Enhancing Text-to-Video Editing with Motion Map Injection

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Abstract

Based on the remarkable performance of text-to-image diffusion models, text-guided video editing studies recently have been expanded. Existing video editing studies have introduced an implicit method of adding cross-frame attention to estimate inter-frame attention, resulting in temporally consistent videos. However, because these methods use models pre-trained on text-image pair data, they do not handle unique property of video: motion. When editing a video with prompts, the attention map of the prompt implying the motion of the video (e.g. 'running', 'moving') is prone to be poorly estimated, which causes inaccurate video editing. To address this problem, we propose the 'Motion Map Injection' (MMI) module to consider motion explicitly. The MMI module provides text-to-video (T2V) models a simple but effective way to convey motion in three steps: 1) extracting motion map, 2) calculating the similarity between the motion map and the attention map of each prompt, and 3) injecting motion map into the attention maps. Given experimental results, input video can be edited accurately with MMI module. To the best of our knowledge, our study is the first method that utilizes the motion in video for text-to-video editing. Extensive experimental results are in https://currycurry915.github.io/Attention-Flow/

1. Introduction

Recent research on text guided diffusion models and large-scale language models has led to unprecedented advances in image generation and image editing. In the field of image editing, various studies [1, 3, 4, 5, 6, 7, 8, 9, 10, 11] have been conducted. Among them, Prompt-to-Prompt (P2P) [1] offers users intuitive image editing by proposing several methods and applications to control the attention map that identifies the semantic relationship between prompt token and input image.

Research on diffusion model has been expanded to text-guided video editing tasks. Most of these studies [2, 12, 13, 14] use text-guided image diffusion models for baseline. However, since a video consists of several frames unlike images, it should be edited in consideration of temporal information. To this end, existing video editing studies [14, 15, 16] have devised an implicit method of adding cross-frame attention to estimate inter-frame attention, resulting in temporal consistent editing. Recently, starting with Video-P2P [2] and vid2vid-zero [16], research on image based P2P [1] have been expanded to video editing.

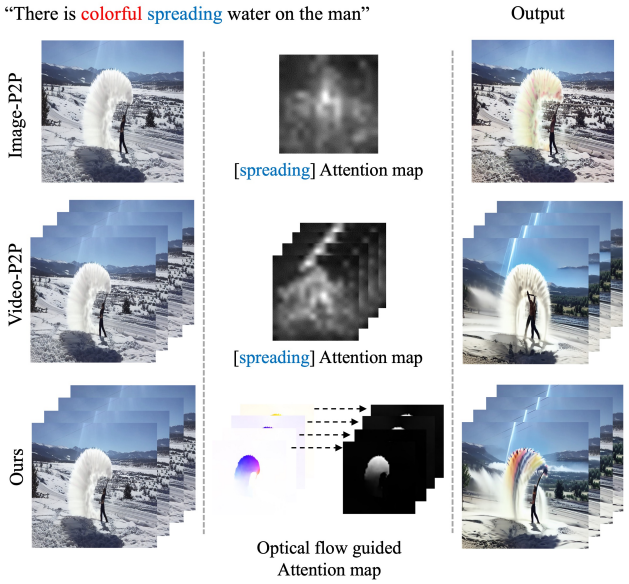


Figure 1: Comparison of attention map and edited video output derived from each existing method. Image-P2P [1] and Video-P2P [2] failed to estimate the attention map, resulting in discrepancy between prompt and video. Our method edited video realistically by exploiting optical flow guided attention maps.

A vast amount of text-video pair dataset is required to train the implicit structures that use cross-frame attention to understand temporal information. However, there are not enough of data to train them. That is why the most of video editing algorithms have chosen the fine-tuning method of image diffusion model [12] for the input video or zero-shot approach [14] to edit video in consideration of temporal information. Because the image diffusion model was trained on the text-image pair dataset, it is not good at estimating the attention map for prompts containing motion as shown

in Fig 1. As a result, it is difficult to perform appropriate attention control for the prompt, which reduces the capability of editing videos. One solution is to estimate motion information explicitly.

Optical flow is the information of pixels that have moved between frames of video (i.e. 'motion'). There are a lot of optical flow estimation methods that have been used in wide range of video tasks. With existing state-of-the-art optical flow estimation network [17], we can obtain highly accurate motion which can be injected into video editing model.

In this paper, we propose a framework to complement attention maps with optical flow to make video editing more effective and accurate. It consists of the following three steps. Firstly, existing optical flow estimation algorithm [17] estimates motion from the input video. Secondly, with the motion, attention maps of off-the-shelf video diffusion model are complemented. Lastly, modify the video by applying the improved attention map.

The most important part of this framework is first and second steps. We propose 'Motion Map Injection (MMI)' module for these steps. Specifically, MMI module has also three steps. Firstly, module estimates optical flow of the input video and derives motion map from the flow. The motion map is magnitude of the optical flow. Secondly, the similarities between the motion map and attention maps of each prompt are computed with template matching algorithm [18]. For template matching, Normalized Cross Correlation (NCC) [19] is used. Finally, the motion map is multiplied by the similarity weights, and added to the every attention map of each prompt. However, the image diffusion model does not accurately estimate the attention map of the motion prompt, so the attention map of motion prompt such as 'moving' is directly replaced with the motion map without template matching. Our proposed MMI module is a efficient method that can supplement motion information in the prompt without learning a vast video dataset, which can dramatically improve the editing of the existing video editing framework.

2. Proposed Method

Let be input video $\mathcal{V}$ which consists of n frames. We define the source prompt as $\mathcal{P}$ just like the Prompt-to-Prompt [1] setting. In $\mathcal{P}$, the prompt containing motion information of the video is called motion prompt $\mathcal{P}_{\mathcal{M}}$ (e.g. 'running', 'moving').

In this section, we provide an overview of our framework, which is illustrated in Fig. 2. The attention map $\mathcal{A}_{\mathcal{P}}$ representing the correlation between the frame of $\mathcal{V}$ and $\mathcal{P}$ is estimated through the cross-attention layer in the T2V-Model. Our proposed MMI module estimates the optical flow V_{flow} of $\mathcal{V}$ using the pre-trained optical flow estimation network [17] in the first step. In the second step, a motion map is obtained by applying L2 norm to the optical flow. After calculating the correlation between the attention map of all prompts and the motion map using NCC, it complements the existing attention map according to the correlation. Lastly, the motion map is inserted into the Attention Map of the motion prompt $\mathcal{P}_{\mathcal{M}}$. Using this approach, the MMI module provides the optical flow information of the video to the T2V-Model, enabling improved video editing capabilities.

2.1. Preliminary

Prompt-to-Prompt P2P [1] based on text-guided diffusion model edits image by modifying source prompt $\mathcal{P}$. Cross-attention layer inside the diffusion model produces cross-attention map indicating spatial correlation between visual and textual feature. Spatial features of noise image $\phi(z_t)$ are projected on query matrix $Q = \ell_Q(\phi(z_t))$ and key matrix $K = \ell_K(\psi(\mathcal{P}))$ through learned linear projections ℓ_Q and ℓ_K. Attention map A can be written as

$$A = Softmax\left(\frac{QK^T}{\sqrt{d}}\right), \tag{1}$$

where d denotes latent projection dimension of K and Q. Because P2P [1] can edit images by controlling these attentions, it gives intuitive image editing by modifying only $\mathcal{P}$. P2P [1] can edit images by replacing A of the word to be edited in $\mathcal{P}$ with the attention of the target prompt or by providing an additional A.

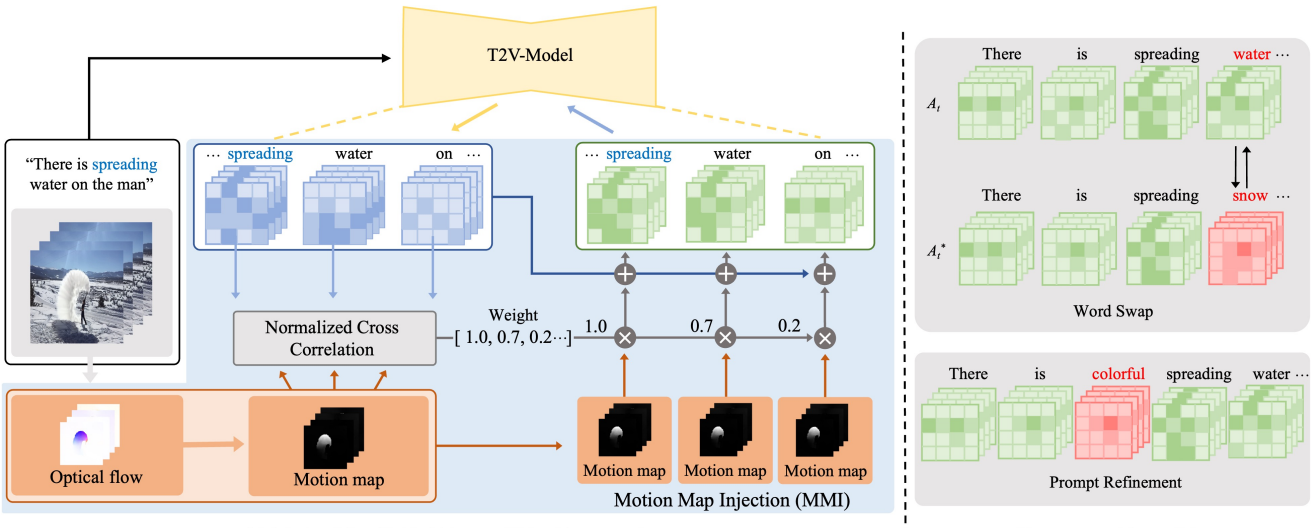
2.2. Motion Map Injection Module

Motion Map Extraction In this paper, we use pre-trained optical flow estimation algorithm, UniMatch [17], to estimate motion of video. Firstly, we calculate the correlation for the pixels of the two frames by matrix product and then normalize for the last two dimensions using the softmax function. Then, matching distribution D_{flow} is obtained for each pixel location in F_{t-1} with respect to all pixel locations in F_t

$$D_{\text{flow}}(i,j,k,l) = \mathcal{S}\left(\frac{\sum_{d'=1}^{d} F_{t-1}(i,j,d') \cdot F_t(k,l,d')}{\sqrt{N}}\right), \tag{2}$$

where N denotes normalization coefficient to prevent the value from increasing after internal operation. $\mathcal{S}$ represents the softmax function. We calculate the weighted average of the matching distribution D_{flow} on the 2D coordinates of the pixel grid G_{2D} to obtain correspondence $\hat{G}_{2D}$. Finally, the optical flow V_{flow} can be obtained by subtracting the two grids. We obtain the motion map V^*_{flow} by applying the L2 norm to the optical flow V_{flow}

Motion Map Injection using NCC It is necessary to calculate the similarity of each other to effectively supplement the existing attention map using the estimated motion map. To this end, we use the template matching algorithm [19].



(a) Motion Map Guided Text-to-Video Framework

(b) Text-to-Video Editing

Figure 2: Overall framework of this study. First, the T2V-Model generates an attention map by receiving video and prompts as input. At the same time, the Motion Map Injection module receives the video frame, generates a motion map, and injects it into the attention map of the T2V-Model. After that, text-to-video editing is performed using the attention map that includes video motion information.

We set the source image to attention map and the target image to motion map and calculate the Normalized Cross Correlation (NCC) as below

$$C_k = \frac{1}{n}\sum_{x,y}\frac{(V^*_{flow}(x,y) - \bar{V}^*_{flow})(A_k(x,y) - \bar{A}_k)}{\sigma_V \sigma_A}, \quad (3)$$

where n denotes the number of pixels, x, y denotes pixel of source image and target image. $\bar{V}^*_{flow}$ and $\bar{A}_k$ denote the average of pixels of V^*_{flow} and A_k. σ_V and σ_A denote the standard deviation of pixels of V^*_{flow} and A_k. k denotes the index of a particular word in the entire prompt. We calculate the correlation score by performing template matching at every denoising step t of the diffusion model, making the sizes of V^*_{flow} and A_k alike for all k.

Finally, as shown in (4), a new attention map is identified by injecting $C_k \cdot V^*_{flow}$ to attention map of each prompt

$$A^*_k = A_k + \lambda \cdot \frac{(C_k \cdot V^*_{flow})}{t}, \quad (4)$$

where λ is a hyperparameter for motion map injection rate, t denotes denoising step. Here, the image diffusion model does not accurately estimate the attention map of the motion prompt token such as 'flowing', so the motion map is directly inserted instead of template matching.

3. Experiments

3.1. Experimental Setup

Baseline model We used the Video-P2P [2] and vid2vid-zero [16] for a baseline model, which can intuitively edits a video with text by manipulating a cross attention map representing the relationship between text and video. We added MMI module to both video editing models to verify the effectiveness of our framework.

Table 1: User study to evaluate the performance of Video-P2P [2] and our model on three criteria: Structure Preserving, Text Alignment, Realism and Quality.

User Preference	Video-P2P (%)	Ours (%)
Structure Preserving	31.25	**68.75**
Text Alignment	21.87	**78.12**
Realism & Quality	43.75	**56.25**

Dataset Experiments were conducted with Davis video dataset [20]. Also, we collected and used YouTube videos to make more experiments.

Implementation details We experimented with NVIDIA RTX A6000 GPUs and set the resolution to 512×512 like Video-P2P [2] and vid2vid-zero [16]. The number of video frames was fixed to four, and the UniMatch [17] model was used to extract the optical flow.

Evaluation Metrics CLIP Score [21] and masked PSNR [2] were used to evaluate textual similarity and region preservation. CLIP Score [21] is a metric to evaluate the correlation between a prompt and image. It has been found to be highly correlated with human judgement. Masked PSNR is a metric to evaluate structure preservation only for the masked region. In this experiment, we exploited non-moving region as a mask.

3.2. User Study

To compare our proposed model with Video-P2P [2] and vid2vid-zero [16], we conducted user study on three

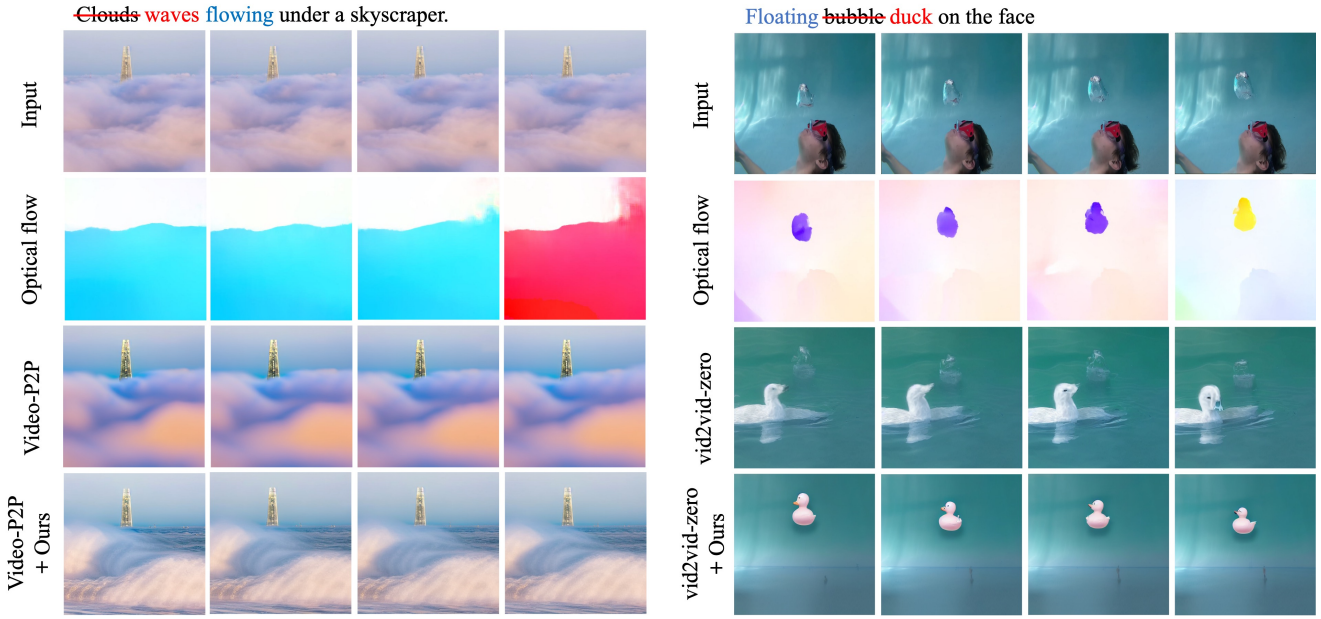


Figure 3: Experimental results of our study. This shows the result of two examples corresponding to each different model [2, 16]. The top row is the input video frame, the second row is the optical flow extracted through the MMI module, the third row is the output of Video-P2P [2] and vid2vid-zero [16], and the last row is the result of our research. It can be seen that the result of the model receiving the motion information of the image through Optical Flow is better.

Table 2: Quantitative comparison results. Higher performance was recorded for CLIPScore [21] and Masked PSNR compared to Video-P2P [2] and vid2vid-zero [16].

	Video-P2P	**Video-P2P + Ours**
CLIP Score	28.98	**29.63**
Masked-PSNR	28.88	**29.38**
	vid2vid-zero	**vid2vid-zero + Ours**
CLIP Score	22.09	**22.60**
Masked-PSNR	21.80	**25.30**

criteria: structure preserving, text alignment, and realism & quality. We presented input video, target prompt, and videos edited with each model to users. Between two edited videos, the outputs were evaluated by making users choose more faithful videos for the presented criteria. The results filled in Table 1 show that the output of our module is more preferable.

3.3. Quantitative Results

The quantitative results of this study are in Table 2. CLIP Score [21] was measured by comparing target prompt with edited image. The results confirmed that our method was better at understanding meaning of prompt compared to the other models. For masked PSNR, the performance of our framework scored slightly higher. This means that the existing models edited more in areas not intended than our proposed model.

3.4. Qualitative Results

Figure 3 shows the qualitative results of the Video-P2P [2] algorithm, the vid2vid-zero algorithm [16], and the proposed MMI algorithm. Previous methods tend to produce structurally unnatural images, but our method produces structurally coherent and content-preserving frames. In Video-P2P [2], due to inaccurate estimation of the attention map for the motion prompt, it was unable to perform editing that aligns with the target prompt. However, with the injection of the motion map using our proposed method, we achieve better performance in editing. In vid2vid-zero [16], the performance is lower compared to Video-P2P model [2] that fine-tuning on input video. Nevertheless our model enhances attention and enables control via target prompts. You can see more results on the project page attached to the abstract and in the zipped file of the supplementary.

4. Conclusion

We propose a Motion Map Injection (MMI) module to inject estimated motion map into the attention map of the image diffusion model. Injecting motion map into attention map with our proposed MMI module makes general video editing performance improved because attention map of motion prompt become apparent. This is proven by improved evaluation metrics. As a future work, we will implicitly apply optical flow to the video editing module.

In this supplementary material, we describe related works, a method for calculating optical flow, an ablation study, a method for optical flow rotation, further explanation of the metric, and a github link to the code.

A. Related Work

A.1. Text-Guided Editing

The diffusion model [22, 23], which has recently been actively studied, generates data from noise through the process of adding or removing noise. Based on this diffusion model, text-guided image editing models such as DALL-E2 [24], Imagen [25], and stable diffusion [26] show the results of high-quality image editing. In particular, Prompt-to-Prompt [1] presents text-guided image editing that controls the relationship between the prompt text token and the corresponding image pixel with the attention maps, enabling unprecedented semantic editing. In addition, subsequent papers such as DreamBooth [3], EDICT [27], and Imagic [4] have been actively studied recently, showing impressive results for text-guided image editing.

Based on the significant progress of text-guided image editing, research has recently been expanded to text-guided video editing with the generative model. Dreamix [12] presents the first diffusion-based method of performing text-guided motion and application editing of videos through fine-tuning, but there are difficulties with localized editing by replacing a word. Video-P2P [2] divides their framework into two branches for unchanged parts and edited parts, and incorporates each attention map to enable detailed editing.

Concurrent to above works, vid2vid-zero [14] performs stable video reconstruction and editing by adding cross-frame attention to the U-Net structure of the existing diffusion model. In addition, FateZero [28], based on zero-shot, stores an attention map during the inversion process to maintain temporal consistency for structure and motion information. We attempt the first study to extract motion information directly from video and apply it to video editing.

A.2. Optical Flow Estimation

Optical flow estimation is a computer vision task that involves computing the motion of objects in a video sequence. Recently, this field is significantly advanced through the rise of deep neural networks. FlowNet [29] was the first fully convolutional neural network for estimating optical flow. Then, a series of works, represented by SpyNet [30], PWC-Net [31], LiteFlowNet [32], and RAFT [33] were proposed to reduce the computational costs through coarse-to-fine and iterative estimation methodology. Recently GMFlow [17] were proposed to achieve highly accurate results without relying on a large number of refinements by performing global matching with a Transformer.

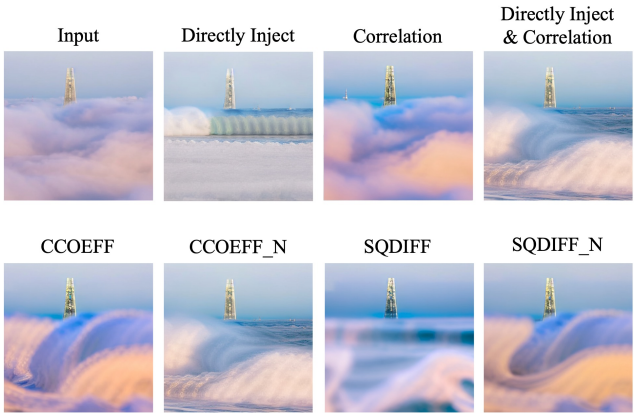


Figure 4: Outputs of various methods to measure the correlation between the motion map and the attention maps.

Optical flow estimation is used in various video tasks. First, video action recognition [34, 35] aims to automatically recognize the behavior of objects in video sequences, where optical flow is used as a useful motion representation in video motion representation. Using spatio-temporal information from surrounding scenes to fill in new content for damaged areas, video inpainting [36, 37, 38] enables spatio-temporally stable synthesis between frames of video through optical flow. Video super resolution [39, 40, 41] is the field of generating high-resolution video frames from low-resolution video frames, and generally maintains temporal consistency between video frames by using optical flow as motion compensation. Video frame interpolation (VFI) [42, 43], a technology that generates an intermediate frame between two consecutive frames, also effectively extracts motion and shape information between frames by utilizing optical flow to estimate motion information between frames. Our work is the first attempt to apply optical flow to text-guided video editing where motion information is important based on the proven validity of the optical flow estimation in various video fields.

B. Ablation Study

Fig. 4 shows the results for different injection methods of motion map. "Directly Inject" injects the motion map directly into the attention map of the motion prompt. "correlation" injects motion map to entire prompt's attention maps through the correlation between the each word attention maps and the motion map. "Directly Inject & Correlation" is combination of above described two methods. Specifically, "Correlation" is firstly applied, and then, "Directly Injection" is applied to the motion prompt. To inject the motion map into all words, the correlation between the attention maps of the input prompt and motion map is calculated. We applied various functions of template matching that represent a correlation between the two images. The

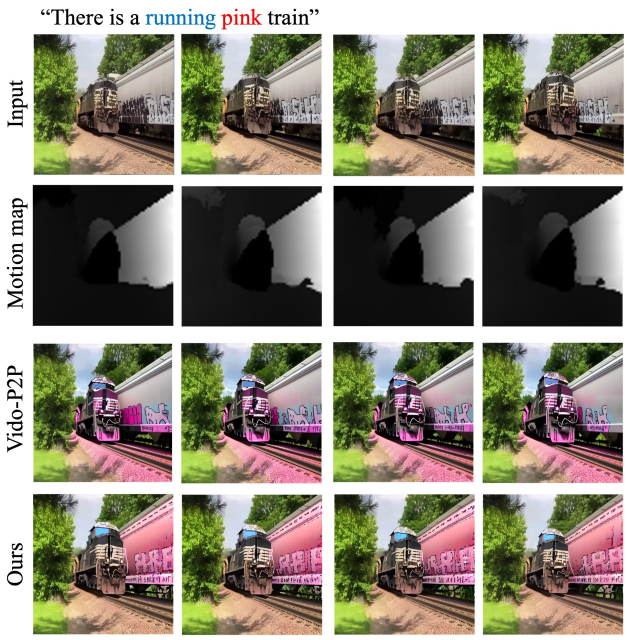


Figure 5: Editing method for objects moving in the direction specified by the user. Before editing, the user first selects one of the 8 directions.

"CCOEF" applied to the first image used correlation coefficient, and the second image is the result of "CCOEF_N" that normalizes it. The third image used "SQDIFF", a sum of squared differences, and the fourth image used "SQDIFF-N", which was normalized. As you can see in Fig. 4, the most suitable function to reinforce semantically editable is seen as "CCOEFF_N", which helps to edit semantically by varying weights depending on the degree of association of the prompter word. Therefore, we choose "CCOEFF_N" in method which is same as NCC.

C. Method for Optical Flow Rotation

Since V_{flow} has information on the magnitude of pixel movement between frames, as well as the direction in which pixel moved between frames, the user can select and edit the motion value in the desired direction. Our model allows the user to edit contents in a specific direction by rotating the optical flow V_{flow} according to the direction D provided by the user before injecting it. We propose a method to edit using information on the direction in which pixels move in optical flow representing information on pixel motion between previous frame F_{t-1} and present frame F_t. Our proposed model receives one of eight directions from the user, including Northeast (NE), Southeast (SE), Southwest (SW), and Northwest (NW), which are made from a combination of four directions in the 2D coordinate system.

$$\begin{bmatrix} X' \\ Y' \end{bmatrix} = \begin{bmatrix} X\cos\theta_D & -Y\sin\theta_D \\ X\sin\theta_D & Y\cos\theta_D \end{bmatrix}, \quad (1)$$

where θ_D denotes the angel between axis in frame and user provided direction D. X, Y denotes each motion vector in axis X, and Y. X', Y' denote the motion vectors rotated by θ in each axis.

After rotating the optical flow for the user-provided direction D, only the region of pixels with positive directional motion of the x axis in the rotated coordinate system is specified. The value of the motion map is extracted from the specific region and video edit is performed on the corresponding area. The results can be seen in Fig. 5.

D. Detailed Description of Evaluation Metrics

CLIPS core [21] is calculated in the CLIP model [44], generating embedding vectors for input images and prompts. CLIP Score [21] is measured by computing the cosine similarity between image and caption embedding. We measured how close the target prompt and the edited video frames are semantically in the CLIP Score[21] . We measured the CLIP Score [21] between target prompt and each edited video frame, and quantitatively compared the performance of our model and other models by the average of the scores measured per each frame. The CLIP Score [21] is calculated with the following equation.

$$extCLIPScore(F_t, \mathcal{P}^*) = max(100 * cos(E_{F_t}, E_{\mathcal{P}^*}), 0), \quad (2)$$

where F_t denote the t th edited frame, and $\mathcal{P}^*$ denotes the target prompt. We use official ViT-Base-Patch16 CLIP model.

Masked PSNR To evaluate whether our proposed model performs undesired edit out of target region to be edited, we measured masked PSNR (M.PSNR) proposed by Video-P2P [2]. On this purpose, we measure how much the external region of the target region has changed from the frame of the original video. In consideration of the averaged attention mask sequence M of the changed object, we measure masked PSNR by computing the pixel distance in the out-of-target regions of the edited video V^* and the input video V,

$$M.PSNR(V^*, V) = PSNR(B(V^*, M), B(V, M)), \quad (3)$$

according to Video-P2P [2], $B(V, M) = V_M$ is defined as a reversed mask binary function, so only regions not to be changed are involved in measuring masked PSNR.

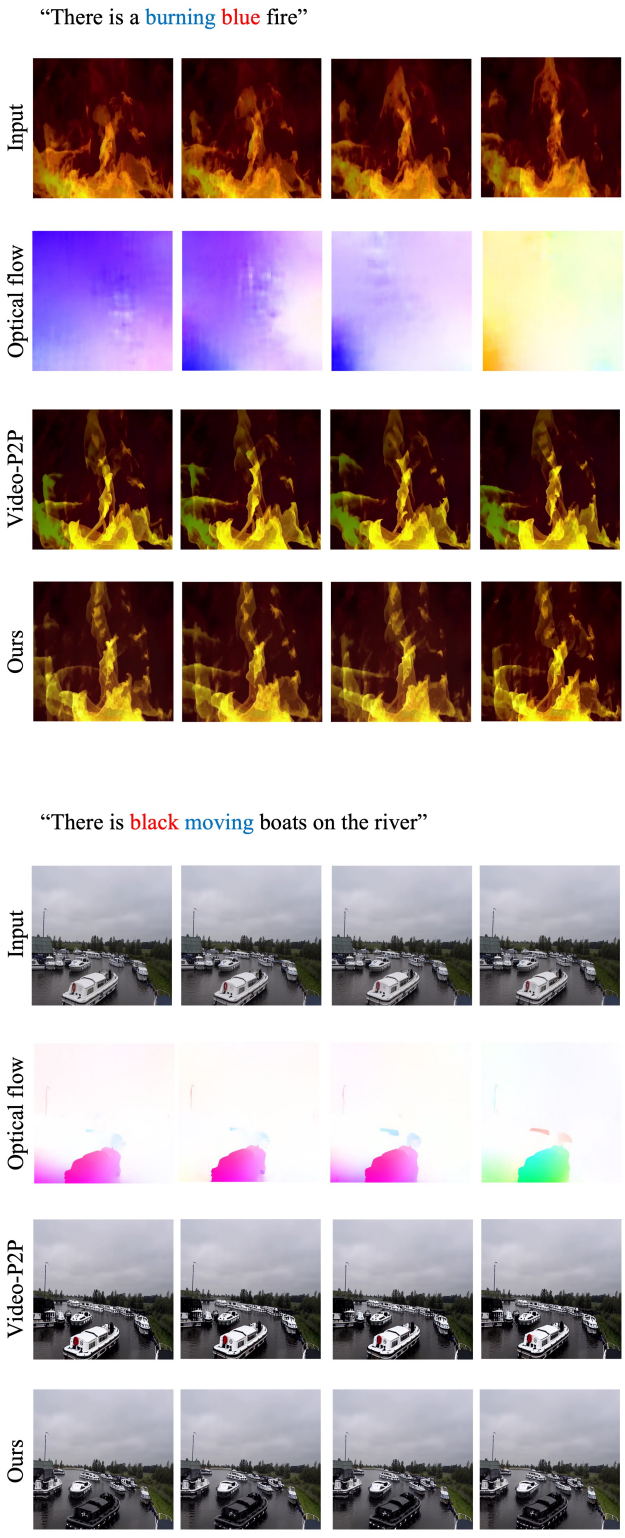


Figure 6: Results of Video-p2p [2] and our video editing model with inaccurately estimated optical flow

D.1. Ablation Study

D.2. Limitations

Accurate motion estimation of input video is essential for editing using optical flow. Therefore, even if optical flow is used, the bad results as shown in Fig. 6 may be obtained when it is difficult to estimate motion information from an image. The optical flow for the movement of fire could not be estimated, so there was no difference from the Video-P2P [2]. In addition, in the example of boat, motion was estimated only for ships that occupy a large area of the image, and small ships were not estimated. If the estimated motion of the optical flow for input video is not accurate, it is confirmed that our model, like existing Video-P2P [2], is difficult to perform accurate editing.

E. Code Descriptions

Our code is based on PyTorch version of Video-P2P [2]. We use Video-P2P [2] to edit videos. We set the parameters as follows: frame_size_h = 512, frame_size_w = 512, number of frames = 4,

Code is available at `https://anonymous.4open.science/r/AttentionFlow-197C/README.md`

F. Additional Qualitative Results

Additional experimental results and code can be found in the supplementary archive zipped with the supplementary paper.

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