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"There is no one who loves pain itself, who seeks after it and wants to have it, simply because it is pain..."

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Video Action Transformer Network

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http://rohitgirdhar.github.io/ActionTransformer

Abstract

We introduce the Action Transformer model for recognizing and localizing human actions in video clips. We repurpose a Transformer-style architecture to aggregate features from the spatiotemporal context around the person whose actions we are trying to classify. We show that by using high-resolution, person-specific, class-agnostic queries, the model spontaneously learns to track individual people and to pick up on semantic context from the actions of others. Additionally its attention mechanism learns to emphasize hands and faces, which are often crucial to discriminate an action – all without explicit supervision other than boxes and class labels. We train and test our Action Transformer network on the Atomic Visual Actions (AVA) dataset, outperforming the state-of-the-art by a significant margin using only raw RGB frames as input.

1. Introduction

In this paper, our objective is to both localize and recognize human actions in video clips. One reason that human actions remain so difficult to recognize is that inferring a person's actions often requires understanding the people and objects around them. For instance, recognizing whether a person is 'listening to someone' is predicated on the existence of another person in the scene saying something. Similarly, recognizing whether a person is 'pointing to an object', or 'holding an object', or 'shaking hands'; all require reasoning jointly about the person and the animate and inanimate elements of their surroundings. Note that this is not limited to the context at a given point in time: recognizing the action of 'watching a person', after the watched person has walked out of frame, requires reasoning over time to understand that our person of interest is actually looking at someone and not just staring into the distance.

Thus we seek a model that can determine and utilize such contextual information (other people, other objects) when determining the action of a person of interest. The Transformer architecture from Vaswani *et al.* [43] is one suitable model for this, since it explicitly builds contextual support for its representations using self-attention. This architecture has been hugely successful for sequence modelling tasks compared to traditional recurrent models. The question, however, is: how does one build a similar model for human action recognition?

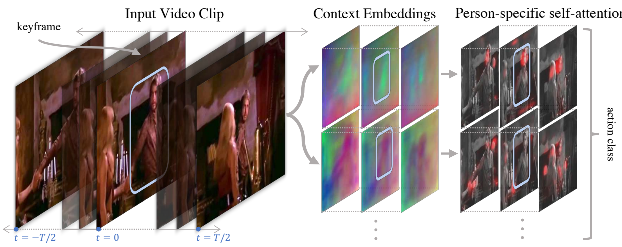

Figure 1: **Action Transformer in action.** Our proposed multi-head/layer Action Transformer architecture learns to attend to relevant regions of the person of interest and their context (other people, objects) to recognize the actions they are doing. Each head computes a clip embedding, which is used to focus on different parts like the face, hands and the other people to recognize that the person of interest is 'holding hands' and 'watching a person'.

Our answer is a new video action recognition network, the **Action Transformer**, that uses a modified Transformer architecture as a 'head' to classify the action of a person of interest. It brings together two other ideas: (i) a spatio-temporal I3D model that has been successful in previous approaches for action recognition in video [7] – this provides the base features; and (ii) a region proposal network (RPN) [33] – this provides a sampling mechanism for localizing people performing actions. Together the I3D features and RPN generate the query that is the input for the Transformer head that aggregates contextual information from other people and objects in the surrounding video. We describe this architecture in detail in section 3. We show in section 4 that the trained network is able to learn both to track individual people and to contextualize their actions in terms of the actions of other people in the video. In addition, the transformer attends to hand and face regions, which is reassuring because we know they have some of the most relevant features when discriminating an action. All of this is

*Work done during an internship at DeepMind

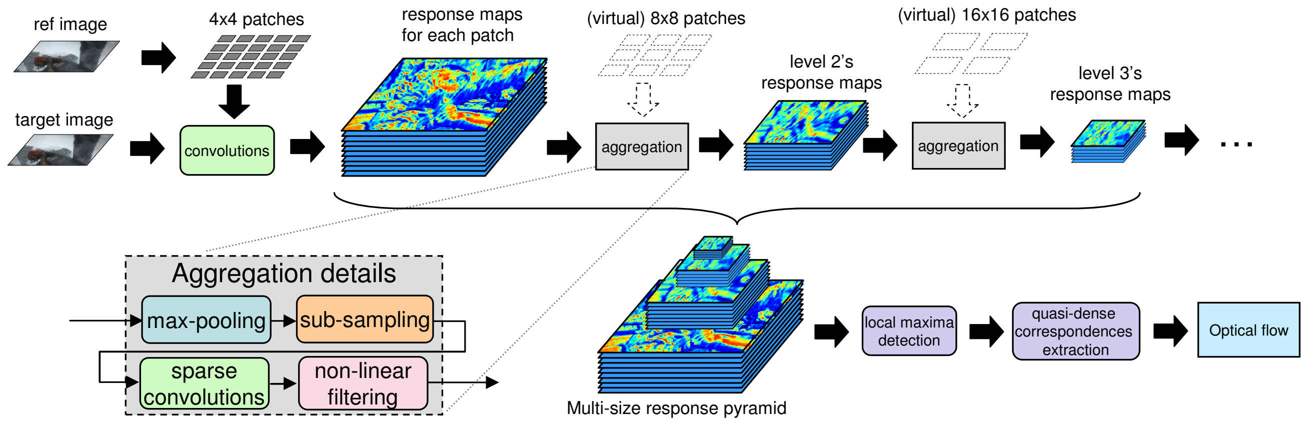

Figure 1. Outline of DeepFlow.

variational optical flow approach termed DeepFlow. Finally, we present experimental results in Section 5.

2. Related work

Large displacement in optical flow estimation. Variational methods are the state-of-the-art family of methods for optical flow estimation. Since the pioneering work of Horn and Schunck [1], research has focused on alleviating the drawbacks of this method. A series of improvements were proposed over the years [4, 31, 7, 21, 2, 25, 29]. Brox *et al*. [5] combine most of them into a variational approach. Energy minimization is performed by solving the Euler-Lagrange equations, then reducing the problem to solving a sequence of large and structured linear systems.

To handle large displacements, a descriptor matching component is incorporated in the variational approach in [6]. One major drawback of this method is that local descriptors are reliable only at salient locations and are locally rigid. Adding a matching component challenges the energy formulation as it could deteriorate performance at small displacement locations. Indeed, matching can give false matches, ambiguous matches, and has low precision (a pixel). In a different context, namely scene correspondence, descriptors or small patches were used in SIFT-flow [17] and PatchMatch [3] algorithms. Xu *et al*. [33] integrate matching of SIFT [26] and PatchMatch [3] to refine the flow initialization at each level. Excellent results were obtained, yet at the cost of expensive fusion steps. Leordeanu *et al*. [16] propose to extend sparse matching, with locally affine constraint, to dense matching before using a total variation algorithm to refine the flow estimation. We present here a computationally efficient, yet competitive approach for large displacement optical flow using a deep convolutional matching procedure.

Descriptor matching. Image matching consists of two steps: extraction of local descriptors and matching them. Initial image descriptors were extracted at sparse, scale-invariant or affine-invariant image locations [26, 20]. For the purpose of optical flow estimation, recent work showed that dense descriptor sampling improves performance [27, 6, 17]. In all cases, descriptors are extracted in rigid (generally square) local frames. Matching descriptors is then generally reduced to a nearest-neighbor problem [26, 3, 6]. Methods such as reciprocal nearest-neighbors allow to prune lots of false matches, but as a side effect also eliminate correct matches in weakly to moderately textured regions. We show here that (i) extraction of descriptors in non-rigid frames and (ii) dense matching in all image regions, yields a competitive approach, with a significant performance boost on MPI-Sintel [8] and KITTI [10] datasets.

Non-rigid matching. Our proposed matching algorithm, called *deep matching*, is strongly inspired by non-rigid 2D warping and deep convolutional networks [15, 28, 12]. It also bears similarity with non-rigid matching approaches developed in different contexts. In [9], Ecker and Ullman proposed a similar pipeline to ours (albeit more complex) to measure the similarity of small images. However, their method lacks a way of merging correspondences belonging to objects with contradictory motions (*e.g*., on different focal planes). In a different context, Wills *et al*. [32] estimated optical flow by robustly fitting smooth parametric models (homography and splines) to local descriptor matches. In contrast, our approach is non-parametric and model-free. More recently, Kim *et al*. [13] proposed a hierarchical matching to obtain dense correspondences, but their method works in a coarse-to-fine (top-down) fashion, whereas deep matching works bottom-up. In addition, their method requires inexact inference using loopy belief propagation.

3. Deep Matching

In this section, we present the matching algorithm, termed deep matching, and discuss its main features. The matching algorithm builds upon a multi-stage architecture