modulation factors based on indeterminacy values to reduce the influence of uncertain or noisy regions in the enhancement decision.

Further, in some aspects of the present disclosure, the decision fusion engine (122) is configured to generate a combined enhancement signal that reflects both structural significance and uncertainty characteristics of each pixel. Accordingly, the decision fusion engine (122) enables coordinated utilization of multiple analytical paradigms, thereby providing a context-aware and robust basis for adaptive image enhancement within the system (100).

The fusion weight optimization unit (124) is operatively associated with the decision fusion engine (122) and is configured to determine and optimize the weights applied during the multi-logic fusion process. In some aspects of the present disclosure, the fusion weight optimization unit (124) is configured to assign weighting factors to the gradient-based clarity score, the neutrosophic representation, and the fuzzy clarity values, thereby controlling their relative contribution to the overall enhancement decision.

In some aspects of the present disclosure, the fusion weight optimization unit (124) may be configured to determine the weights based on predefined configurations, user-defined inputs, or adaptive optimization strategies derived from image characteristics such as noise level, contrast variation, or structural complexity. The fusion weight optimization unit (124) may further dynamically adjust the weights in real time to improve enhancement performance under varying imaging conditions.

Further, in some aspects of the present disclosure, the fusion weight optimization unit (124) ensures balanced integration of multiple analytical inputs by preventing dominance of any single logic component, thereby enhancing stability and robustness of the decision fusion process. Accordingly, the fusion weight optimization unit (124) facilitates optimized multi-logic fusion for accurate and adaptive image enhancement within the system (100).

The enhancement confidence computation unit (126) is operatively coupled to the decision fusion engine (122) and is configured to receive the combined enhancement signal for computing a pixel-wise enhancement confidence. In some aspects of the present disclosure, the enhancement confidence computation unit (126) is configured to generate a quantitative confidence value for each pixel based on the fused outputs of the gradient-based clarity score, the neutrosophic representation, and the fuzzy clarity values.

In some aspects of the present disclosure, the enhancement confidence computation unit (126) may be configured to apply a mathematical mapping or aggregation function to the fused signal to derive a normalized confidence measure indicative of the degree of enhancement to be applied. The enhancement confidence computation unit (126) may further incorporate penalty factors associated with indeterminacy values to reduce confidence in regions exhibiting higher uncertainty or noise.

Further, in some aspects of the present disclosure, the enhancement confidence computation unit (126) may generate an enhancement confidence map representing spatial distribution of enhancement intensity across the image. Accordingly, the enhancement confidence computation unit (126) provides a structured basis for adaptive pixel-wise intensity adjustment, thereby enabling controlled and context-aware image enhancement within the system (100).

The intensity adjustment module (128) is operatively coupled to the enhancement confidence computation unit (126) and is configured to receive the pixel-wise enhancement confidence for modifying pixel intensities of the image. In some aspects of the present disclosure, the intensity adjustment module (128) is configured to adjust the intensity of each pixel as a function of the corresponding enhancement confidence, thereby enabling adaptive enhancement based on local image characteristics.

In some aspects of the present disclosure, the intensity adjustment module (128) may be configured to apply a transformation function to increase or decrease pixel intensity values in a controlled manner, wherein the transformation may be governed by an enhancement strength parameter. The intensity adjustment module (128) may further ensure that the adjusted pixel values remain within a predefined intensity range to prevent saturation or loss of detail.

Further, in some aspects of the present disclosure, the intensity adjustment module (128) may generate an enhanced image by applying the computed adjustments across all pixels, while maintaining consistency and continuity in intensity transitions. Accordingly, the intensity adjustment module (128) facilitates context-aware and non-linear enhancement of the image, thereby improving clarity while minimizing artefacts within the system (100).

The noise suppression controller (130) is operatively coupled to the intensity adjustment module (128) and is configured to regulate the pixel intensity adjustment process so as to suppress amplification of noise during image enhancement. In some aspects of the present disclosure, the noise suppression controller (130) is configured to identify regions exhibiting high ambiguity, fluctuation, or noise likelihood based on the enhancement confidence and associated analytical measures, and to correspondingly constrain the degree of intensity modification applied to such regions.

In some aspects of the present disclosure, the noise suppression controller (130) may be configured to apply one or more control rules, thresholding operations, or attenuation factors to prevent undesired enhancement of random noise components, especially in low-light, blurred, or non-uniform image regions. The noise suppression controller (130) may further interact with the neutrosophic representation and the fused enhancement signal to distinguish uncertain or noisy pixels from valid structural information.

In some aspects of the present disclosure, the noise suppression controller (130) ensures that the enhancement process remains stable and visually coherent by reducing artefacts that may otherwise arise from aggressive pixel-wise adjustment. Accordingly, the noise suppression controller (130) contributes to generation of an enhanced image with improved clarity and reduced noise propagation within the system (100).

The edge preservation controller (132) is operatively coupled to the intensity adjustment module (128) and is configured to regulate the pixel intensity modification process so as to preserve structural edges and fine details within the image during enhancement. In some aspects of the present disclosure, the edge preservation controller (132) is configured to identify regions corresponding to edges, contours, and high-frequency components based on gradient-based clarity scores and associated analytical measures, and to maintain the integrity of such regions during intensity adjustment.

In some aspects of the present disclosure, the edge preservation controller (132) may be configured to apply constraint functions, adaptive scaling factors, or boundary-preserving rules that prevent blurring, distortion, or over-smoothing of edges while performing enhancement. The edge preservation controller (132) may further coordinate with the noise suppression controller (130) to ensure that edge features are enhanced selectively without amplifying noise components.

In some aspects of the present disclosure, the edge preservation controller (132) ensures continuity of structural information by maintaining sharp transitions between adjacent regions, thereby preventing loss of detail and visual artefacts. Accordingly, the edge preservation controller (132) facilitates preservation of fine structural features while enabling adaptive enhancement within the system (100).

The adaptive parameter controller (134) is operatively coupled to the decision fusion engine (122) and the intensity adjustment module (128) and is configured to dynamically regulate operational parameters of the system (100) during image enhancement. In some aspects of the present disclosure, the adaptive parameter controller (134) is configured to adjust parameters including fusion weights, enhancement strength, normalization ranges, and threshold values based on characteristics of the input image such as noise level, contrast distribution, and structural complexity.

In some aspects of the present disclosure, the adaptive parameter controller (134) may be configured to determine parameter values using predefined rules, user-defined configurations, or adaptive optimization strategies derived from real-time analysis of image data. The adaptive parameter controller (134) may further enable context-aware tuning by modifying parameters across different regions of the image to achieve localized enhancement.

Further, in some aspects of the present disclosure, the adaptive parameter controller (134) ensures that the enhancement process remains robust and consistent under varying imaging conditions by preventing over-enhancement or under-enhancement. Accordingly, the adaptive parameter controller (134) facilitates dynamic control of the multi-logic processing pipeline, thereby improving the effectiveness and adaptability of the system (100).

The output module (136) is operatively coupled to the intensity adjustment module (128) and is configured to generate an enhanced image based on the modified pixel intensities. In some aspects of the present disclosure, the output module (136) is configured to reconstruct the processed pixel data into a complete image representation while preserving spatial coherence and visual continuity. The output module (136) may further be configured to format the enhanced image in one or more standard image formats suitable for storage, transmission, or display.

In some aspects of the present disclosure, the output module (136) may be configured to provide the enhanced image to external devices, storage systems, or user interfaces, thereby enabling visualization or further processing. The output module (136) may also be configured to associate metadata with the enhanced image, including enhancement parameters or processing indicators, to facilitate traceability and reproducibility.

Further, in some aspects of the present disclosure, the output module (136) ensures that the final output image reflects improved clarity, reduced noise influence, and preservation of structural details as achieved through the coordinated operation of the system (100). Accordingly, the output module (136) provides a finalized clarity-enhanced image suitable for diverse imaging applications.

In operation, the system (100) initiates processing by receiving the input image via the input acquisition module (102), wherein the input acquisition module (102) acquires the image from the source and generates the corresponding image data. The image data is then forwarded to the preprocessing module (104), wherein the preprocessing module (104) normalizes the pixel intensity values, standardizes the image format, and conditions the image data for further analysis.

Subsequently, the preprocessed image data is provided to the gradient analysis unit (106), wherein the gradient analysis unit (106) computes the pixel-wise gradient magnitudes to identify the structural variations within the image. The computed gradient magnitudes are then processed by the gradient normalization module (108), wherein the gradient normalization module (108) normalizes the gradient values to ensure consistency across the image. The normalized gradient values are then utilized by the clarity score computation unit (110), wherein the clarity score computation unit (110) generates the gradient-based clarity score for each pixel representing the structural significance.

In parallel, the preprocessed image data is provided to the neutrosophic transformation engine (112), wherein the neutrosophic transformation engine (112) transforms each pixel into the neutrosophic representation comprising the truth value, the indeterminacy value, and the falsity value. The neutrosophic parameter estimation unit (114) computes the local statistical parameters including the mean, the deviation, and the contrast, which are utilized by the neutrosophic transformation engine (112) to ensure accurate modelling of the uncertainty.

The neutrosophic representation is then provided to the heptagonal fuzzy valuation module (116), wherein the heptagonal fuzzy valuation module (116) assigns the clarity levels using the seven-parameter fuzzy membership structure. The fuzzy membership function generator (118) generates the heptagonal membership functions defining the clarity transitions, and the linguistic weight assignment module (120) assigns the corresponding weights to the clarity levels to convert the linguistic values into the quantitative representation.

Thereafter, the clarity score from the clarity score computation unit (110), the neutrosophic representation from the neutrosophic transformation engine (112), and the fuzzy clarity values from the heptagonal fuzzy valuation module (116) are provided to the decision fusion engine (122). The decision fusion engine (122) performs the coordinated multi-logic fusion using the weighted combination, wherein the fusion weight optimization unit (124) determines and dynamically adjusts the fusion weights to balance the contribution of each analytical component.

The fused output is then processed by the enhancement confidence computation unit (126), wherein the enhancement confidence computation unit (126) computes the pixel-wise enhancement confidence indicating the degree of intensity modification required. The computed enhancement confidence is provided to the intensity adjustment module (128), wherein the intensity adjustment module (128) adjusts the pixel intensities in accordance with the enhancement confidence.

During the intensity adjustment process, the noise suppression controller (130) regulates the adjustment to prevent amplification of the noise, and the edge preservation controller (132) ensures preservation of the structural edges and the fine details. The adaptive parameter controller (134) dynamically controls the operational parameters including the fusion weights, the enhancement strength, and the threshold values based on the characteristics of the image to ensure optimal performance.

Finally, the processed image data is provided to the output module (136), wherein the output module (136) generates the enhanced image with improved clarity, reduced noise influence, and preserved structural details.

Fig. 2 illustrates a method (200) for adaptive image enhancement using integrated multi-logic processing comprising gradient-based analysis, neutrosophic transformation, and heptagonal fuzzy valuation, in accordance with an aspect of the present disclosure. The method (200) steps are as follows: -

At step (202), the input image is received via the input acquisition module (102), wherein the input image is obtained from one or more sources including imaging devices, storage systems, or communication networks, and the corresponding image data comprising pixel intensity values is generated for further processing.

At step (204), the image data is pre-processed via the preprocessing module (104), wherein the pixel intensity values are normalized to the predefined range, and the image is conditioned by performing operations including noise smoothing, format standardization, and conversion into the luminance or grayscale representation to ensure uniformity for subsequent analysis.

At step (206), the pixel-wise gradient magnitudes are computed via the gradient analysis unit (106) to identify the structural variations within the image, and the computed gradient magnitudes are normalized via the gradient normalization module (108) to ensure consistency and numerical stability across different regions of the image.

At step (208), the gradient-based clarity score is generated for each pixel via the clarity score computation unit (110), wherein the clarity score represents the degree of structural significance associated with the pixel based on the variations in the gradient magnitude.

At step (210), each pixel is transformed into the neutrosophic representation via the neutrosophic transformation engine (112), wherein the representation comprises the truth value, the indeterminacy value, and the falsity value indicative of the clarity certainty, the ambiguity, and the noise, and the corresponding parameters including the local mean, the deviation, or the contrast are estimated via the neutrosophic parameter estimation unit (114) to enable context-aware modelling of the uncertainty.

At step (212), the clarity levels are assigned via the heptagonal fuzzy valuation module (116) using the seven-parameter fuzzy membership structure, wherein the heptagonal membership functions are generated via the fuzzy membership function generator (118), and the corresponding linguistic weights are assigned via the linguistic weight assignment module (120) to convert the clarity levels into the quantitative values.

At step (214), the gradient-based clarity score, the neutrosophic representation, and the assigned clarity levels are fused via the decision fusion engine (122) using the weighted multi-logic fusion process, wherein the fusion weights are determined via the fusion weight optimization unit (124) to control the relative contribution of each analytical component.

At step (216), the pixel-wise enhancement confidence is computed via the enhancement confidence computation unit (126) based on the fused output, wherein the enhancement confidence indicates the degree of intensity modification to be applied to each pixel.

At step (218), the pixel intensities are adjusted via the intensity adjustment module (128) based on the computed enhancement confidence, and the adjustment is regulated via the noise suppression controller (130) to prevent amplification of the noise and via the edge preservation controller (132) to maintain the structural edges and the fine details.

At step (220), the operational parameters of the method (200) are dynamically controlled via the adaptive parameter controller (134), wherein the parameters including the fusion weights, the enhancement strength, and the threshold values are adjusted based on the image characteristics to ensure robust and context-aware enhancement.

At step (222), the enhanced image is generated via the output module (136) based on the adjusted pixel intensities, wherein the enhanced image exhibits the improved clarity, the reduced noise influence, and the preservation of the structural details suitable for further use or visualization.

The implementation set forth in the foregoing description does not represent all implementations consistent with the subject matter described herein. Instead, they are merely some examples consistent with aspects related to the described subject matter. Although a few variations have been described in detail above, other modifications or additions are possible. In particular, further features and/or variations can be provided in addition to those set forth herein. For example, the implementation described can be directed to various combinations and sub combinations of the disclosed features and/or combinations and sub combinations of the several further features disclosed above. In addition, the logic flows depicted in the accompanying figures and/or described herein do not necessarily require the particular order shown, or sequential order, to achieve desirable results. Other implementations may be within the scope of the following claims.

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We claim

1. A system (100) for adaptive image enhancement, the system (100) comprising:

   an input acquisition module (102) operatively coupled to a pre-processing module (104);

   a gradient analysis unit (106) operatively coupled to the pre-processing module (104), a gradient normalization module (108) operatively associated with the gradient analysis unit (106), and a clarity score computation unit (110) operatively coupled to the gradient analysis unit (106);

   a neutrosophic transformation engine (112) operatively coupled to the pre-processing module (104), and a neutrosophic parameter estimation unit (114) operatively associated with the neutrosophic transformation engine (112);

   a heptagonal fuzzy valuation module (116) operatively coupled to the neutrosophic transformation engine (112), a fuzzy membership function generator (118) operatively associated with the heptagonal fuzzy valuation module (116), and a linguistic weight assignment module (120) operatively coupled to the heptagonal fuzzy valuation module (116);

   a decision fusion engine (122) operatively coupled to the clarity score computation unit (110), the neutrosophic transformation engine (112), and the heptagonal fuzzy valuation module (116), and a fusion weight optimization unit (124) operatively associated with the decision fusion engine (122);

   an enhancement confidence computation unit (126) operatively coupled to the decision fusion engine (122), and an intensity adjustment module

(128) operatively coupled to the enhancement confidence computation unit (126);

a noise suppression controller (130) and an edge preservation controller (132) operatively coupled to the intensity adjustment module (128);

an adaptive parameter controller (134) operatively coupled to the decision fusion engine (122) and the intensity adjustment module (128); and

an output module (136) operatively coupled to the intensity adjustment module (128);

characterized in that, the decision fusion engine (122) is configured to perform a coordinated multi-logic fusion of the gradient-based clarity score, the neutrosophic representation, and the heptagonal fuzzy clarity levels to derive an enhancement confidence for pixel-wise adaptive, non-linear image enhancement with reduced ambiguity and improved preservation of structural details.

2. The system (100) as claimed in claim 1, wherein the gradient analysis unit (106) is configured to compute gradient magnitudes using at least one of a Sobel operator, a Scharr operator, or a central-difference operator, and the gradient normalization module (108) is configured to normalize the gradient magnitudes using a linear or non-linear scaling function.
3. The system (100) as claimed in claim 1, wherein the clarity score computation unit (110) is configured to derive the gradient-based clarity score based on magnitude variations and a sensitivity parameter indicative of local contrast.
4. The system (100) as claimed in claim 1, wherein the neutrosophic transformation engine (112) is configured to compute the truth value based on normalized pixel intensity, the indeterminacy value based on a deviation function of local intensity statistics, and the falsity value as a complement of the truth value.

5. The system (100) as claimed in claim 1, wherein the neutrosophic parameter estimation unit (114) is configured to determine local statistical parameters including mean intensity, deviation, or contrast within a predefined neighborhood window.
6. The system (100) as claimed in claim 1, wherein the heptagonal fuzzy valuation module (116) is configured to assign clarity levels comprising Very Low, Low, Slightly Low, Moderate, Slightly High, High, and Very High using a seven-parameter fuzzy membership structure.
7. The system (100) as claimed in claim 1, wherein the decision fusion engine (122) is configured to generate the enhancement confidence based on a weighted combination of the gradient-based clarity score, the neutrosophic truth value, a fuzzy clarity value, and an indeterminacy penalty factor.
8. The system (100) as claimed in claim 1, wherein the fusion weight optimization unit (124) is configured to determine the weights for the weighted combination based on user-defined parameters or automated optimization.
9. The system (100) as claimed in claim 1, wherein the intensity adjustment module (128) is configured to modify pixel intensities based on the enhancement confidence and an enhancement strength parameter while the noise suppression controller (130) and the edge preservation controller (132) regulate the modification to suppress noise and preserve structural details.

10. A method (200) for adaptive image enhancement, the method (200) comprising:

receiving (202), via an input acquisition module (102), an input image and generating image data;

pre-processing (204), via a pre-processing module (104), the image data to normalize intensity values;

computing (206), via a gradient analysis unit (106), pixel-wise gradient magnitudes and normalizing, via a gradient normalization module (108), the computed gradient magnitudes;

generating (208), via a clarity score computation unit (110), a gradient-based clarity score for each pixel;

transforming (210), via a neutrosophic transformation engine (112), each pixel into a neutrosophic representation comprising truth, indeterminacy, and falsity values, and estimating, via a neutrosophic parameter estimation unit (114), parameters for the neutrosophic representation;

assigning (212), via a heptagonal fuzzy valuation module (116), clarity levels using a seven-parameter fuzzy membership structure, generating, via a fuzzy membership function generator (118), heptagonal membership functions, and assigning, via a linguistic weight assignment module (120), weights to the clarity levels;

fusing (214), via a decision fusion engine (122), the gradient-based clarity score, the neutrosophic representation, and the assigned clarity levels using weighted multi-logic fusion, and determining, via a fusion weight optimization unit (124), fusion weights;

computing (216), via an enhancement confidence computation unit (126), a pixel-wise enhancement confidence based on the fused output;

adjusting (218), via an intensity adjustment module (128), pixel intensities based on the enhancement confidence, and regulating, via a noise suppression controller (130) and an edge preservation controller (132), the adjustment to suppress noise and preserve structural details;

dynamically controlling (220), via an adaptive parameter controller (134), operational parameters of the method (200); and

generating (222), via an output module (136), an enhanced image based on the adjusted pixel intensities.

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ABSTRACT

A SYSTEM AND A METHOD FOR ADAPTIVE MULTI-LOGIC BASED IMAGE CLARITY ENHANCEMENT

Disclosed is a system (100) for adaptive image enhancement using a coordinated multi-logic processing framework. The system (100) comprises an input acquisition module (102) operatively coupled to a pre-processing module (104) for conditioning image data. A gradient analysis unit (106), a gradient normalization module (108), and a clarity score computation unit (110) are configured to extract structural features. A neutrosophic transformation engine (112) with a neutrosophic parameter estimation unit (114) generates uncertainty-aware representations. A heptagonal fuzzy valuation module (116), a fuzzy membership function generator (118), and a linguistic weight assignment module (120) assign non-linear clarity levels. A decision fusion engine (122) with a fusion weight optimization unit (124) integrates multi-logic outputs. An enhancement confidence computation unit (126) and an intensity adjustment module (128) perform adaptive pixel modification, regulated by a noise suppression controller (130) and an edge preservation controller (132).