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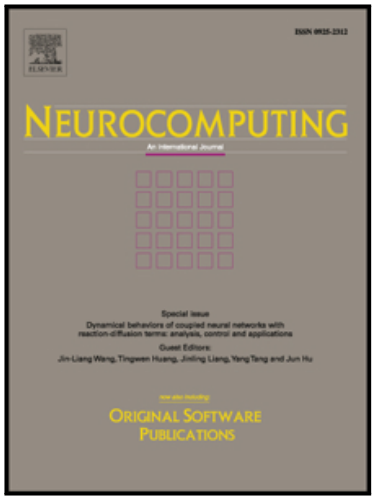

Parallel and efficient approximate nearest patch matching for image editing applications

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Parallel and efficient approximate nearest patch matching for image editing applications

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Abstract

This paper presents a novel GPU-based patch matching method which efficiently finds approximate nearest neighbor correspondences for patches between images. Our approach improves traditional patch matching algorithms in two aspects. First, we propose to improve the convergence of matching with two new types of forward enrichment operations, enabling the fast propagation of a richer set of potentially good candidates on different images. Second, we reduce the search space of patch direction by estimating a coherent feature direction field for each image and computing the similarity between patches with a direction-aware alignment scheme. Furthermore, we develop a number of GPU-based image editing and processing applications by incorporating our new patch matching algorithm, including object matching, nonlocal means denoising, image completion, texture synthesis, and image retargeting. Experimental results and comparisons are shown to demonstrate the effectiveness of the proposed approach.

Keywords: k nearest neighbors, patch-based synthesis, image completion, image retargeting, GPU

1. Introduction

Correspondence matching between image patches is a fundamental issue in a variety of image processing and computer vision problems [1, 2, 3, 4, 5, 26]. Image nearest patch matching has been widely used in many applications, such as object detection, image denoising, texture synthesis, image completion, image retargeting, and so on. Nearest patch matching typically proceeds by finding one or more nearest neighbors from an image to another image according to a predefined patch distance metric. On one hand, it is rather inefficient if the patch matching is performed in a brute-force manner by exhaustively visiting the search space [6, 7, 8]. On the other hand, the human vision is not sensitive to minor color errors. Visually plausible approximate solutions can be competent to many image editing and processing applications [5, 10, 34, 54]. In recent years, research has focused on approximate patch matching algorithms.

There are in general three categories of approximate patch matching techniques. Tree-based matching techniques [11, 12] usually involve the dimensionality reduction and the insertion of feature vectors into a hierarchical tree structure. The performances of these applications are usually too slow to meet the requirement of interactive image editing. Hashing-based matching techniques [10, 13, 14] map from a high dimensional feature space to a low dimensional hash bucket space so that similar patches correspond to the same hash table bucket with high probability. However, the construction of hash table is difficult to be accelerated using GPUs. Another kind of matching techniques [15, 16, 17, 7] limits the search on the image space. In particular, Barnes et al. [17] propose PatchMatch, a novel image-based patch matching algorithm, enabling various efficient image editing applications. Barnes et al. [6, 18] further extend the primary PatchMatch to a generalized PatchMatch algorithm to support more patch-based applications. However, we observe that there remains room for improvement in terms of the convergence speed and the search space. In this paper, we would like to further accelerate the performance by exploiting both the convergence and the search space of these traditional patch matching algorithms [17, 6].

Our new approximate patch matching algorithm proceeds in a coarse-to-fine optimization manner. It is roughly divided into four main operations: initialization, propagation with jump flooding, random search, and forward enrichment. By taking advantage of the mathematical transitivity property, two new types of forward enrichment operations are introduced to improve the convergence of patch matching. By estimating a feature direction field for each image, we support efficient direction-aware alignment for computing the similarity between two patches. This alignment scheme allows us to avoid the exhaustive search on a range of possible directions and effectively reduces the search space of patch direction using a precomputed feature direction field. Furthermore, we incorporate the proposed patch matching into a number of efficient image editing and processing applications. Note that our algorithm is highly parallel, enabling an efficient GPU implementation.

In summary, this paper has the following contributions:

- Two new types of enrichment operations are introduced into the traditional pipeline of patch matching, supporting fast convergence of matching between different images.
- A coherent direction-aware patch alignment scheme is

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