Title	スケッチによるアートスタイルの描画支援に関する研究
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Citation	
Issue Date	2023-03
Type	Thesis or Dissertation
Text version	ETD
URL	http://hdl.handle.net/10119/18422
Rights	
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学 位 の 種 類	博士（情報科学）	
学 位 記 番 号	博情第 496 号	
学 位 授 与 年 月 日	令和 5 年 3 月 24 日	
論 文 題 目	STUDY ON SKETCH-BASED ART STYLE DRAWING ASSISTANCE	
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論文の内容の要旨

Drawing has creative, expressive, and educational value. It remains fundamental to translate and analyze the world. However, traditional drawing requires sophisticated skills. For general users, it is not easy to access professional drawing skills due to lack of artistic training, which is time-consuming and labor-intensive. Nowadays, with the development of f Artificial Intelligence (AI), those artistic drawing styles have been achieved by Non-Photorealistic Rendering (NPR) or Neural Style Transfer (NSF) techniques from images. However, recent studies have shown that the drawing process predicted by AI is definitely different from a human's behavior -- there's still a long way to go to make AI understand the drawing and support users for artistic creation following their expectation.

The final goal of this dissertation is to let AI understand users' freehand rough sketches and provide suitable guidance to support users' art creativity interactively and extend users' drawing ability. As applications, this dissertation is dedicated to supporting the creation of artistic portraits for both realistic style and anime style. In order to achieve this goal, the major research question is how to translate the features extracted by machine learning or deep learning into a user-recognizable form that can be used to converse with users.

From a mathematical perspective, this goal is essentially to utilize features extracted from AI to help the user explore the optimal solution in mind in the process of creating a new artistic drawing. If a user's response to the guidance given by the AI is regarded as a user-perception evaluation function, then the greatest problem in this dissertation is that the function is dynamically varying and non-differentiable, even with individual differences. How to maximize this user-perception function which only exists in one's mind with AI is the major research question in this dissertation.

To address this research problem, this paper proposes a User-AI cooperation paradigm which considers the user as a black-box part of the whole drawing assistance

system and interactively approximates the above user-perception evaluation function by constructing an overall optimization function with a certain prior knowledge of this system. With this paradigm, the AI obtains more valuable input information, and the user's drawing ability is extended, making it a win-win situation for both the AI and the user %to communicate through conversation. Depending on whether the extracted features are directly visualized as user feedback for conversation, the strategies for constructing the overall optimization function can be divided into two types: explicit strategy and implicit strategy.

The various works in this dissertation are centered on this paradigm, which can be summarized in the following three parts.

(1) Data preparation.

As there is no off-the-shelf sketch-art database available for deep learning yet so far, I proposed a sketch-Art pair generation framework based on style transfer for realistic style and anime-style artistic portraits. In particular, for line drawing generation in anime style, a one-shot line drawing style transfer approach from color illustrations is proposed to solve the limited data problem. Note that this one-shot framework is a prior-knowledge-based style transfer, which is derived from a feedback-free version of the above paradigm.

(2) AI-assisted Drawing with Explicit Conversation Strategy.

To achieve realistic style drawing assistance, ``dualFace" was proposed, which decomposes the overall system optimization function into nested functions and designs a two-stage drawing assistance scheme - the AI offers sketch contour guidance in the global stage while providing detailed guidance in the local stage.
To allow sketches to be converted to other recognizable input for realistic portrait style transfer with intermediate real as prior knowledge, a low-level feature-matching algorithm is proposed which converts rough sketches to semantics masks for real-style artistic portrait generation automatically and connects these two stages. Since the guidance given by both stages of dualFace relies heavily on the prior knowledge of real human faces as an intermediate, the method fails when one's drawing style differs significantly from real faces, such as an anime face. Therefore, this dissertation also designs the anime face drawing assistance system using implicit strategy.

(3) AI-assisted Drawing with Implicit Conversation Strategy.

Unlike the two-stage explicit strategy, this part proposes an implicit optimization function for the end-to-end sketch-guidance style transfer. An unsupervised stroke-level disentanglement training strategy for prior knowledge in StyleGAN is proposed so that rough sketches with sparse strokes can automatically match the corresponding local facial parts in anime portraits respectively. What's more, to analyze the correspondence between strokes and semantics in portraits for smooth conversation with users in anime style, a one-shot semantics-level matching framework is proposed in the final interactive drawing

assistance system.

Besides the success of each part in the above, the validity of the User-AI cooperation paradigm is demonstrated by analyzing and discussing the relationship between system evaluation with objective metrics and user evaluations with user studies for art portrait drawing assistance of both realistic style and anime style in the final drawing assistance.

論文審査の結果の要旨

深層学習(以降、AI)の発達により、芸術的な描画スタイルが実現されているが、AI に絵画を理解させ、ユーザの期待に沿った芸術的創作を支援するには、まだ長い道のりがある。

本論文は、写実ケイとのアニメ調の肖像画制作支援に特化し、絵画の制作過程に対する AI の理解と解釈を探求したものである。この目標を達成するためには、AI によって抽出された特徴量を、いかにしてユーザが認識可能な形に変換し、ユーザと AI との会話に利用できるかが大きな研究課題となる。すなわち、制作過程で、ユーザの心の中で最適解を探れるようにすることである。

これに対し、まず、利用できるスケッチ・アートデータベースが存在しないため、スタイル転送に基づくスケッチ・アートのペア生成フレームワークを提案した。特に、アニメ調の線画生成では、限られたデータの問題を解決するために、カラーイラストからのワンショット線画スタイル転送アプローチを提案している。1 ペアの学習データを用いてイラストからスケッチのような線画を抽出する手法を提案し、一連の研究の基盤となるスケッチデータセットの構築を可能とした。

つづいて、人の顔の概形と詳細をユーザが描くことで、写実的な顔イラストを生成できる手法を開発した。これは、AI がグローバルステージでスケッチ輪郭を案内し、ローカルステージで詳細な案内を行うという 2 段階の描画支援スキームを設計したものである。

最後に、教師なしストロークレベルの disentangle 学習法を提案し、疎なストロークを持つラフスケッチを、アニメの肖像画の対応する顔の局所パーツに自動マッチングさせた。さらに、似顔絵のストロークとセマンティクスの対応を分析するために、セマンティクスレベルのワンショットマッチングの枠組みを最終的な描画支援システムで提案している。

以上、本論文は、入力されたスケッチを AI が理解できる特徴量に翻訳し、最終的に所望の画像をうまく生成するユーザ-AI 協調パラダイムを示したものであり、学術的に貢献するところが大きい。よって博士（情報科学）の学位論文として十分価値あるものと認めた。