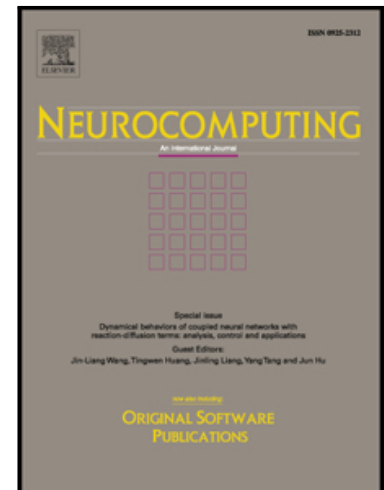# Accepted Manuscript

Sketch Simplification Based on Conditional Random Field and Least Squares Generative Adversarial Networks

Lu Qianwen , Tao Qingchuan , Zhao Yalin , Liu Manxiao

Please cite this article as: Lu Qianwen , Tao Qingchuan , Zhao Yalin , Liu Manxiao , Sketch Simplification Based on Conditional Random Field and Least Squares Generative Adversarial Networks, *Neurocomputing* (2018), doi: https://doi.org/10.1016/j.neucom.2018.07.065

Sketch Simplification Based on Conditional Random Field and Least Squares

Generative Adversarial Networks

Lu Qianwen   Tao Qingchuan [*]   Zhao Yalin   Liu Manxiao

Collage of Electronic and Information Engineering, Sichuan University

Abstract   **Sketch simplification is a critical part of cartoon drawing work. Some existing approaches are already capable of simplifying simple sketches, but in some cases, they are still insufficient because of method diversity of sketch drawing and complexity of sketch content. In this paper, we present a novel approach of building the model for sketch simplification, which is based on the conditional random field (CRF) and Least Squares generative adversarial networks (LSGAN). Through the zero-sum game of the generator and the discriminator in the model and the restriction of the conditional random field, the model can generate the simplified images, which are more similar to standard line images. The dataset we build contains a large number of image pairs that are drawn in different painting ways and with different contents. Finally, experiments show that our approach can obtain better results than the state of the art approaches in sketch simplification.**

Keywords：*sketch simplification, Least Squares generative adversarial network, deep learning, conditional random field*

1.Introduction

Most painters, when drawing sketches, are more concentrated on completing the character's main posture and the image's global construction in a very short time, which makes the lines in the sketches messy and uncertain. In order to modify sketches into clean line-art drawings, painters need to add or reduce some lines based on the previous rough sketches. In this process, the workload for cleaning up the sketches multiplies with the increase of complexity of sketches. Utilizing the well-trained convolutional neural networks to reduce unnecessary lines in sketches and obtain clean images automatically can largely improve the efficiency of cartoon drawing and reduce workload of painters.

Before our approach, some sketch simplification methods have already been available. Some sketch simplification algorithms proposed by Wilson and Ma [2004], Grabli et al. [2004], and Cole et al. [2006] aimed to pick out unnecessary lines, and then remove them. Other algorithms focused on adjusting the line shape to simplify sketches. In particular, Grimm and Joshi [2012] provided a line-merging method based on the proximity and topology. Fišer et al. [2015] proposed a sketch simplification method using various rules of geometric relationships between lines. Orbay and Kara [2011] utilized a supervised stroke clustering algorithm to obtain simplified images based on the geometric relationship among lines in the training images. Liu et al. [2015] proposed a closure-aware sketch simplification that simplified a rough sketch by searching the closed region of lines for semantic analysis and then processing the region.

The latest sketch simplification algorithm was proposed by Simo-Serra et al. [2016]. This method can acquire simplified sketches using a convolutional neural network. The network was trained to learn the complex map function between the distribution of input sketches and the standard line arts. After training, the network can generate simplified images according to the input sketches. Compared with the previous methods, this algorithm has some irreplaceable advantages such as more automatic in simplification process and no size limitation of input sketches. However, if workers want to obtain better results, the size of input images needs to be adjusted manually, and when input images has more complex content, the sketch simplification capability of this algorithm is limited. This algorithm proves that convolutional neural networks have strong capability of sketch simplification after training, and based on this point, we utilize the generative adversarial networks (GAN) to improve the simplification ability of common convolutional