Understanding Rembrandt: Directed Knowledge Improves Robustness and Evolution of Facial Phenotype Modeling

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2022 9th International Conference on Dependable Systems and Their Applications (DSA) | 978-1-6654-8877-8/22/$31.00 ©2022 IEEE | DOI: 10.1109/DSA56465.2022.00131

***Abstract*—Directed knowledge understanding is a deep knowledge service structure strategy proposed in the face of logically complex solving needs along with the increasing scale of data production. This study proposes an improved method for facial phenotype modelling based on directed knowledge information understanding, which effectively utilizes the information framework constructed by the concept of directed knowledge understanding, and uses Renaissance physiological and anatomical knowledge, medical pathology detection, artwork hyperspectral image data, Netherlandish oil painting genealogy and Rembrandt art feature study as directed regions, and transforms directed knowledge through the classification constraints of emotional understanding into behavioral laws, realize parametric extraction and then encode with coupled solution method to complete the improved embedding of facial feature extraction algorithm. The experimental analysis shows that 1) deep knowledge understanding achieves the compensation of sparse feature localization for the deficiency of expression sensitivity, 2) the calculation of surface curvature after drawing on anatomical knowledge can vividly describe the implicit features of facial phenotype, and 3) the sensitivity of implicit emotion observation of facial objects can be effectively improved in the general technique by virtue of the characteristics of facial feature region texture influenced by physiological indicators, combined with the edge recognition of highlight region. The improved facial modelling process has more humane perceptual habits and enhances the accuracy and robustness of the service domain requirements.**

Keywords- group intelligence; directed knowledge; facial modelling; Rembrandt

I. Introduction

This paper attempts to embed human perceptual thinking patterns and evolutionary accumulation paths into relatively mature technical modules with specific case studies, to realize directed knowledge understanding into evolutionary goals and data parameter indicators, and to deeply intervene in the algorithm and modeling stages. In the specific challenge for facial modeling, the knowledge base of perception, transmission, inheritance, and mutation between human and human and the ecological laws of social knowledge evolution itself need to be migrated to the direct interaction between human and machine to transform directed knowledge into dynamic, emotional, and accessible understanding capabilities and metrics.

The second part of the article discusses the logical translation of directed knowledge into computable parametric idea transformations; the third part of the article provides an introduction to the progress of facial observation research; the fourth part describes the principles and requirements for understanding Rembrandt's facial modeling; the fifth part presents improved strategies for facial modeling based on directed knowledge; and the sixth part provides conclusions and further discussion.

II. Motivation

Defining information entropy for images. How knowledge can be transformed into observable, callable and adjustable parameter metrics and algorithms with the help of automated methods to achieve self-iterative evolution and participate in the process of enhancing human design creation by asking new questions is crucial. Domain experts select and define the problem, and the process of search behavior is performed by the evolution of automated tools, usually the breadth of coverage and depth of exploration of solutions that can be found by technical tools supported by arithmetic power, often appear to be superior to the effect of domain expert design because of the advantage of occupying resources. This concept of data- and algorithm-enabled evolution is applicable to both solving optimal problems and to areas such as organizational control and ecological design. It is even possible to use evolutionary computation for the derivation of forward evolution and reverse degradation, and to participate in the restoration of social knowledge ecologies that have disappeared. Even so, the rational bias involved is that the development of prototype automated tools necessarily relies on the directed knowledge constructs of experts in a domain itself, and the initial goal setting can limit the scope of research that defines the problem. With an already constrained scope, the value of the optimal solution is in some sense destined to come at the expense of the boundaries of exploration.

Complexity itself is a concept of "complexity". In complexity science, "to understand complexity, we must first understand complexity". At the moment, we can still understand the image in terms of the parameters of order, which can be understood as follows: complexity is a state between complete order and complete disorder, and beauty and complexity themselves are metaphors for each other. Because complexity itself is a complex concept, there is so much controversy over the definition and measurement of complexity. The former is physical or ontological complexity, such as entropic complexity, which cannot be simplified through cognition, while the latter refers to complexity that can become simple as human cognition improves and the laws are mastered. On this basis, complexity can then be divided into several categories such as information, entropy, descriptiveness, depth, complexity, diversity, dimensionality, and synthesis (metaphor) [1].

Understanding how artistic expression and design principles evolve over time is a central issue in the study of art history, aesthetics, and culture. Take the example of Western Renaissance figure painting, which plays an important role in human expression and whose evolution, accompanied by a complex interplay of social evolution, social knowledge accumulation, and scientific evolutionary processes. In the visual arts, once artists determined the main characteristics of artworks through the interaction of some hidden variables, and concealed into the technological accompaniment and directed knowledge of the times. In traditional studies in the field of computer image graphics, formalistic concepts such as lines, shapes, tones, and textures are used to explain and generalize the poor effectiveness of variables in the creation of art. A series of quantitative analysis methods, including network analysis and information extraction, are forming a new knowledge service in the new field of "computational aesthetics" or "information aesthetics" [2].

There is generally and simultaneously both cooperation and competition between knowledge domains. The concept of directed knowledge stems from the fact that evolution never occurs in isolation, but in embodiment in specific research domains is often independent. The adaptive nature of directed knowledge depends on the open-ended dynamics of competition or cooperation between the research community and other domains, and directed knowledge must be expanded to meet evolutionary needs, while the framework protocols and linking ports of directed knowledge are designed to guarantee that they themselves can also collaboratively serve the various sub-modules under the demand goals through circular iterations. The deep involvement of directed knowledge will be a prerequisite for creating more complex solutions.

How to translate directed knowledge understanding into annotation criteria to assign values to analytical energy efficiency for facial phenotype modeling? How to perform effectiveness evaluation by understanding validity and directed knowledge evolution? How to achieve logical evolution of human perception of faces in engineering and even unknown domains? How is the scope of directed knowledge defined and acquired? Are there all reasonable possibilities for the evolutionary logic in the digital twin era? In turn, it must be explored experimentally through a specific feedback intervention to reinforce directed evolution to create mutational possibilities. By targeting random mutational features as a blueprint for observation, then the basis of variation with a specific design target being selected will appear to have an amplification effect to inform the ongoing directed source expansion knowledge implantation.

Human emotion expression is highly individualized and not easily defined. The complexity of facial emotion and the diversity of individuals make facial modeling very challenging. How to understand and learn the multiplicity and directionality of human perception of facial thinking and the variation law of thinking evolution? At this stage, the academic community focuses on facial modeling emotion perception research that simply improves recognition rates and large computing power [3], intensifies research under the intervention of multimodal recognition techniques, and uses, for example, breathing rhythms, gas emissions, body surface thermography, physiological indicators, stress tests and audio parameters in order to recognize the emotional patterns under facial phenotypes, and the technical templates of this type of research recognition methods are widely used by neural networks (NN), support vector machines (SVM) [4], rule-based methods, and so on.

III. Facial Observation Study

Facial modeling evolution has been able to propose solutions in highly complex systems, supported by massive training samples and powerful arithmetic power, progressing rapidly. However, the facial cognitive experience of observing, feeling, understanding, and empathizing with real humans still dwarfs the effectiveness evaluation through assessment metrics such as robustness, generality, and reliability.

In nature, by constructing an ecological niche and changing the environment rather than itself, an organism is going to gain a survival advantage in a way that affects natural selection. In this process, feedback mechanisms give rise to evolutionary efficacy. Human beings always face each other, and the gaze, understanding and feedback on each other's faces accompany the whole process of human evolution and social evolution, and the perceptual properties and observation methods generated by evolution tend to become more and more complex over time, and the evolutionary acceleration of the effectiveness of facial observation reflects the openness of the research evolutionary process along with the evolution of group intelligence triggered by a larger exploration of human-computer coexistence, there is also an urgent need to address facial information The future of facial observation research will also be an important cornerstone of future technological evolution as the recessive genes for acquiring and distributing facial information. The future of facial observation research will also be an important cornerstone of future technological evolution. This evolution will lead to unstable technological development and adaptive and infinitely scalable development space to the digital environment, rather than rapid convergence.

How to further improve the facial modeling algorithm? We must require considering how the evolution in the algorithm differs from the real evolution, so that targeted improvements can be made. The logical path of this study follows the past knowledge ecological trajectory to understand the past knowledge understanding and directed research records, and then analyze the present research needs from the past knowledge understanding growth law, and attribute the present shackles and research blind spots from the present needs and the past knowledge evolution trajectory ensemble, so as to find the scope of directed knowledge existence and realize the effective acquisition, structural organization and parameters of directed knowledge empowerment.

IV. ORIENTATION TO REMBRANDT

As the greatest master of the Baroque era in the history of European art, Rembrandt had his unique insights and persistence in both oil painting techniques, the language of painting and the expression of color language.

Understanding Rembrandt is not an understanding of his life and artistic value, but an implicit knowledge decoding and in encryption of a perfect source of directed knowledge with the scientific-philosophical attitude of deep convolution [5]. Taking the key steps of facial judgment, facial tracking, feature recognition, and facial reconstruction in facial modeling as a benchmark to re-examine Rembrandt's artistic creation, Rembrandt's behavior can be understood as:

A. Taking into account the need for multi-view face capture

Rembrandt's process of constantly pursuing freedom, using inspiration, and examining people based on his own preferences and opinions is the path of realism. The process of oil painting sketching at that time is almost identical to the behavior of today's multi-view face capture concept, with the significant difference that the three-dimensional construction of computer vision concept is based on triangular fractals to obtain facial geometry [6], while the sketching construction of morphological features relied on the painter's understanding of physiological and anatomical knowledge in relation to the penetration of the subject's aesthetic (identification with his own facial structure).

B. Strengthen the single view face cognitive effectiveness

Rembrandt borrowed from Caravaggio light and dark contrast painting method, the light and shadow record and interpretation of expression to the extreme, and formed their own unique style of painting, later known as "Rembrandt-style light and dark painting method". In the creation of the use of light to shape the shape, expression of space and highlight the focus, so that the face of the figure picture vivid, richly layered drawing behavior, and single-view face capture the internal logic of the same. The current stage of cutting-edge exploration of single-view facial depth perception continues to break through, with its core being the transfer of hardware pressure from multi-view capture computation to single-view reconstruction of highly detailed and dense positioning [7][8]. This research trend is oriented with a similar pattern to the global observation before sketching - local recording during sketching by painters.

C. Overcome the ambiguous limitation of parametric model

The active and changing color language, the subtle and delicate, harmonious and rich phenotypes in the painter's focus on detailed depiction and portrayal, the alternation between reality and reality of the image, and the spatial sense of modeling all help to discover the implicit pathological features of the face with strong dramatic emotional records in Rembrandt's realistic works. This feature mining is trained by the multilinear model (Vlasic) and principal component analysis (PCA) supported by the sample library to capture the resolution of facial expressions of characters with parametric data of local expressiveness and he records, overcoming the bottleneck of global parametric blurring of facial tracking, providing experimental support of different regional granularity subdivision for then revealing the inner activities of characters and uncovering hidden personalities.

At present, a variety of face feature extraction methods proposed by researchers can be distinguished into categories based on a priori rules, based on geometric shape information, based on color information, based on appearance information and based on association information according to the type of basic information on which they are based [9]. Candide 3 [10], for example, contains some FDP vertices, some FAP expression definitions, excludes secondary expression variations such as ears and tongue, and constructs a base model with 113 feature points and 168 triangular face slices. Obviously, based on the technical path of early computer image graphics computational logic growth, in which the a priori rules are also based only on facial symmetry features, selected symmetry points for location calibration, from this logic, the subsequent derived extraction methods for emotional cognition and directed knowledge areas of research is "computationally" neglected [11].

The experiments using depth-to-rotation angle bias localization in column coordinates proposed by Gordon [12] are analyzed. Firstly, he proposed to roughly localize the nose, use the constraint with the curvature value of the surface to refine the nose position, and then use the positioning with the nose to assist in locating the eyes. The method relies on the curvature value, requires high accuracy of the facial model, is more sensitive to noise interference, and does not have the property of pose constancy because the depth-to-rotation angle bias is related to the position established by the column coordinate system. Pan Gang [13] improved the study by taking any point on the 3D graph, realizing the neighborhood shape structuring, and proposing the curvature symbol distribution shape descriptor (curgram) as feature description of that point, and use curvature symbol distribution shape descriptor for feature matching during detection, which relies on the accuracy of curvature symbol distribution shape descriptor (curgram) and can improve the sensitivity to expression influence.

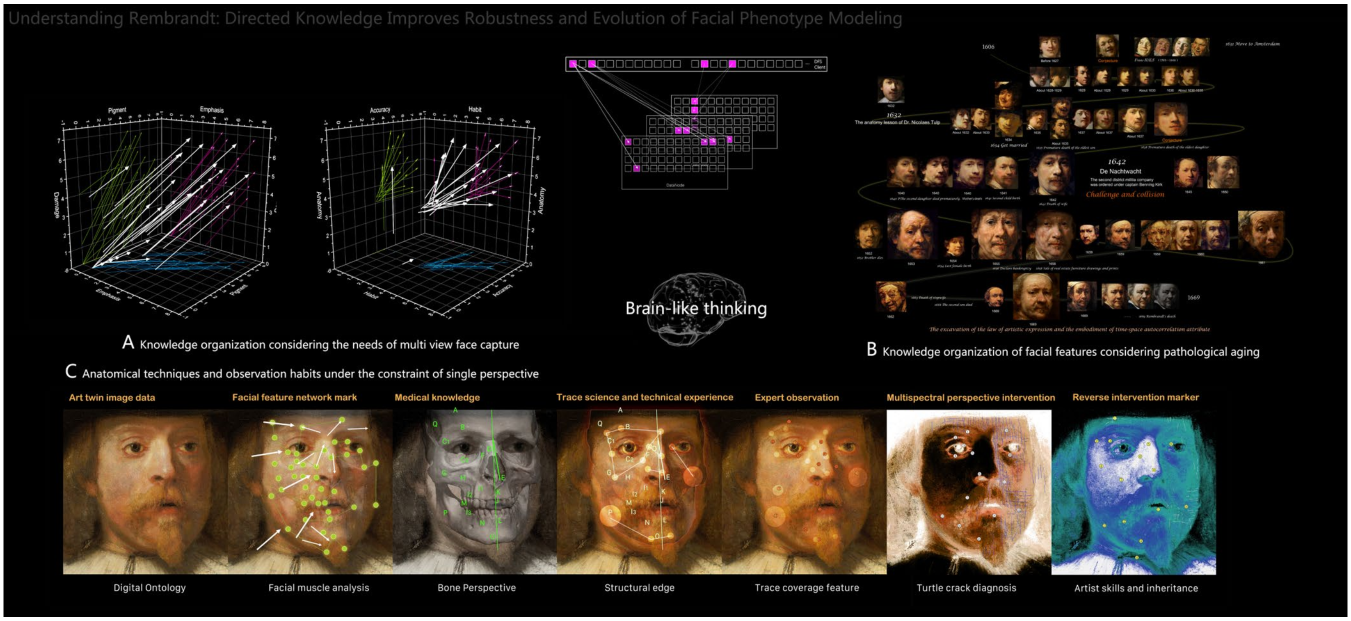

Fig. 1. Facial affective evaluation factors after the expansion of the targeted knowledge domain.

V. An Improved Strategy for Facial Modelling Based on Directed Knowledge

The paper proposes an improved strategy for facial modeling based on directed knowledge, after parameterizing the image data from the extended domain study, as an intervention for curvature, texture, and emotion-based facial feature extraction.

A. *Facial modeling structure ecology*

1) In facial modeling, relatively stable facial features and regions need to become the coordinate central axis, but not directly with the nose bridge as the central axis, need to build the most basic triangular position relationship with the interbrow, brow arch and nasal bone, and calculate the maximum and minimum curvature of the facial surface with this structure, and the feature points left after binarization as the location base of facial modeling, the region is not easy to change in facial muscle aging, emotional changes, and belongs to the stable feature region.
2) The secondary triangular position relationship composed of the brow arch, nasal bone, and eye sockets, the maximum and minimum curvature of the repertoire of the eye region needs to be calculated, and the shape response function and luminance response function of the brow arch, zygomatic bone, and nasal tip with the central region of the eye, and the fusion result can determine the corner of the eye, brow bone, and eye (with the pupil as the reference); this logic gradually confirms the tertiary position relationship of the left and right cheek regions, the atrium region, and the mouth region, and zygomatic bone, frontal bone, cranial bone and other anatomical knowledge presumed position for coupling; this part of the construction logic, is the typical emotional control of interbrow, nasal, cheek muscle group, masticatory muscle group, orbicularis oris muscle group in series and parallel, supporting the direct expression and emotional expression of the active shape change marker.
3) The points where the auxiliary triangle positions are located are then determined based on the curved shape of the interbrow-nasal bones-nasal tip and foot-brow-zygomaticus-legal muscle groups and the rules of anatomical bone point distribution. The enhanced longitudinal data location marker chain with coordinate medial axis separates the facial features and inserts curve groups in the lateral-frontal-lateral morphological structure. After subdivision, changes in the facial structure involving expression realization and emotion perception such as pathological aging, fat accumulation, and texture aging can be marked by the grid.

The method achieves the order and focus of the image data collected and recorded with the drawing process by observing the human portrait in Rembrandt's creation, reinforcing the feature areas and taking into account the non-feature areas by classifying and layering the location marking rules, and using the order of extracting the eyebrow arch, inter-brow, and nasal bone feature points before determining the eye. Not to use the generic facial modeling logic to determine the tip of the nose first, then the corner of the eye and the corner of the mouth, can reduce the lack of observation of the automatic modeling process to avoid the establishment of facial models but can not be associated with domain knowledge, in the reuse, recall only the distress of the phenotype and the lack of emotional fine granularity caused by interference [14].

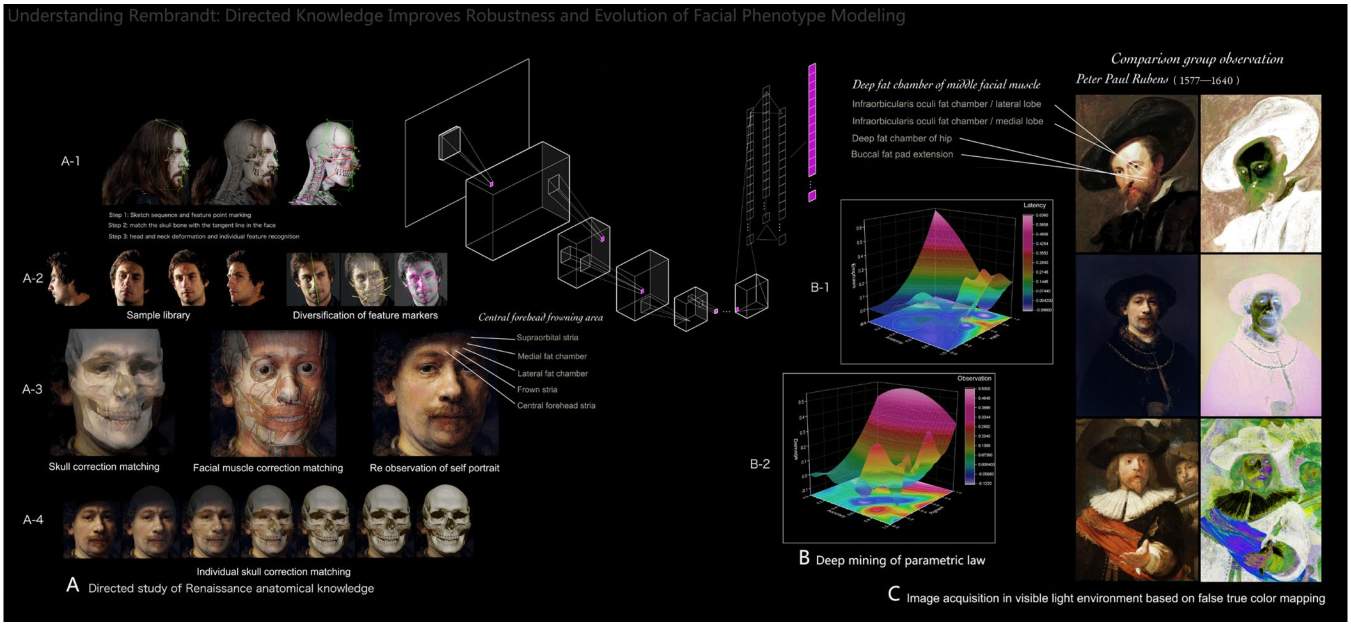

Fig. 2. Data parameterization experiments for targeted knowledge interventions.

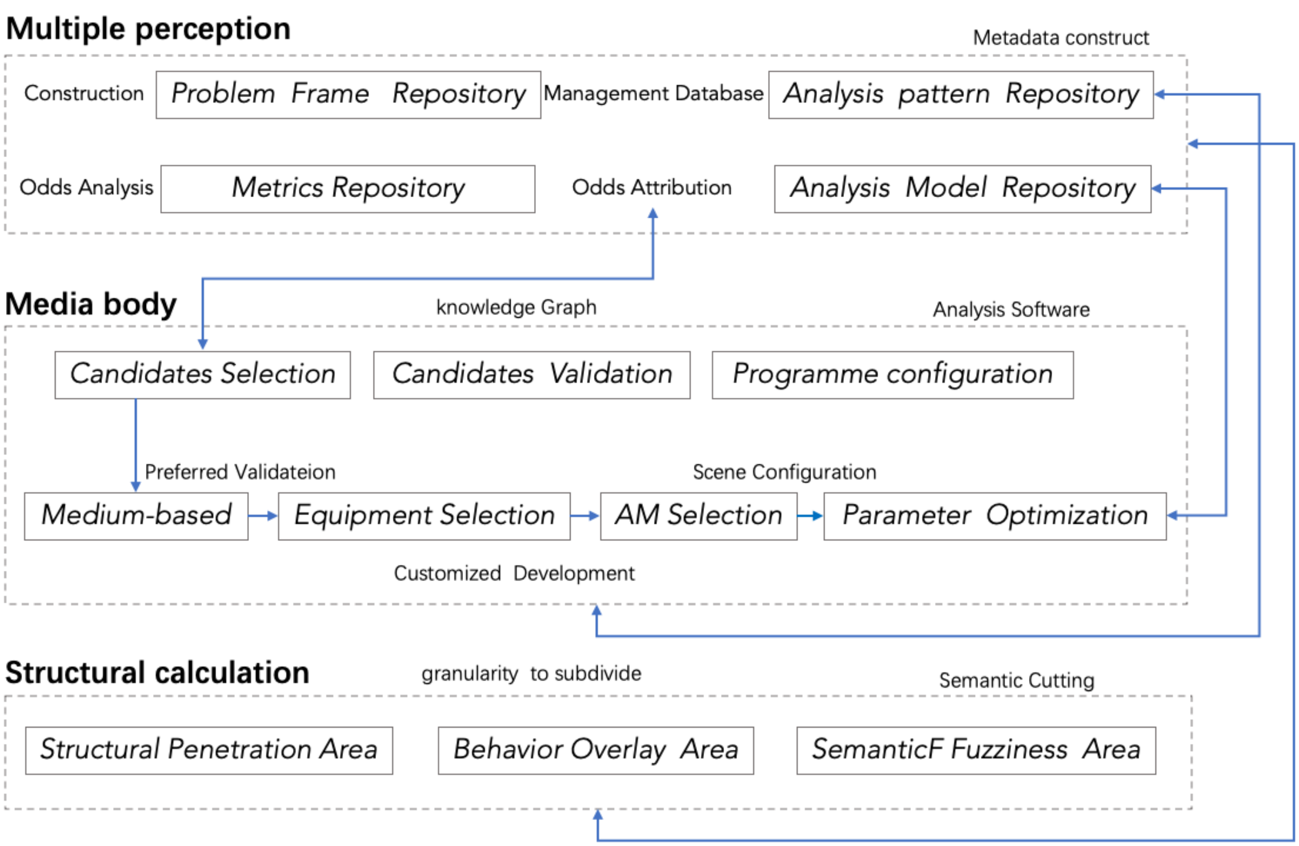

Fig. 3. Structured muti-sensory data.

B. Facial modeling metrics

1) *Curvature index:* The surface S is described as $z = f(x,y)$, with the parameter of the surface $X(u,v) = (x(u,v), y(u,v), z(u,v)) = (u, v, f(u,v))$ .Define two vectors: X_u and X_v, whose subscripts denote differences in local directions, thus forming a fundamental pair X_u, X_v of parameters tangent to the plan $T(u,v)$ at the point $X(u,v)$.The intersection of a surface S with a plane P contains a tangent vector $t(u,v) \in T(u,v)$.The surface normal n is the normal segment of the surface S at the point $X(u,v)$ along the direction $t(u,v)$, and the curvature of the normal segment is called the normal curvature. The 2 extremal normal curvatures on $X(u,v)$ are called the maximum and minimum curvatures, denoted by k_1, k_2 respectively, and the 2 unit tangent vectors e_1, e_2 in the corresponding directions are called the maximum and minimum principal directions, respectively. The Gaussian curvature *K* and the mean curvature *H* can be described by the maximum and minimum curvatures as follows.

$$k = \mathrm{k}_1 \cdot \mathrm{k}_2 \tag{1}$$

$$H = \frac{1}{2}(\mathrm{k}_1 + \mathrm{k}_2) \tag{2}$$

$$k_1, k_2 = H \pm \sqrt{H^2 - K} \tag{3}$$

According to Gordon's method [15], the Gaussian curvature K and the mean curvature can be directly used to clearly segment and describe the shape of the face surface. The face structure can be divided into 3 shapes: *K*>0, *H*>0 is convex; *K*>0, *H*>0 is concave; *K*<0, *H*>0 and $(\mathrm{k}_1 + \mathrm{k}_2) > 0$ is concave, *K*>0, *H*>0 and $(\mathrm{k}_1 + \mathrm{k}_2) < 0$ is concave, and the subsequent missing data can be fitted using semi-dense shapes.

2) *The local shape index:* The local shape index [16] specifies nine shape features that cover the basic structure of the facial phenotype and can be calculated to measure any shape of the facial surface. Let the shape index *S*(*p*) be the local curvature valuation at point p determined by the maximum curvature k_1 and minimum curvature k_2. The values of *S*(*p*) are taken in [0,1]. Shape index values for typical surface shapes.

$$S(p) = \frac{1}{2} - \frac{1}{\pi} arctan \frac{k_1(p) + k_2(p)}{k_1(p) - k_2(p)} \tag{4}$$

C. Directed service strategy

The directed knowledge mined by Rembrandt's study of domain expansion is transformed into location tags by the solution method, which can be encoded into DNA-like sequences by a generic facial acquisition model first, and then constitutes the basis for modeling evolution after the intervention of extraterritorial knowledge by simulating the experimental scheme of genetic evolution, combined with the variation and reorganization of the "solution encoding".

Manual and computational observations can be designed by evolutionary algorithms and modules for evaluating the fitness of the neural network are built, and by continuously changing the evaluation function, this method allows the labeled sample library image data to generate repetitive depth structures through the neural network, while the evolutionary process is open and without preconceptions.

In the facial modeling optimization strategy, the initial introduction of ex-domain knowledge can directly affect the experimental optimization of the display is not strong, and the sudden appearance of variation does not exist. Before and after the occurrence of the cyclic computational process, by simulating biological mechanisms, higher deeper thinking can be added to the strategy evolution, for example, the neural network controlling the input knowledge can encapsulate the actions of learning, migration, destruction, reconstruction, etc. as modules, and then on top of that, the possibility of repair, creation, etc. can evolve, and the way of encoding and correspondence can be radically changed with the intervention of cognitive strategies.

However, in the above process, the increase of the abstraction level comes from human intervention rather than evolutionary spontaneous generation. Indeed, increasing the complexity of procedures in research is not always necessary, and open-ended directed knowledge understanding can lead to unexpected and useful solutions. If evolutionary ideas are introduced, this study only attempts to address humanistic thinking in industrial applications of facial modeling. Since the industrial goal is to solve a specific problem, open-ended approaches are not commonly used at this time. As evolutionary computation grows in scale, there is every reason to introduce openness to produce designs with more creativity and higher complexity.

D. Coverage of multiple goals

In biology, adaptation has multiple dimensions - meaning that different survival strategies can be used in complex environments. Human perceptual adaptation to emotion is a complex process involving multiple elements - reproduction, survival, and reflection - and the need for full traversal of multiple goals, in which multidimensional and indirect trade-offs are made, introduces complexity to emotional traversal analysis.

Since facial perception contains multiple ecological niches and their corresponding survival strategies, the diversity of strategies needs to be enhanced, and this requires changing the optimization function to include the novelty of strategies as part of the goal, thus showing the promotion of strategies to construct their own ecological niches. However, for problems of higher complexity, artificially defined interventions are inconvenient to engage too much, which requires a more radical, and also more natural, way to enable goals at high abstraction levels, containing segmentation of numerous sub-goals.

As an example, a study of facial slices in Rembrandt's artwork could be chosen to segment subgoals - constrained by luminance feedback. The R, G, and B values of each pixel on the brushstroke texture on the image slice can be separately displaced in the HIS space, and the luminance I component is segmented using a threshold to establish a luminance threshold-based extraction model.

In the image luminance map brow arches, nasal bones and zygomatic bones have obvious speckle halo features, Harris corner detector [17] can be introduced to calculate the luminance changes in each direction in the neighborhood of the corner point part. Harris corner detector has good reproducibility in diverse environments [18]. Let the Hessian matrix H of the luminance function I(m, n) in the domain of the point P(x, y, z), if the 2 eigenvalues of H are large, then a smaller change in any direction will cause a more significant change in luminance, and the point P can be proved to be a corner point. That is, the larger the value of C(p), the more likely the point p is a corner point. The response function of the brightness of the corner point [19] is

$$C(p) = \frac{\frac{\partial^2 I}{\partial m^2}\frac{\partial^2 I}{\partial n^2} - \left(\frac{\partial^2 I}{\partial m \partial n}\right)^2}{\frac{\partial^2 I}{\partial m^2} + \frac{\partial^2 I}{\partial n^2}} \tag{5}$$

Through parameter adjustment, highlighting features in different layers with spotted halo boundaries can be found, and traversing all facial regions in turn, data clustering can be performed on light source environment, facial perception, emotion mapping [20] and recording features of Rembrandt's observed face, and then after topology with facial modeling indicators, feature extraction of subtle classification of expressions can be distinguished to achieve curvature value domains such as frustration, grief, contemplation and other approximate emotions.

VI. Conclusion

The comprehensibility and evolvability of directed knowledge and phenotypic data are of great importance in specific studies. Most facial modeling techniques with different phenotypes tend to be highly intertwined, and therefore connections between them are very common. However, it is often difficult to think beyond the limitations of single-domain knowledge, so the most common, yet overlooked, breakthrough inspirations that can only be found in cross-domain knowledge are rarely found. However, limited by the lack of complexity, flexibility, and plasticity of knowledge ecosystems, our discussion of improvements in Rembrandt-directed knowledge-enabled facial modeling has so far been limited to the richness of knowledge phenotypes and the organization of multiple homogeneous and heterogeneous data within them, without focusing on the connections between different phenotypes. The degree of involvement of directed knowledge in computation is still far from the height of human thinking it attempts to mimic, and the simulation of the instantaneous nature of basic geometric reasoning ability and emotional perception is not possible at this stage.

The stroke scale hypothesis of finding Rembrandt's traces of knowledge and production has improved our understanding of facial decline and volume variation; however, uncared-for regions are subjectively neglected. We investigated the proportion of feature density in Rembrandt's self-portrait sequence using skeletal analysis, aging patterns, expression management, and age metrics. Most metrics exhibited segmental scaling, above average critical density, and preferential attraction of image feature region volume structure. Subsequent analysis of the density scaling adjustment metric (DSAM) using hierarchical clustering, networks, and self-organizing maps (SOM) can attempt to reveal regional differences and the inverse relationship between eye-movement perceived value and a range of analyzable rates (e.g., volume recognition, color discrimination, biological observation). The most surprising finding of this study is that the pre-post image perception experimental subject data broke the expectations of the experimental hypothesis, where the overly similar educational environment did not spawn dynamism, but apparently converged with the fundamental properties of the group. Ignoring the artist observation perspective is a missed opportunity for researchers studying the perceptual proximity of facial modeling. The existence of an art anatomy-data modeling boundary justifies the study of directed knowledge and also provides a clearer comparison that can make claims about regions of directed knowledge concentration. The lack of fine-grained data on the critical density of structural regions and a clearer explanation as to why they appear in such consistent locations is an important unresolved issue.

The success of related methods suggests that no set of laws can completely describe a master-slave study sample. No directed knowledge is automatically randomly distributed around a study sample, but instead is widely correlated and reveals ongoing structural and regional variation. As a useful feedback strategy, co-evolution, multi-objective evolution, and openness are characteristic parameters that can be used to describe the evolutionary process of directed knowledge if we can achieve a response to the challenges posed by directed knowledge services; moreover, both robustness and evolution increase with the number of genes in directed knowledge, and increasing the complexity level of the knowledge data and increasing the sample set size can effectively enhance both properties.

Acknowledgment

This project is funded by the National Social Science Foundation of China "Research on Virtual Reality Media Narrative" (No. 21&ZD326). Special thanks to the Shenzhen Museum of Contemporary Art and Urban Planning (Shenzhen, China) for providing the computing power for our research project "Narrative Theory and Brain-like Computing in Art Science".

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