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Final Report for the Changepoint in Adaptive Motion Deblurring study

YINGWEI SONG

YANG CAO

Sub-topic 1: Visualize how the threshold changes in the changepoint detection problem affect the deblurred outcomes

Brief intro:

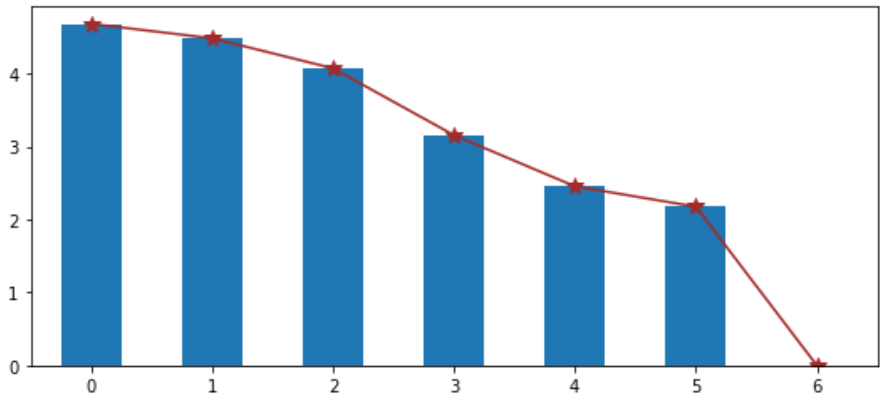
Since we detect the changepoints to simulate the flux, the variation of the threshold to the change point may affect the final deblurred images. That's because we need to use them to form the change point video and get the warp matrix. To detect the change points, we use the PELT algorithm. In the cost function, the $\boldsymbol{\lambda}$ is the penalty term that prevents overfitting by penalizing the number of fluxes changepoints, which is the representation of the threshold to this subproject. This subproject shows the relationship between the $\boldsymbol{\lambda}$ and image similarity to the desired deblurred image

Method:

We assume that when the $\boldsymbol{\lambda}$ = 6, it is the desired correct outcome here. By adjusting the various $\boldsymbol{\lambda}$, we generate different CPV (change point video), and deblur them based on their CPV. Finally, we use the dot product (cosine similarity) to quantify the image simulation.

Result:

```
When penalty = 0, the optimization problem can be calculated.
When penalty = 1, the optimization problem can be calculated.
When penalty = 2, the optimization problem can be calculated.
When penalty = 3, the optimization problem can be calculated.
When penalty = 4, the optimization problem can be calculated.
When penalty = 5, the optimization problem can be calculated.
When penalty = 6, the optimization problem can be calculated.
When penalty = 7, it stopped before the convergence.
When penalty = 8, it stopped before the convergence.
When penalty = 9, it stopped before the convergence.
When penalty = 10, it stopped before the convergence.
```



X-axes represents the penalty lambda mentioned before. Here we set when lambda=6 is the ground truth image, and we calculate image cosine similarity based on that.

Y-axes represents the cosine similarity distance between the ground truth image and the current image.

Conclusion:

As the graph shows above, when the penalty is set after 7, the optimization problem cannot be solved since it stopped before the convergence. The overall trend is, with the increase of penalty, the quality of the deblurred image is close to the desired image. However, the difference in image similarity is pretty small (may not be significant on the bar chart above). The changes in thresholds seem to have very less impact on the results.

Sub-topic 2: Deblurring images only based on changepoint images

Brief intro:

In the previous work, we first use the change points videos to generate a warp matrix, then apply them to deblur the original datasets. Now we only use the changepoint images, which means we discord the original datasets once we get the matrix, then apply the warp matrix to deblur the changepoint images.

Method:

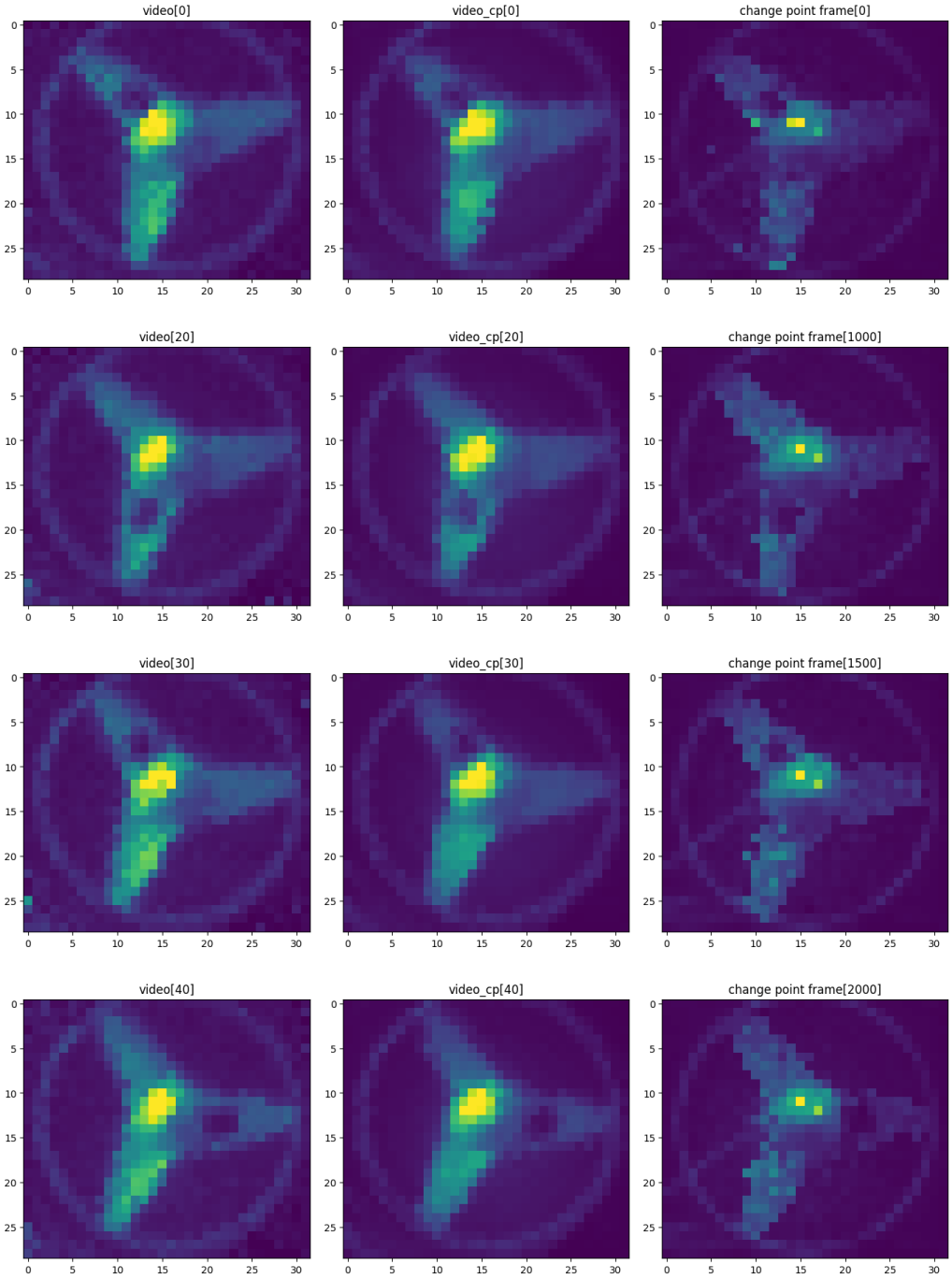
1. Don't use the original dataset once we get the warp matrix. All the following deblurring is only based on the CPV.
2. Only select the changepoint frames in the original data, and then combine them to generate a new dataset. Then use the originally given function to deblur the images

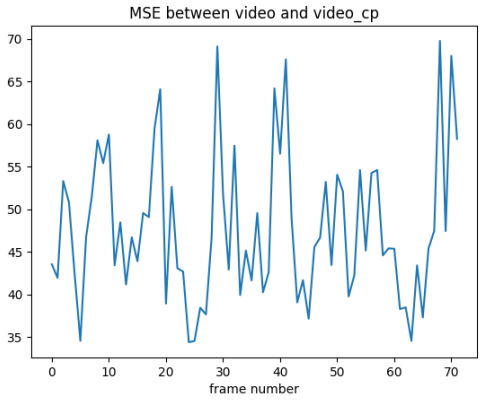
Result:

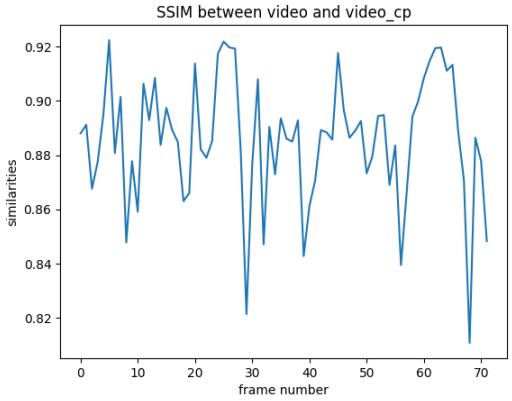
`Video`: deblur image from original frames

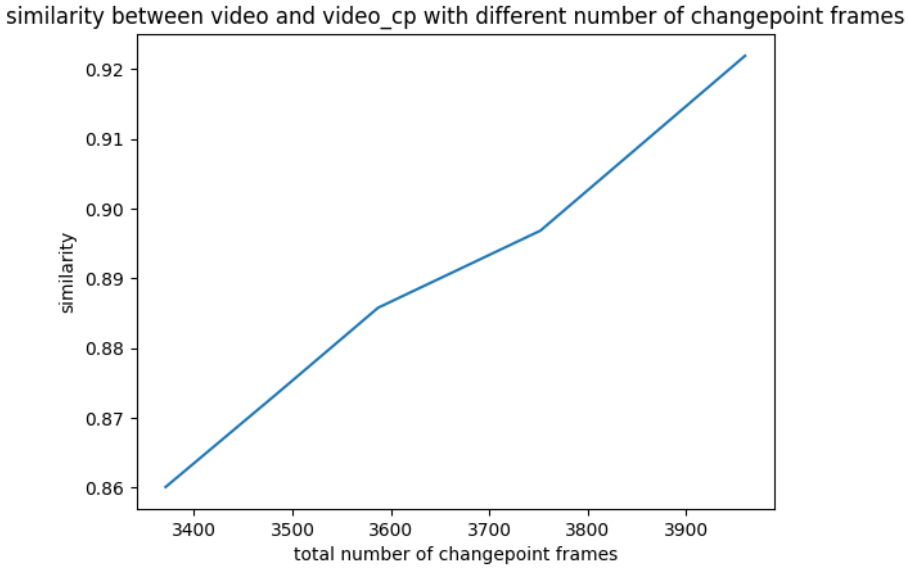
`video_cp`: deblur image from changepoint video

`changepoint frame`: frames of changepoint video









Conclusion:

1. As is shown in graphs, deblurring the changepoint video works very well. It's around 89 percent similar to the one which obtained by deblurring original frames with penalty=6. Comparing them with changepoint video frames, we can see that they are much clearer.

2. According to the graph “similarity between video and video_cp with different penalty”, we can conclude that the accuracy of deblurred changepoint video decreases as the total number of changepoint frames increases.

Sub-topic 3: Visualize and evaluate based on SSIM to show how threshold changes will affect the deblurred outcomes only based on changepoint images

Brief intro:

We now have two tasks.

Task 1: We evaluate how penalty changes will influence the image similarity where just deblur images based on cpv frames.

Task 2: We introduced a new threshold, which is to present whether we pick the current frame as the CPV or not. For example, if a frame from the original image contains 2 change points, but if we set the threshold as 3, it will not be counted as the CPV to generate a final deblurred image.

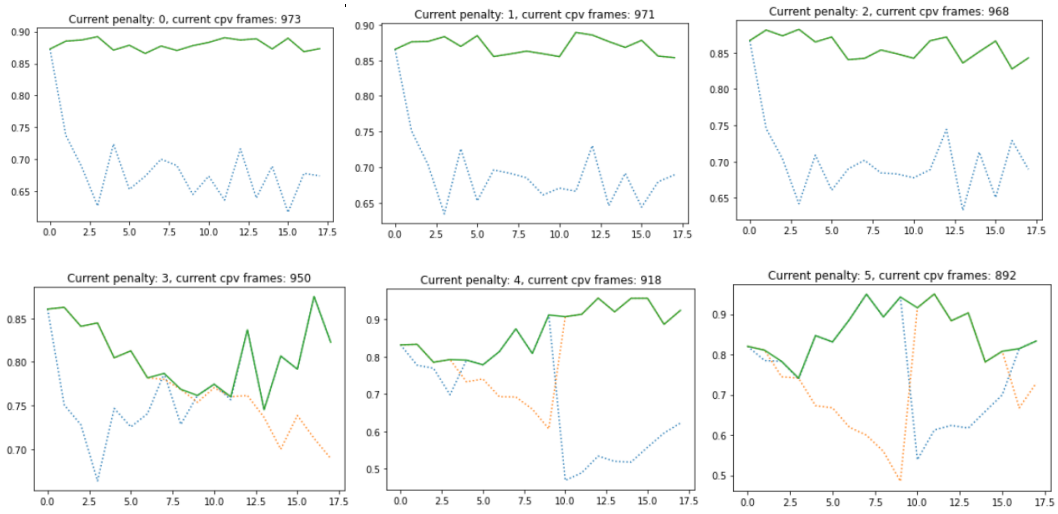
Method:

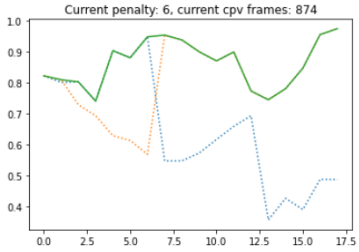
1. For task 1, the penalty, which is the lambda changes as iteration goes on. For now, we set the threshold as 0, which means once a frame contains any change point, it will be counted as a cpv to generate final image. Then we calculate the SSIM for each image between deblurred outcomes and the ground truth images.
2. For task 2, we set the penalty as lambda = 6, and the threshold mentioned before changes as iteration goes on.

Result:

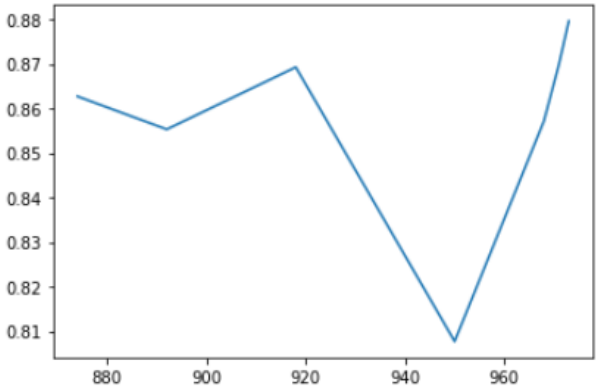
Task 1:

The green line represents the upper bound similarity, while the blue and the orange line represents two different ways compare images between current and ground truth image.



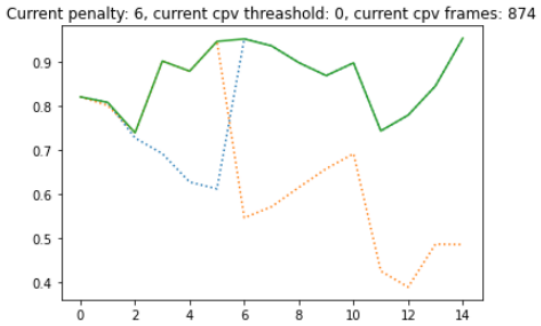


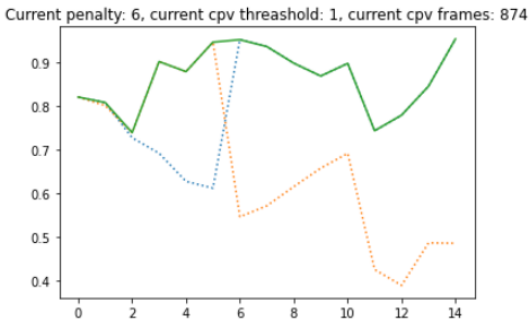
This is the overall score while penalty changes, how it will influence the deblurred outcomes which only based on changepoint images. The x-axes represent the number of frames. Higher penalty indicates smaller number of frames.

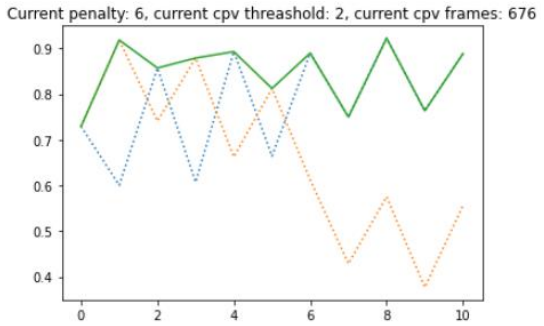


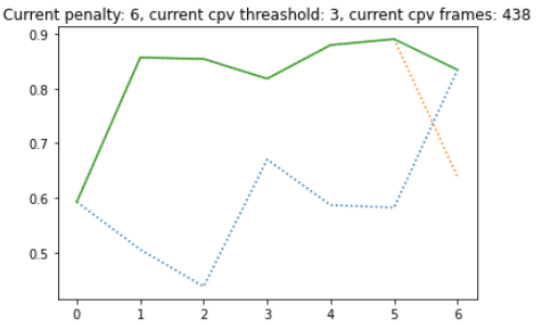
Task 2:

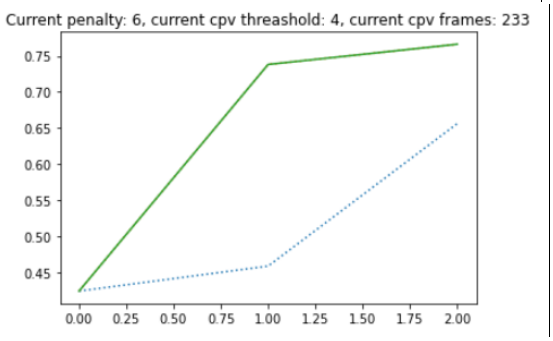
The green line represents the upper bound similarity, while the blue and the orange line represents two different ways compare images between current and ground truth image.



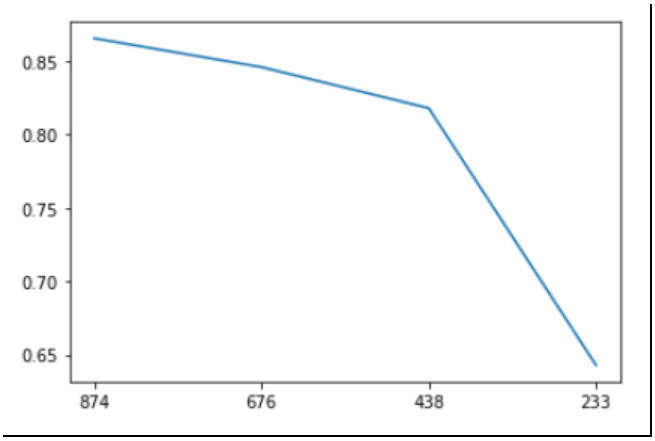








This is the overall score while the threshold changes, how it will influence the deblurred outcomes which only based on changepoint images. The x-axes represent the number of frames. Higher threshold indicates smaller number of frames.



Conclusion:

Task 1: The final graph showing above does not indicate a relationship between penalty and the image similarity just based on cpv. However, surprisingly, there is very few differences between penalty as 6 and as 0. Which means that penalty influences very little on the deblurred outcomes which only based on changepoint images.

Task 2: The final graph shown above clearly indicates that a higher threshold to pick cpv will influence the final deblurred image dramatically. And this also makes sense since such changes in the threshold will dramatically influence the number of frames we will use in the following

step. CPV frames can be treated as samples from the original dataset. Since we pick very few sample frames, the image similarity decrease.

Sub-topic 4: Deblur weighted change point video frames according to their variance and determinant.

Brief intro:

In the previous work, we get final clear images by deblurring changepoint video itself. We use MSE and SSIM to measure the similarities between images that we get by deblurring original frames and changepoint video. Also, we explore influences of the penalty $\boldsymbol{\lambda}$. To improve this method, we deblur weighted change point video frames according to their variance and determinant.

Method:

1. According to the reference, we use the formula $\tilde{T} = \frac{1}{N}\sum_{k=0}^{N-1} T_k + A_k(T_0 - T_k)$ where $A_k = \frac{|T_0 - T_k|^2}{|T_0 - T_k|^2 + c\sigma^2}$, σ^2 is the variance of T_k and c is a constant that accounts for the scaling of variance.
2. We use SSIM to measure the similarities between images I get from three different methods. Also, I change the c to see its effect on similarity.

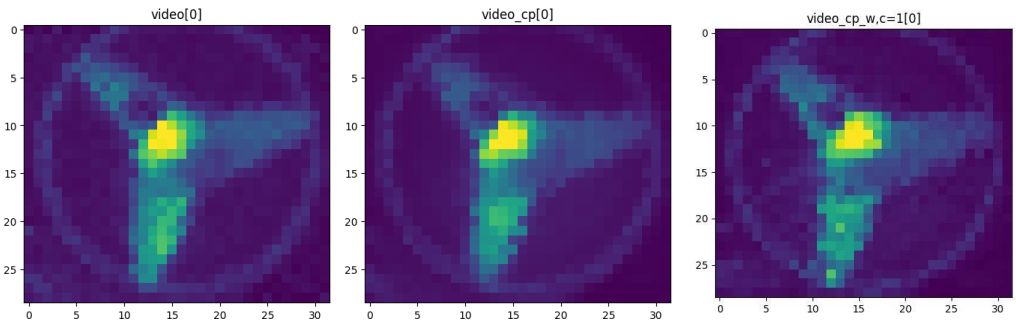
Result:

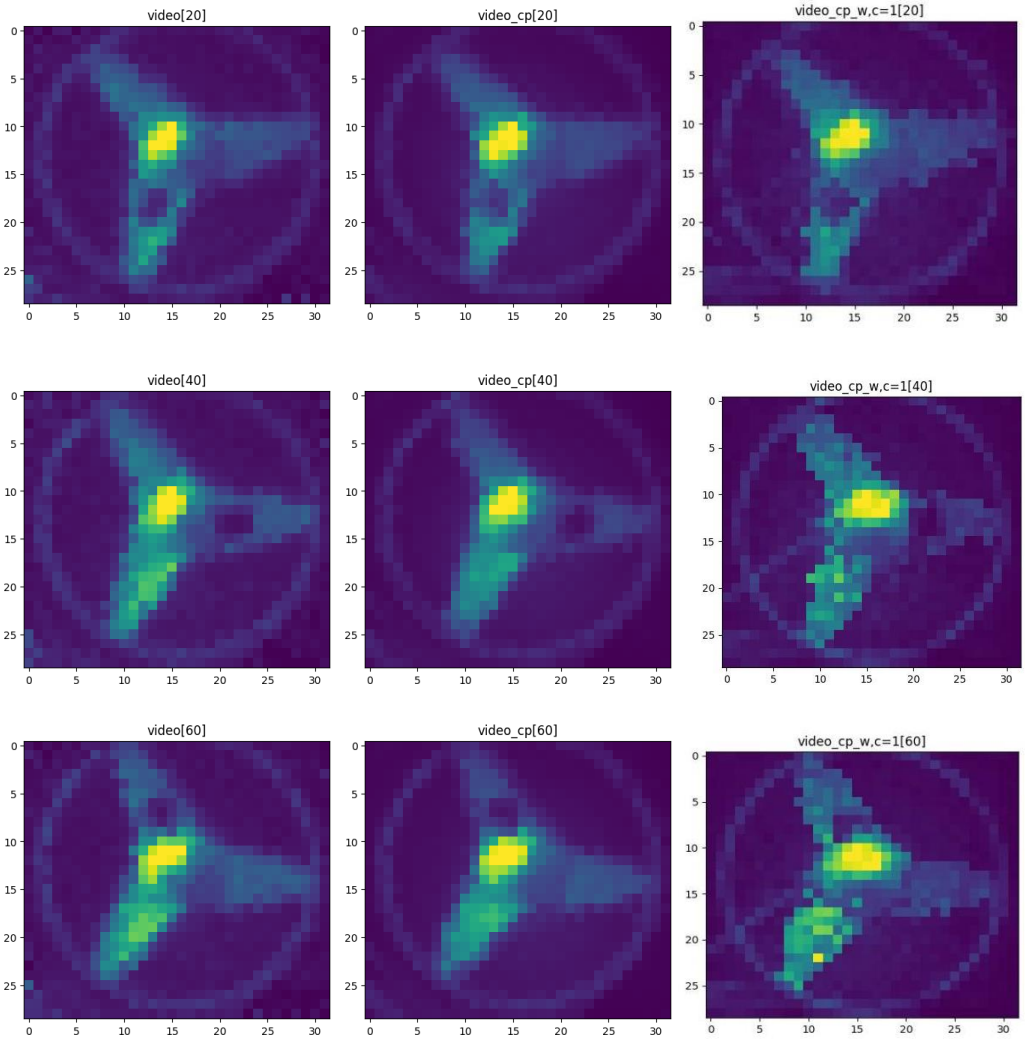
Result 1：Comparison between three methods

`Video`: deblur image from original frames

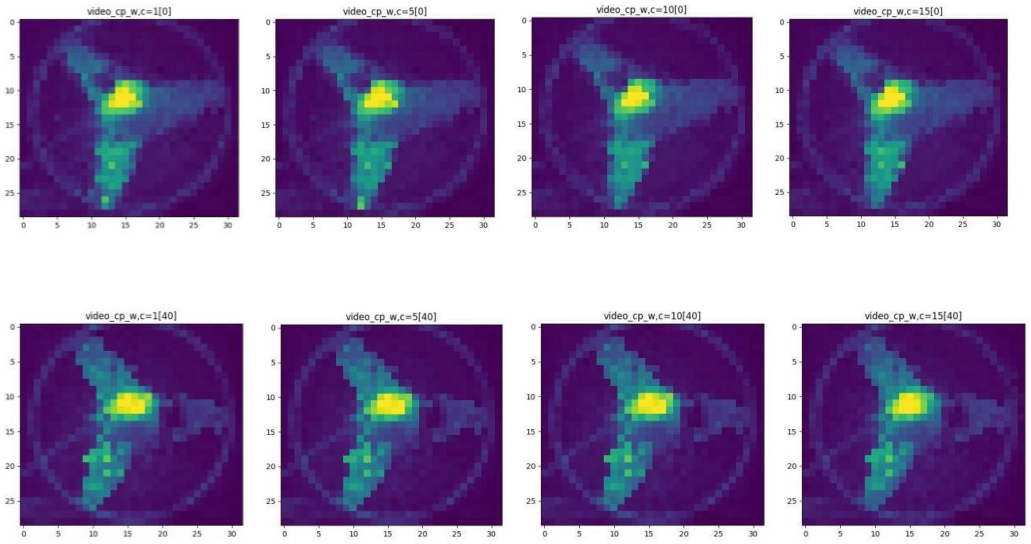
`video_cp`: deblur image from changepoint video

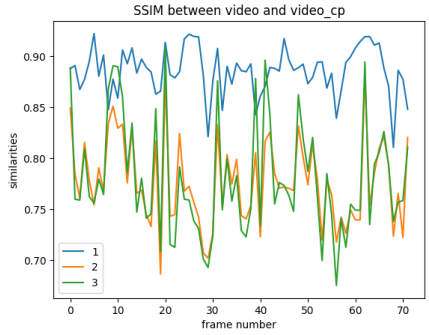
`video_cp_w`: deblur image from weighted changepoint video

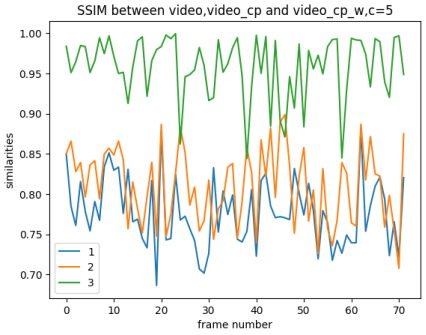


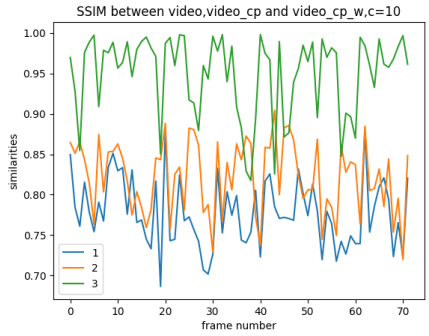


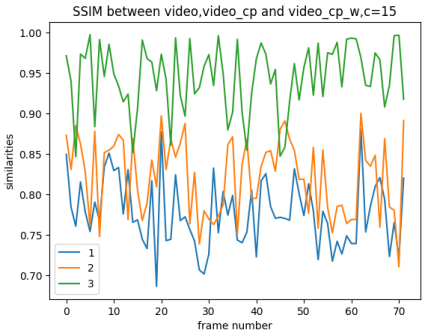
Result 2：Comparison between different c











Line1 is the SSIM between video and video_cp

Line2 is the SSIM between video and video_cp_w

Line3 is the SSIM between video_cp and video_cp_w

Conclusion:

As is shown in graphs, deblurring the weighted changepoint video produce higher-contrast images. However, it seems that some part of the noise has been enlarged. In addition, deblurring with higher c can produce sharper images which are quite similar to the images produced by deblurring original frames (Video).

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