



Improvement in Video Inpainting in Presence of Moving Subjects

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ABSTRACT

Inpainting or completion is used with the purpose of restoring damaged images and video frames. This paper proposes an applicable algorithm to inpaint corrupted subjects in video frames. To begin with, background and foreground (moving subject) are separated from each other in each frame, with the aim of getting to a more visually pleasant result. Static background inpainting is done using a patch-based method. To inpaint the corrupted moving subject, a subject-based method that is an improvement on the rigid object-based method is used in this study to consider the special issue of inpainting the human body. To fill in the holes created by occluding subjects the most appropriate template is found using a similarity measure which is based on both contour and pixel values. The inpainted video is acquired by superimposing the completed foreground on the inpainted background

Keywords: Video Inpainting, Video Completion, Contour, Moving Subjects Separation.

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1. Introduction

Video inpainting or completion is one of the attractive subjects in the field of video processing. Video inpainting is done with the purpose of restoring damaged parts of the video. To do this, a similarity measure is used to find the most appropriate data which is applied for filling in holes (holes are created by suppression of an occluding object) [1]. It should be noticed that inpainting is done in such a way that it does not generate pixels that may make the result unpleasant to the viewer; it is important to preserve the visual consistency of the inpainted video [2].

An initial consideration for extending image inpainting methods to video inpainting is to define video data as some distinct images [3]. By this definition, there are some individual images that image inpainting

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methods can be applied separately to each of them. As a result, high temporal consistency between video frames is not considered by this definition and therefore, results would not be pleasant [4].

In order to preserve temporal continuity of the moving object, none of image inpainting approaches should directly be used for video inpainting. The first attempt for this purpose was introduced in [5]. Partial Differential Equations (PDE) were used to preserve continuity between video frames [6].

Generally, video inpainting problems are divided into three different categories [7]: a) Static background with moving objects, b) No static background with static objects, and c) No static background with moving objects [8]. Most studies on video inpainting consider the first category and therefore, it is the preferred one in this study aiming to have an appropriate comparison. Also, there are some researches that consider (b) and (c) categories [9].

With respect to foreground/background separation, video inpainting techniques can be partitioned into two subsets [10]: 1) Techniques which separate background and foreground and inpaint them separately and 2) Techniques which do not separate background and foreground.

Since the first category has advantages over the second one [11], we have used it in this paper. These advantages can be mentioned as: i) Foreground and background separation results in finding more suitable matches. Moreover, search space for finding an appropriate template reduces and ii) For static backgrounds inpainting is done once. Then for other frames, this inpainted background is copied.

Video inpainting methods can be divided into five branches [1]: a) Patch-based, b) Object-based, c) Motion layer-based, d) PDE-based, and e) Combinational.

Patch-based methods: these methods consider a patch with the highest priority. Then, source region (video data except the target region) is searched to find the most appropriate patch that is going to be used for hole filling. The work [4] applied this approach to introduce an efficient framework for image/video inpainting.

Object-based methods. These methods consider objects rather than patches [12]. In fact, objects are bigger patches. Therefore, these approaches complete one frame per iteration. [13] has firstly introduced this approach.

Motion layer-based methods. These methods define a video sequence as a number of motion layers. By this definition, layer order is determined in overlapping areas. Removing of an object is done by removing of the layer of that object. This process results in holes on other layers. Completing these holes completes the remaining layers. Superimposing these layers results in inpainted video. Authors of [14] has initially introduced this approach.

PDE-based methods. These methods are used when holes are small. Research [15] has originally introduced the partial differential equations approach.

Combinational methods: in these methods motion layer-based approaches are combined with patch-based methods. Motion layer-based techniques restrict the search space. Authors in [16] introduced this approach at first.

In this paper, the second category (object-based methods) is used because these methods take less time to complete hole subjects. Also inpainting one object in each step preserves continuity better than other

methods. Authors have already improved the similarity measure and have used a novel method to differentiate between the goal subject and other moving subjects [17]. In this paper a new technique is applied to inpaint a subject considering its periodic motion. What is more, the subject is divided into two different parts and each part is inpainted using a different techniques. The assumptions in this study are static background, periodic motion and also no scale changing for the foreground.

2. The Proposed Video Inpainting Method

Figure 1 shows the algorithm proposed in this study, schematically. To begin with, a threshold-based mechanism is applied to differentiate between the moving foreground and the static background. Considering the state of the occluding object, if it is moving, the background is copied from safe frames.

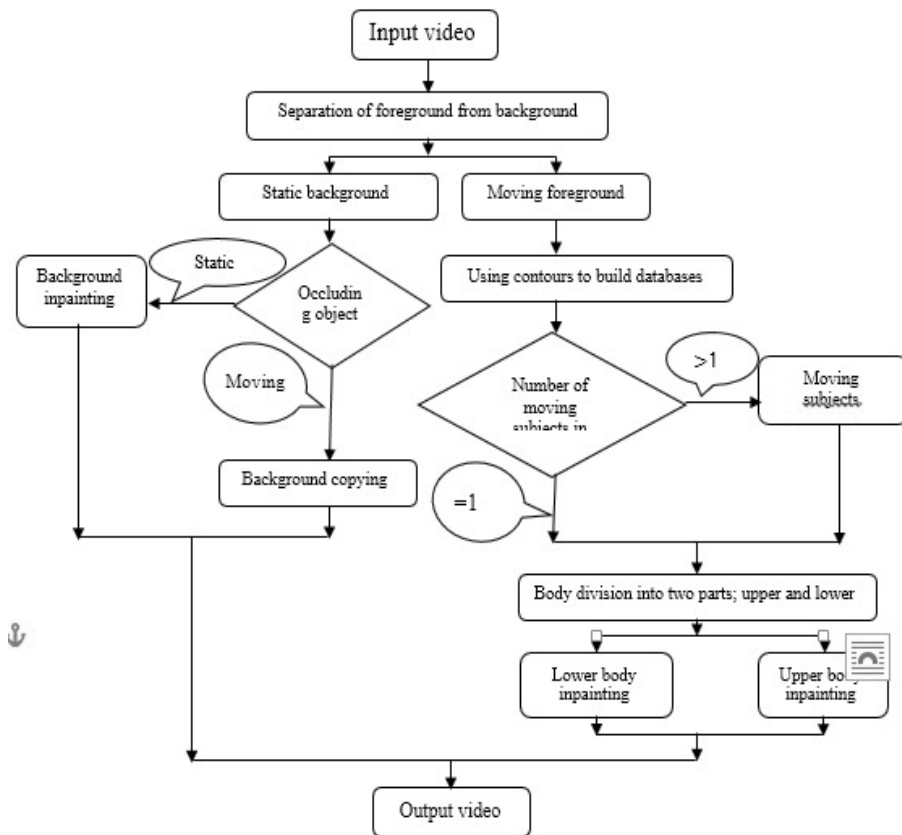


Figure 1. Schematic overview of the proposed algorithm.

Yet, if there is a static occluding object, inpainting is needed to fill in the hole since there is not any information about the background region behind the mentioned occluding object. In case of existing more than one moving foreground, the goal object must be separated from other moving objects. Now, it is time to divide human body into two parts: upper and lower body parts. Then, each of these two parts is inpainted separately and their combination results in inpainted foreground. Composing this inpainted foreground and the already acquired background gives the inpainted video.

2.1. Separation of the Moving Foreground from the Static Background

At first, the absolute difference between two components, current frame's pixels and the model of the background is calculated [18]. Then, this differentiation and threshold are used in Eq. (1).

$$frg_t = \begin{cases} 1 & \text{if } |image_t - Back_{t-1}| > T \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where *image_t* is the input frame at time t, *Back_{t-1}* is the background model, and *frgt* is the foreground at frame t. Gaussian Mixture Model (GMM) is used for modeling the background. To model each pixel, a mixture of *NumGauss* Gaussian distributions is used. Having the probability of observing a certain pixel at previous time, the probability of observation of that pixel at time t is

$$P(X_t|Back) \cong \sum_{n=1}^{NumGauss} wght_{n,t} N\left(X_t, \mu_{n,t}, \sum_{n,t}\right) \quad (2)$$

Where *NumGauss* is the number of components of GMM and *wght_{n,t}*, $\mu_{n,t}$ and $\sum_{n,t}$ introduce weight, mean value and covariance matrix for the *i*th Gaussian in the mixture at time t, respectively. By now, a model of each pixel is acquired. Using *NumLrg* largest items of the model, an estimation of the background is determined. *NumLrg* is specified in Eq. (3).

$$NumLrg = \operatorname{argmin}_{NumLrg} \left(\sum_{n=1}^{NumLrg} w_n > (1 - fdata) \right) \quad (3)$$

Where *fdata* is the maximum portion of data that is defined as foreground. Differentiation between each frame and the model of the background shows the moving foreground.

2.2. Background Inpainting

In this paper, the inpainting algorithm applied for the background is the exemplar-based which was introduced in [19]. The target region that its data is missed (hole) is filled in by patches from the source region (region with correct data). For each individual pixel on the boundary of the corrupted region, a value is determined as priority using Eq. (4). After finding priorities of pixels, a patch with the center at the pixel with the highest priority is chosen to be the first part of the hole that is supposed to be filled in.

$$prip(p) = \operatorname{Con}(p) \operatorname{Dat}(p) \quad (4)$$

Where *Con(p)* and *Dat(p)* are confidence and data values, respectively. To define these two values, Eqs. (5) and (6) are used.

$$\operatorname{Con}(p) = \frac{\sum_{q \in \Psi_p \cap (I-\Omega)} \operatorname{Con}(q)}{|\Psi_p|} \quad (5)$$

$$\text{Dat}(p) = \frac{|\nabla I_p^\perp \cdot n_p|}{\gamma} \quad (6)$$

Where Ψ_p defines a patch that is centered at pixel p . $|\Psi_p|$ defines the area of the patch Ψ_p . γ is used as a normalization factor (e.g. for greyscale images, $\gamma = 255$). n_p depicts orthogonal unit vector to the boundary of the hole and $^\perp$ expresses the orthogonal operator.

Considering the patch with the highest priority as Ψ_p' , the patch Ψ_q' can be determined as the best match of Ψ_p' in the source region. In order to replace Ψ_p' with Ψ_q' , only those pixels of Ψ_p' which have already been specified as target region will get new values. After that, confidence values of individual pixels surrounding the remaining portion of the hole are updated. This process iterates until the target region is completed. The exemplar-based method preserves both structure and texture and therefore, is suitable for background inpainting.

If the occluding object is static, this completed hole is copied into other frames. Yet, considering a moving object, there is no need for inpainting; information about the region behind the moving occluding object can be used for filling in hole.

2.3. Foreground Inpainting

There are several approaches for foreground inpainting [20]. In this paper, to inpaint the foreground, a contour-based foreground comparison [15] and an improved object-based inpainting algorithm is used. To begin with, the approach is described considering one moving subject. Later, we change the problem and introduce more than one moving subject where differentiation between the goal foreground and other foregrounds is needed.

2.3.1. Foreground inpainting in presence of one moving subject

By now, separation of the static background and the moving foreground is complete. The next step is extraction of the template of the foreground in each frame and bringing forward the resulted databases.

The method explained in Section 2.1 produces frames which illustrate background in black and foreground in white. The first generated database is the contour-database which is built from foregrounds' contours in consecutive frames. *Figure 2* shows a portion of the contour-database.



Figure 2. A portion of the contour-database.

(To have a suitable presentation, we have placed different frames' contours beside each other).

Next is the foreground-database which is shown in **Figure 3**. Notice that the background is unchanged, yet, the foreground is changed to be the same as in the original frame.



Figure 3. A portion of the foreground-database.
(We have placed different frames' foregrounds beside each other).

To inpaint the foreground, four different conditions are considered. The first one will be explained, but the others will be presented just as equations.

- Partially occluded objects are not considered, the best matched sequence of objects is equal to the number of frames of the hole.
- Partially occluded objects are not considered, the best matched sequence of objects is less than the number of frames of the hole.
- Partially occluded objects are considered, the best matched sequence of objects is equal to the number of frames of the hole.
- Partially occluded objects are considered, the best matched sequence of objects is less than the number of frames of the hole.

2.3.2. No partially occluded objects, complete sequence

No partially occluded object is considered here. Therefore, objects are considered either not destroyed or completely destroyed. The next assumption is existence of a complete sequence of object's motion. In simpler terms, this sequence's length is equal to the hole's length.

We consider video frames as $f_1 f_2 \dots f_{h-1} f_h f_{h+1} \dots f_{h+n-1} f_{h+n} \dots f_N$. f_h to f_{h+n-1} are frames containing the hole. Suppose moving objects as $O_1 O_2 \dots O_{h-1} O_h O_{h+1} \dots O_{h+n-1} O_{h+n} \dots O_N$. O_h to O_{h+n-1} represent objects in the hole. The aim in our previous work was to find an appropriate template from database to inpaint each of these n frames. Yet, in this paper, the appropriate template is only used to inpaint the lower part of the body. As a result, body division that will be covered later is needed.

Defining the periodicity of the motion as per , we have $O_i \approx O_{i \pm per}$ (i is the frame number). To find the most appropriate template, [21] used **Eq. (7)**. This study fills in the hole from left.

$$d(h-1, i) = |con_{h-1} - con_i|, \quad i = 1, 2, \dots, N, \quad i \neq h-1, h, \dots, h+n-1. \quad (7)$$

Where d is the distance between two contours, con_i is the contour of the not destroyed object. i is the frame number and N is the number of frames in video.

To preserve continuity, [21] extend the above approach so that five best templates (those which have the least values for $d(h-1, i)$) are chosen. These contours are named as con_{b1} , con_{b2} , con_{b3} , con_{b4} and con_{b5} . *Eq. (8)* is the final equation used to find the most appropriate template.

$$B = \arg \min_i (|con_{h-2} - con_{b_{i-1}}| + \sum_{k=1}^2 (|con_{h+n+k-1} - con_{b_{i+n+k}}|) + d(h-1, b_i)), i = 1, 2, 3, 4, 5. \quad (8)$$

Where B is the index of the best template. Consequently, the replacement is done using the following relation:

$$f_h f_{h+1} \dots f_{h+n-1} \leftarrow O_{B+1} O_{B+2} \dots O_{B+n}. \quad (9)$$

2.3.3. No partially occluded objects, no complete sequence

In this situation replacement is done as:

$$f_h f_{h+1} \dots f_{h+p} \leftarrow O_{B+1} O_{B+2} \dots O_{B+p-1}, \quad B+p+1 < h+n-1, \quad (10)$$

where p-1 is the length of the sequence of the best match found. To find the index of the best template, *Eq. (8)* is replaced with *Eq. (11)*.

$$B = \arg \min_i \left(\sum_{k=1}^2 (|con_{h-1-k} - con_{b_{i-k}}|) + d(h-1, b_i) \right), \quad i = 1, 2, 3, 4, 5. \quad (11)$$

After using relation (10), the new hole is defined as $f_{h+p+1} f_{h+p+2} \dots f_{h+n-1}$. Again, *Eq. (11)* is applied to find B, but note that now con_{B+p+1} is defined as con_h . This process is repeated until the whole hole is complete.

2.3.4. Partially occluded objects, complete sequence

Eqs. (7) and *(8)* change to *(12)* and *(13)*, respectively.

$$d(h, i) = |con_h - con_i|, \quad i = 1, 2, \dots, N, \quad i \neq h, h+1, \dots, h+n-1. \quad (12)$$

$$B = \arg \min_i \left(|con_{h-1} - con_{b_{i-1}}| + \sum_{k=1}^2 (|con_{h+n+k-1} - con_{b_{i+n+k}}|) + d(h, b_i) \right), i = 1, 2, 3, 4, 5. \quad (13)$$

2.3.5. Partially occluded objects, no complete sequence

Eq. (12) is used as before, but *Eq. (13)* is replaced by *Eq. (14)* in order to exert not existence of a complete suitable sequence.

$$B = \arg \min_i \left(\sum_{k=1}^2 (|\text{con}_{h-k} - \text{con}_{b_i-k}|) + d(h, b_i) \right), \quad i = 1, 2, 3, 4, 5. \quad (14)$$

Foreground Inpainting in Presence of more than One Moving Subject

If more than one moving subject exists in a video sequence, it is needed to differentiate between the goal subject and other subjects. **Figure 4** illustrates presence of more than one moving subject in the scene.

Separation of the goal subject from other subjects is done in such a way that each time subject 1 overlaps with other moving subjects, we consider the other subject (for example, subject 2) as the goal subject and use the pre-described method to find its best match which is appropriate to be placed in destroyed frames. In other words, we temporally change the goal subject with other moving subjects and suppose that the new goal subject is occluded by the old goal subject. Therefore, we should find the most suitable template for this new occluded goal subject.



Figure 4. A video frame with three moving subjects.

(Subject 1 is the goal subject that is going to remain in the video and be separated from subjects 2 and 3).

It is the same for other moving occluding subjects. More details can be found in [17].

2.4. Body Division

To remove jumps generated between frames in the inpainted video, frame information close to the hole is more suitable to be used. Investigations on inpainted videos show that if we divide the body of the subject into two upper and lower portions and inpaint each separately, we will have more suitable templates and results.

2.4.1. Body division into two parts: upper and lower

Figure 5 shows that when a subject is moving across a scene, the angle between the line of sight of the camera and the line between the subject and camera varies.

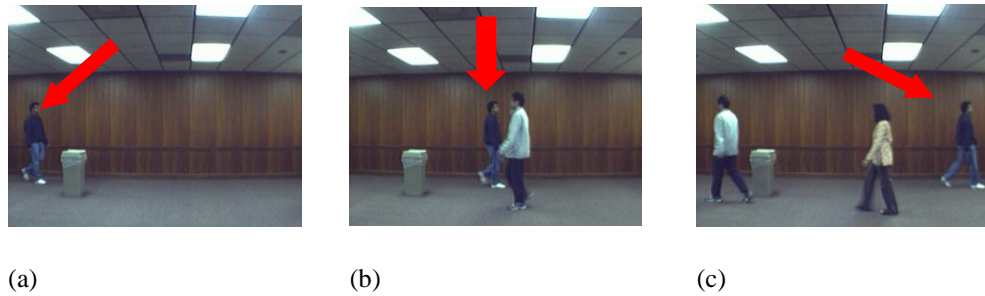


Figure 5. Different body shapes of the subject are obtained when he is viewed from different angles.
((a) first frame, (b) middle frame, and (c) last frame).

As it is illustrated in **Figure 5**, if the subject is viewed from different angles, the body shape will be different. Our previous results in [17] show that this change in the body shape is visible in the upper part much more compared to lower part. For this reason and also because this variation of angles have less effect on the body contour, we decided to partition the body into two parts, upper and lower and complete each of them separately.

Hands movement is very important in the inpainting of the upper part. Therefore, body division is done somehow that the upper body includes hands of the subject and below that is considered as the lower body. To differentiate between upper and lower bodies, we find the most down place of the hand and name this separating row as *rowSep*.

2.4.2. Lower body inpainting

The algorithm described in Section 2.3 is used for lower body inpainting. Yet, it should be mentioned that only the region from *rowSep* to most down part of the template is inpainted using this method.

2.4.3. Upper body inpainting

The most important and effective part of the idea of body division relates to the inpainting of the upper body. As in **Figure 5(b)** it can be seen that in some situations the upper part of the body is undamaged. Yet, the lower part is damaged because of the occlusion. As a result, the whole template needs not to be used. If we partition the body then the safe upper part can be used while the destroyed lower part is inpainted.

The similarity measure used to find the most appropriate template of the upper part is based on pixel values instead of contour points that was introduced before. The reason is that for cases where the hand is in front of the body, the contour is almost the same; in these situations using pixel values as similarity measure is more appropriate.

Figure 3 depicts the foreground database which can be used for generating the upper database. **Figure 6** illustrates a generated upper body database.



Figure 6. A portion of the upper body database.

Supposing the period of hand movement as *perH* and the sequence of uppers as $u_1 u_2 \dots u_i \dots u_N$, we have:

$$u_i = u_{i \pm \text{perH}}. \quad (15)$$

Where i is the current frame number.

Considering the three persons video, the first hole is produced almost in the middle of the scene. Completion of this hole can be done using upper database from either before the hole or after the hole. But there is a note: suppose the mean angle between the line of sight of the camera and the line between the subject and camera before the hole, inside the hole and after the hole are θ_1 , θ_2 and θ_3 , respectively. *Eq. (16)* determines their relation.

$$\theta_1 < \theta_2 < \theta_3 \Rightarrow \theta_1 \ll \theta_3. \quad (16)$$

Eq. (16) shows that if we use the prior information for filling in the hole, it will generate a visible jump. Therefore, it is better to use information after the hole, since the subject is moving towards that side of the scene. As a result, there is one equation from *Eq. (15)* that can satisfy this hole completion: $u_i = u_{i + \text{perH}}$. Although we described why we should use information after the hole, for the second hole which is almost at the end of the frame, there is not a complete period of hand movement. Therefore, there is an obligation to use information before the hole. In simpler terms, we will use $u_i = u_{i - \text{perH}}$. As you can see, we selected a video that defines two different conditions according to two different holes. Each of these two hole fillings will be covered below and two general equations used for completing the hole will be determined based on the two situations. Before moving on these various cases imagine that we are going to work on sequence $u_1 u_2 \dots u_{h1-3} u_{h1-2} u_{h1-1} u_{h1} \dots u_{h1+n-1} \dots u_{c1-2} u_{c1-1} u_{c1} u_{c1+1} u_{c1+2} u_{c1+3} u_{c1+4} \dots u_{c2-4} u_{c2-3} u_{c2-2} u_{c2-1} u_{c2} u_{c2+1} u_{c2+2} \dots u_{h2} u_{h2+1} \dots u_{h2+n-1} u_{h2+n} u_{h2+n+1} u_{h2+n+2} \dots u_N$.

Where $h1$ and $h2$ are frame numbers of the first and the second hole, $c1 = h1 - 1 + \text{perH}$ and $c2 = h2 + n - \text{perH}$, respectively.

- First Hole Filling.

As mentioned before, the measurement used here is based on pixel values. *Eq. (17)* is applied for this purpose.

$$B_Index_1 = \arg \min_i \sum_{i=-2}^2 \|u_{h_1-1} - u_{c_1+i}\|_2 + \sum_{i=-2}^2 \|u_{h_1-2} - u_{c_1+1+i}\|_2 + \sum_{i=-2}^2 \|u_{h_1-3} - u_{c_1+2+i}\|_2 \quad (17)$$

Moreover, since information after the hole is used for the first hole, hand movement is somehow that a period of this motion is available after the hole. Because of this, for inpainting the upper part of the foreground, we reverse hand's motion. In other words, hand moves towards front and then goes back. Therefore, $c_1+B_Indx_1$ is the index of the most similar template to the template u_{h1-1} . Considering the above discussion, u_{h1} is replaced with $u_{c1+B_Indx1-1}$ and this repeats until the hole is totally inpainted. *Eq. (18)* retells the above explanations mathematically.

$$u_{h-1+k} = u_{c_1+B_Indx_1-k}, \quad k = 1, 2, \dots, \left\lfloor \frac{\text{perH}}{2} \right\rfloor. \quad (18)$$

▪ Second Hole Filling.

As it was already described, there is one choice for completing the second hole; using information before the hole. Therefore, *Eq. (17)* is replaced with *Eq. (19)* to find the most suitable template $c_2+B_Indx_2$ for u_{h2+n} .

$$B_Index_2 = \arg \min_i \sum_{i=-2}^2 \|u_{h_2-n} - u_{c_2+i}\|_2 + \sum_{i=-2}^2 \|u_{h_2+n+1} - u_{c_2-1+i}\|_2 + \sum_{i=-2}^2 \|u_{h_2+n+2} - u_{c_2-2+i}\|_2 \quad (19)$$

Since the prior information is applied here for inpainting, equation (18) is replaced with (20).

$$u_{h+n-k} = u_{c_2+B_Indx_2+k}, \quad k = 1, 2, \dots, \left\lfloor \frac{\text{perH}}{2} \right\rfloor. \quad (20)$$

3. Results and Discussion

The videos used in this study are “jumping girl”, “three persons” and “seq2_ori”.

Figure 7 compares the proposed algorithm with the one introduced in [12].



Figure 7. Comparison between the results of the technique proposed in this study and the results of method proposed in [19].

(a) Results of the method in [19]; (b) Results of the proposed method.

Our method distinguishes between two components: the static background and the moving foreground. Therefore there is no over-smoothing for the background. What is more, jumps that usually occur while the moving subject enters the hole or exits from it, have been reduced.

Figure 8 shows another comparison of the proposed algorithm with the one introduced in [19].

Figure 9 shows comparison of the proposed algorithm with the one introduced by [4].



Figure 8. Comparison between the results of the technique proposed in this study and the results of [19].

(a) Results of the method in [19] & (b) Results of the proposed method.

On the first row, the first and the second pictures from left have two right hands. Yet, the proposed algorithm solved this problem. On the first row, the right picture does not have a complete template. The proposed algorithm has solved this problem.

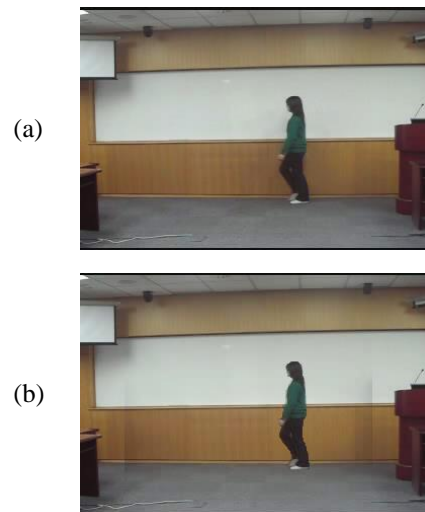


Figure 9. Comparison between the results of the technique proposed in this study and the results of [4].

(a) Results of the method in [4] & (b) Results of the proposed method.

The left side picture is with shadow of the occluding subject. Yet, the proposed algorithm has solved this problem. For better comparison you can see our produced videos at <https://rapidshare.com/files/1179750960/video.rar>.

This paper introduced a new approach for inpainting occluded objects in videos. To begin with, separation of two components of video was done. Then, with respect to the occluding object being static or moving, holes of the background were completed by inpainting or copying from correct frames, respectively. To fill in the corrupted portions of the foreground, an object-based inpainting approach was used. Moreover, the subject's body was divided into two lower and upper parts. Each of them was inpainted using different similarity measures with the purpose of finding the most suitable template for completing the hole.

Some challenges to be mentioned for future work include: consideration of non-periodic motion, consideration of scale changing for foreground subjects and speed variation for subject motion.

References

- [1] Ghanbari A., & Majdi M. (2017). Video inpainting using a contour-based method in presence of more than one moving objects. *International journal of advanced engineering and management*, 2(2), 37 - 44.
- [2] Javed, S., Mahmood, A., Al-Maadeed, S., Bouwmans, T., & Jung, S. K. (2018). Moving object detection in complex scene using spatiotemporal structured-sparse RPCA. *IEEE transactions on image processing*, 28(2), 1007-1022.
- [3] Pawar, A. J., Jadhav, H. L., Ukarande, V. V., & Chavan, S. R. (2018, January). A comparative study of effective way to modify different object in image and video using different inpainting methods. *2018 2nd international conference on inventive systems and control (ICISC)* (pp. 1098-1102). IEEE.
- [4] Pinjarkar, A. V., & Tuptewar, D. J. (2019). Robust exemplar-based image and video inpainting for object removal and region filling. In *computing, communication and signal processing* (pp. 817-825). Singapore: Springer.
- [5] Bertalmio, M., Bertozzi, A. L., & Sapiro, G. (2001, December). Navier-stokes, fluid dynamics, and image and video inpainting. *Proceedings of the 2001 IEEE computer society conference on computer vision and pattern recognition, CVPR 2001* (Vol. 1, pp. I-I). IEEE.
- [6] Le, T. T., Almansa, A., Gousseau, Y., & Masnou, S. (2018). Removing objects from videos with a few strokes. *SIGGRAPH Asia 2018 technical briefs* (pp. 1-4). <https://dl.acm.org/>
- [7] Talouki, A. G., Majdi, M., & Edalatpanah, S. A. (2017). An introduction to various algorithms for video completion and their features: a survey. *Journal of computer sciences and applications*, 5(1), 1-10.
- [8] Soryani, M., Ghanbari, A., & Koochari, A. (2014). Dynamic video texture inpainting using improving LDS. *British journal of mathematics & computer science*, 4(20), 2872-2883.
- [9] Le, T. T., Almansa, A., Gousseau, Y., & Masnou, S. (2017, September). Motion-consistent video inpainting. *2017 IEEE international conference on image processing (ICIP)* (pp. 2094-2098). IEEE.
- [10] Bouwmans, T., Maddalena, L., & Petrosino, A. (2017). Scene background initialization: a taxonomy. *Pattern recognition letters*, 96, 3-11.
- [11] Zakir, Y. K., Prajot, R., Krishna, K., & Anish, K. (2016). A hierarchical super resolution based video inpainting tool. *International journal of advance research and innovative ideas in education*, 2(2), 236-240.
- [12] Gaur, S., Degadwala, S., & Mahajan, A. (2019). Multiple objects tracking under occlusion detection in video sequences. In *emerging trends in expert applications and security* (pp. 189-196). Singapore: Springer.
- [13] Cheung, S. C. S., Zhao, J., & Venkatesh, M. V. (2006, October). Efficient object-based video inpainting. *2006 international conference on image processing* (pp. 705-708). IEEE.

- [14] Zhang, Y., Xiao, J., & Shah, M. (2005, January). Motion layer based object removal in videos. *2005 seventh IEEE workshops on applications of computer vision (WACV/MOTION'05)* (Vol. 1, pp. 516-521). IEEE.
- [15] Bertalmio, M., Sapiro, G., Caselles, V., & Ballester, C. (2000, July). Image inpainting. *Proceedings of the 27th annual conference on computer graphics and interactive techniques* (pp. 417-424). ACM Press/Addison-Wesley Publishing Co.
- [16] Shiratori, T., Matsushita, Y., Tang, X., & Kang, S. B. (2006, June). Video completion by motion field transfer. *2006 IEEE computer society conference on computer vision and pattern recognition (CVPR'06)* (Vol. 1, pp. 411-418). IEEE.
- [17] Ghanbari A., Soryani M., (2012). *Contour-based video inpainting in presence of more than one moving object*. Paper presented at the meeting of international conference on image processing and pattern recognition (IPPR 2015), Chennai, India.
- [18] *proc. 2nd int. conf. image processing and pattern recognition*.
- [19] Xu, Z., Min, B., & Cheung, R. C. (2019). A robust background initialization algorithm with superpixel motion detection. *Signal processing: image communication*, 71, 1-12.
- [20] Xiang, S., Deng, H., Zhu, L., Wu, J., & Yu, L. (2019). Exemplar-based depth inpainting with arbitrary-shape patches and cross-modal matching. *Signal processing: image communication*, 71, 56-65.
- [21] Aadhirai S., Srinivasan M. N., Rekha R. L., (2016). An approach of video inpainting technique to remove undesired objects using mean shift algorithm. *International journal of advanced research in electronics and communication engineering (IJARECE)*, 5, 1181-184.
- [22] Ghanbari, A., & Soryani, M. (2011, November). Contour-based video inpainting. *7th Iranian conference on machine vision and image processing* (pp. 1-5). Tehran, Iran: IEEE.