CSC2014 DIGITAL IMAGE PROCESSING

Group Assignment

Name	Student ID
Chan Kah Gin	23038367
Ho Zi Shan	22116347
Lee Wen Xuan	22115737
Thit Sar Zin	21082755

Introduction

This project consists of two tasks, namely task A (YouTube video processing) and task B (paragraph extraction). Task A involves developing a program that processes four videos to enhance and modify their contents by:

1. Increasing the brightness of the video if it was shot at night.
2. Blurring every face in the video.
3. Resizing and overlaying a talking video (talking.mp4) on the top left of each video.
4. Adding watermarks to the videos to protect video ownership.
5. Adding an end screen video (endscreen.mp4) at the end of each video.

On the other hand, task B involves developing a program that processes a set of scientific papers in image format, extracts all paragraphs, and stores them in the correct order. The detailed process includes:

1. Extracting columns from the images.
2. Extracting paragraphs from the columns.
3. Storing paragraphs in the correct order.
4. Identifying and removing invalid content from the paragraphs.

Task A

1. Proposed Approach

Increase brightness for nighttime videos:

To calculate the brightness of each video, every frame in the video was first converted into grayscale using `cv2.cvtColor()`. Then, their brightness values were computed by calculating the mean pixel intensity of the grayscale frames using `np.mean()`.

These values were stored in a list and were computed later to determine the brightness values of the entire video by using **np.mean()** again.

```
def calculate_brightness(frame):
    # Convert current frame to grayscale (colour information is not necessary to calculate brightness)
    gray_frame = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
    # Calculate average brightness of the frame by calculating the mean of all pixel values
    brightness = np.mean(gray_frame)
    return brightness
```

Since nighttime videos have lower average brightness values, a threshold of 100 is used to differentiate daytime and nighttime videos. Any videos with average brightness values lower than the threshold are defined as videos shot during nighttime.

```
# If the average brightness is less than 100, then it is considered as nighttime
    is_nighttime = avg_brightness < 100
    day_night_status = "NIGHT" if is_nighttime else "DAY"
    print(f"Detected as: {day_night_status}")
```

If nighttime video were detected, its brightness was increased using the **cv2.convertScaleAbs()** function, where the pixel intensities of each frame were scaled by a factor of two to double its brightness.

```
def increase_brightness(frame, factor=2.0):
    # Increase the brightness of the frame by multiplying all pixel values by the factor value 2.0
    bright_frame = cv2.convertScaleAbs(frame, alpha=factor, beta=0)
    return bright_frame
```

After all the steps mentioned above, every frame of the videos was appended to a list for storage, and the processed video was then released to free up memory.

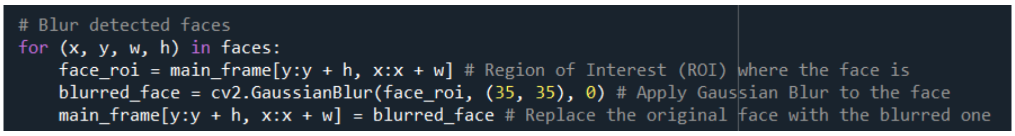
```
# Loop through the frames again and adjust brightness if it's nighttime
vid.set(cv2.CAP_PROP_POS_FRAMES, 0) # Reset to the first frame
frames = [] # List to store processed frames
for frame_count in range(total_no_frames):
    success, frame = vid.read()
    if not success:
        break
    if is_nighttime:
        frame = increase_brightness(frame, 2.0) # Increase the brightness by a factor of 2
    frames.append(frame)

vid.release()
return frames
```

Face blurring:

A Haar Cascade Classifier was used to detect faces in the main video. The **cv2.CascadeClassifier()** function was used to initialise the classifier, and the relevant Haar Cascade file was loaded. The initial step in processing each frame of the main video was to convert it to greyscale using **cv2.cvtColor (main_frame, cv2, COLOR_BGR2GRAY)**. By lowering the computational complexity, this step made the face detection procedure simpler. With **scaleFactor = 1.3** and **minNeighbours = 5**, the **detectMultiScale()** function was applied to the grayscale frame to ensure precise facial detection while removing false positives.

```
# Process each frame in the main video
for frame_idx in range(total_frames):
    main_frame = main_video_frames[frame_idx]
    gray_frame = cv2.cvtColor(main_frame, cv2.COLOR_BGR2GRAY) # Convert to grayscale for face detection
    faces = face_cascade.detectMultiScale(gray_frame, scaleFactor=1.3, minNeighbors=5) # Detect faces
```

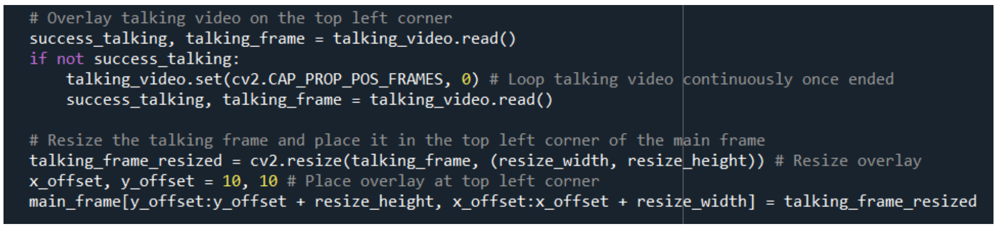
Each region of interest (ROI) that corresponded to a face was then extracted from the frame after the faces were detected. The **cv2.GaussianBlur()** method was then used to apply a Gaussian Blur on these areas, with a kernel size of **(35, 35)** to adequately anonymise the facial details. After that, the blurred ROI was reincorporated into the original frame, essentially replacing the blurred version of the facial characteristics for the real ones. This procedure was carried out again for each identified face in a frame.



```
# Blur detected faces
for (x, y, w, h) in faces:
    face_roi = main_frame[y:y + h, x:x + w] # Region of Interest (ROI) where the face is
    blurred_face = cv2.GaussianBlur(face_roi, (35, 35), 0) # Apply Gaussian Blur to the face
    main_frame[y:y + h, x:x + w] = blurred_face # Replace the original face with the blurred one
```

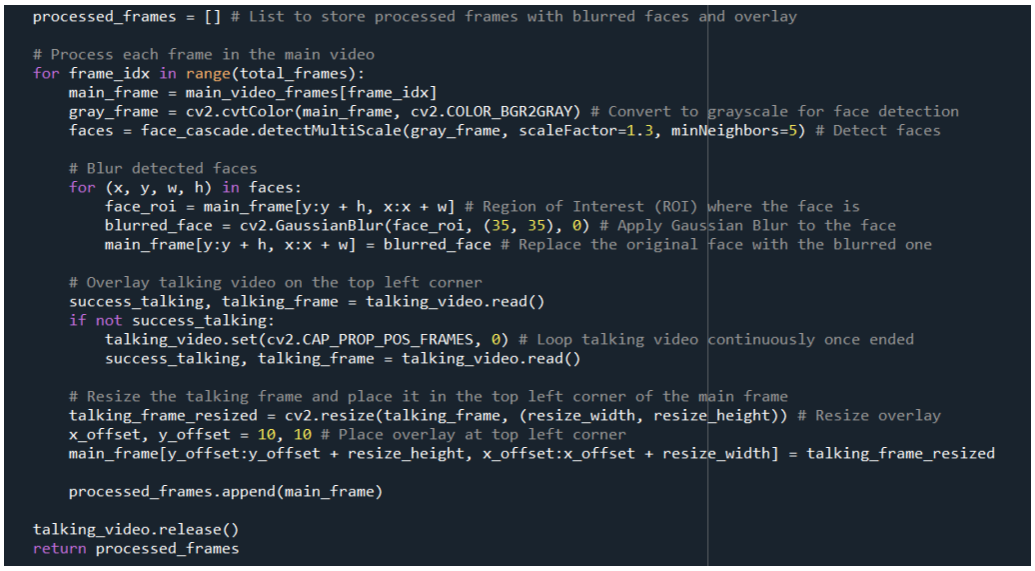
Overlaying talking video:

The **cv2.VideoCapture()** function was used to load talking.mp4, a secondary video, for use as the overlay. The **cv2.resize()** function was used to resize each frame of the talking video to 30% of the original video's dimensions. To prevent the overlay from obscuring crucial elements of the main video, this scaling was required. Each main video frame had the resized overlay placed in the upper-left corner, with 10 pixels away from the top and left margins. Using **cv2.CAP_PROP_POS_FRAMES**, the video playback was looped back to the start if the talking video reached the end of its frames. This made sure the overlay played continuously for the whole main video.



```
# Overlay talking video on the top left corner
success_talking, talking_frame = talking_video.read()
if not success_talking:
    talking_video.set(cv2.CAP_PROP_POS_FRAMES, 0) # Loop talking video continuously once ended
    success_talking, talking_frame = talking_video.read()

# Resize the talking frame and place it in the top left corner of the main frame
talking_frame_resized = cv2.resize(talking_frame, (resize_width, resize_height)) # Resize overlay
x_offset, y_offset = 10, 10 # Place overlay at top left corner
main_frame[y_offset:y_offset + resize_height, x_offset:x_offset + resize_width] = talking_frame_resized
```

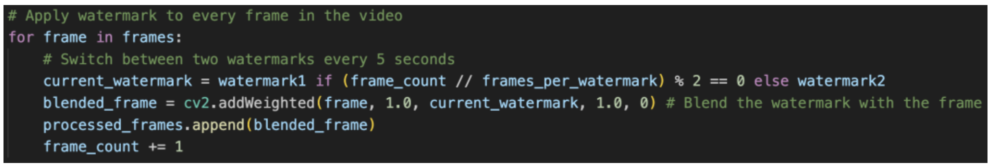
The recognised faces in each frame of the main video were blurred before the resized talking video was overlaid. All the altered frames were appended in a list called **processed_frames**, to which these processed frames were inserted. Following the completion of the changes, the list of processed frames was either returned combined into a final output video. The video processing loop iterated over every frame in the main video.



```
processed_frames = [] # List to store processed frames with blurred faces and overlay

# Process each frame in the main video
for frame_idx in range(total_frames):
    main_frame = main_video_frames[frame_idx]
    gray_frame = cv2.cvtColor(main_frame, cv2.COLOR_BGR2GRAY) # Convert to grayscale for face detection
    faces = face_cascade.detectMultiScale(gray_frame, scaleFactor=1.3, minNeighbors=5) # Detect faces

    # Blur detected faces
    for (x, y, w, h) in faces:
        face_roi = main_frame[y:y + h, x:x + w] # Region of Interest (ROI) where the face is
        blurred_face = cv2.GaussianBlur(face_roi, (35, 35), 0) # Apply Gaussian Blur to the face
        main_frame[y:y + h, x:x + w] = blurred_face # Replace the original face with the blurred one

    # Overlay talking video on the top left corner
    success_talking, talking_frame = talking_video.read()
    if not success_talking:
        talking_video.set(cv2.CAP_PROP_POS_FRAMES, 0) # Loop talking video continuously once ended
        success_talking, talking_frame = talking_video.read()

    # Resize the talking frame and place it in the top left corner of the main frame
    talking_frame_resized = cv2.resize(talking_frame, (resize_width, resize_height)) # Resize overlay
    x_offset, y_offset = 10, 10 # Place overlay at top left corner
    main_frame[y_offset:y_offset + resize_height, x_offset:x_offset + resize_width] = talking_frame_resized

    processed_frames.append(main_frame)

talking_video.release()
return processed_frames
```

Watermarks:

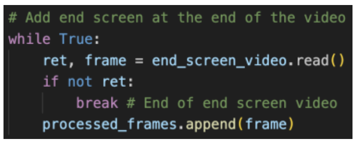
Moving on to the fourth question, we intend to implement two different watermarks every 5 seconds throughout the whole video. This is accomplished by calculating the current time in the video using the frame count divided by the number of frames per second. Based on such, an if-else statement is used to perform toggling between the two watermarks, making sure they change every five seconds. The selected watermark is blended with each frame using OpenCV's `cv2.addWeighted` function, and the processed frame is stored in a list for further use.



```
# Apply watermark to every frame in the video
for frame in frames:
    # Switch between two watermarks every 5 seconds
    current_watermark = watermark1 if (frame_count // frames_per_watermark) % 2 == 0 else watermark2
    blended_frame = cv2.addWeighted(frame, 1.0, current_watermark, 1.0, 0) # Blend the watermark with the frame
    processed_frames.append(blended_frame)
    frame_count += 1
```

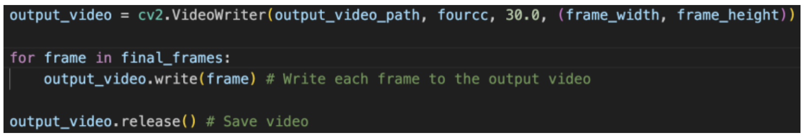
End Screen:

After the watermarking is done, we move to the last question and that is adding end screen video. A while loop that reads frames from the end screen video file handles this. The process continues until no more frames can be read (indicated by a False return value), in which case the loop breaks. Each successfully read frame is otherwise appended to the list of processed frames.



```
# Add end screen at the end of the video
while True:
    ret, frame = end_screen_video.read()
    if not ret:
        break # End of end screen video
    processed_frames.append(frame)
```

Lastly, the processed frames (including brightness adjustment, blurred faces, overlayed talking video, water marked, and end screen) are written to a single output video file. Moreover, to ensure effective management of resources, each video file has been properly closed.



```
output_video = cv2.VideoWriter(output_video_path, fourcc, 30.0, (frame_width, frame_height))

for frame in final_frames:
    output_video.write(frame) # Write each frame to the output video

output_video.release() # Save video
```

2. Result and Discussion

Increase brightness for nighttime videos:

After processing, only two nighttime videos were detected: singapore.mp4 and traffic.mp4. The comparisons before and after processing were shown in the table below:

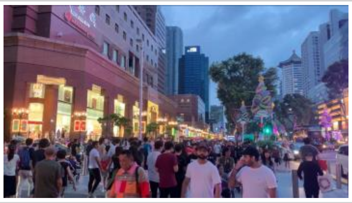
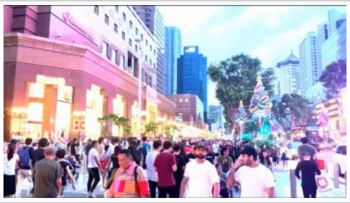
singapore.mp4	
Before	**After**
	

Table 1. Comparison of singapore.mp4 after increasing brightness

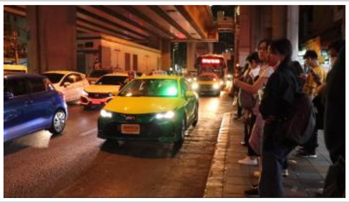
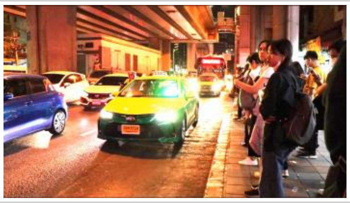
traffic.mp4	
Before	**After**
	

Table 2. Comparison of traffic.mp4 after increasing brightness

Faces Detection and Blurring:

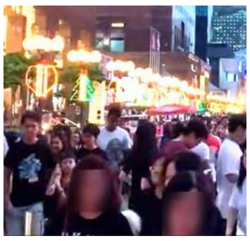
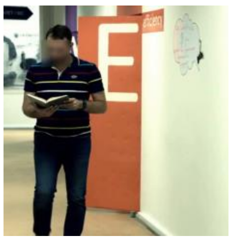
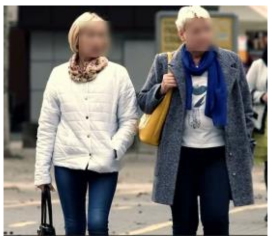
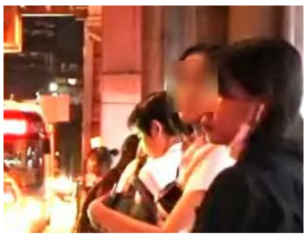
singapore.mp4	office.mp4	alley.mp4	traffic.mp4
			

Table 3. Output of face detection and blurring

Overlaying Talking Video:

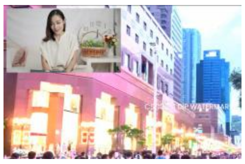
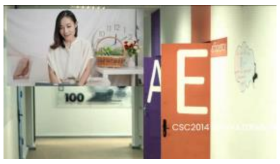
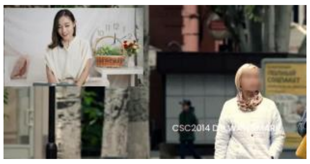
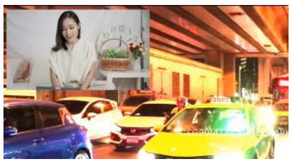
singapore.mp4	office.mp4	alley.mp4	traffic.mp4
			

Table 4. Output of overlaying talking video

Watermark:

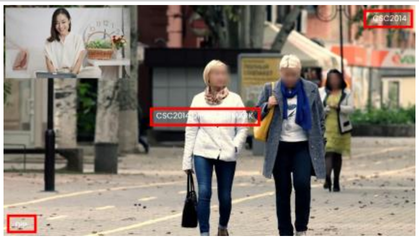
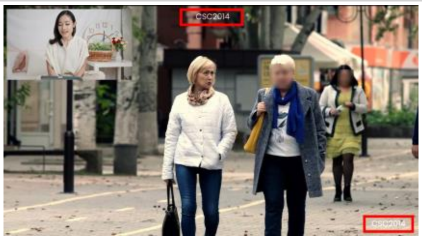
First Watermark	Second watermark
	

Table 5. Output of both watermarks added in alley.mp4

As shown in the output above, first watermark and second watermark (labelled in red box) alternate every 5 seconds throughout the duration of the video, same goes to office.mp4, singapore.mp4 and traffic.mp4.

End Screen:

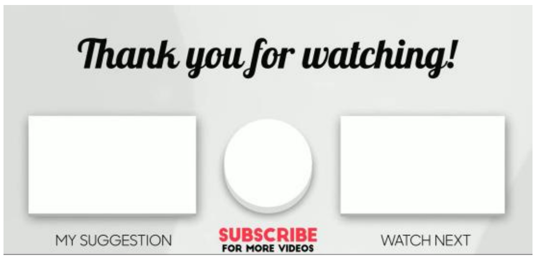


Figure 1. Output of end screen video concatenated to the end of video

The end screen video is successfully added to the end of all four videos (singapore.mp4, office.mp4, alley.mp4, traffic.mp4).

Task B

1. Proposed Approach

The proposed approach for paragraph extraction involves first identifying and extracting columns, which are stored separately. Then, each extracted column is analysed to determine if it meets the criteria for a paragraph. Valid paragraphs and non-paragraph content are stored separately.

The process starts by identifying columns in the image. This is done by converting the image into a binary format, where pixel values are either 0 or 255.

```python
def binarize_image(self):
    '''Convert image to binary'''
    _, self.binary_image = cv2.threshold(self.image, self.white_threshold, 255, cv2.THRESH_BINARY)
    return self.binary_image
```

Next, white vertical columns in the binary image are identified and stored in an array by analysing the vertical pixel intensity sums, where high values indicate regions with mostly white pixels.

```python
def find_white_col(self, hist_proj=False, threshold=0.95):
    '''Identify white columns based on vertical projections'''
    vertical_projection = np.sum(self.binary_image, axis=0)
    peak_threshold = threshold * np.max(vertical_projection)
    self.white_col = np.where(vertical_projection > peak_threshold)[0]

    # Plot the histogram projection if required
    if hist_proj:
        self.plot_hist_proj(vertical_projection, peak_threshold)
```

The start and end points of each column are identified by checking the gaps between consecutive white column indices. Columns that are wider than the predefined minimum column width are considered valid and stored.

```python
def find_col(self):
    '''Identify start and end of each column & filter valid regions'''
    start = None
    for i in range(1, len(self.white_col)):
        if self.white_col[i] - self.white_col[i - 1] != 1: # Detect column boundaries.
```

```
            if start is None:
                start = self.white_col[i - 1]
            if (self.white_col[i] - start) > self.min_col_width: # Filters valid regions.
                self.column_start_end.append((start, self.white_col[i]))
            start = None  # Reset start
```

After extracting the columns and saving them in “Columns” folder, the program identifies rows containing text by checking for non-white pixels.

```
def find_rows(self):
    '''Identify rows containing text by checking pixel intensity'''
    self.rows = [row for row in range(self.nrow) if any(pixel_value < self.white_threshold for pixel_value in self.binary_image[row, :])]
```

Rows are then grouped into paragraphs based on the gaps between consecutive rows. If a gap between rows exceeds a defined threshold, it indicates the end of a paragraph.

```
def find_paragraphs(self):
    '''Identify start and end points of paragraphs based on row gaps'''
    start = None
    for i in range(1, len(self.rows)):
        # Check if the rows are consecutive (no gap)
        if self.rows[i] - self.rows[i-1] != 1:
            # If the gap is larger than the threshold, consider it as the end of the paragraph
            if start is not None and self.rows[i] - self.rows[i - 1] > self.gap_threshold:
                end = self.rows[i - 1]                          # Last non-white row before the gap
                self.paragraph_start_end.append((start, end))   # Store paragraph range
                start = self.rows[i]                            # Start a new paragraph after the gap

        # If there is no gap, continue the current paragraph
        else:
            if start is None:
                start = self.rows[i-1]

    # Handle the last paragraph, from the last non-white row to the end of the image
    if start is not None:
        last_non_white_row = self.rows[-1]
        end = last_non_white_row
        while end < self.nrow and all(pixel_value >= self.white_threshold for pixel_value in self.binary_image[end, :]):
            end += 1

        self.paragraph_start_end.append((start, end))
```

After extracting the paragraphs into the “*Paragraphs*” folder, each one is validated to ensure it contains enough rows and columns and has intermediate white lines as gaps. Paragraphs that do not meet these criteria are moved to the “*Not Paragraphs*” folder.

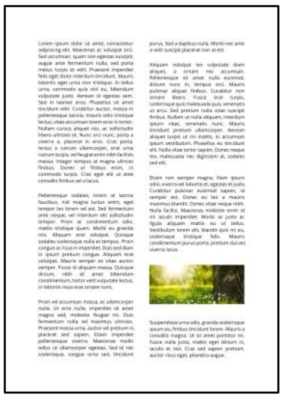
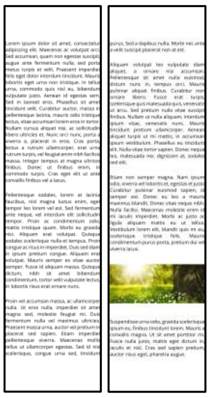
```
def is_paragraph(self, white_threshold=250, line_gap_threshold=1, row_threshold=3, col_threshold=5):
    '''Verify if the input image meets paragraph requirements'''
    # Binarize the image
    _, binary_image = cv2.threshold(self.gray_image, white_threshold, 255, cv2.THRESH_BINARY_INV)

    # Compute row and column densities
    row_density = np.sum(binary_image, axis=1) > 0
    col_density = np.sum(binary_image, axis=0) > 0

    # Count non-empty rows and columns
    num_rows = np.sum(row_density)
    num_cols = np.sum(col_density)

    # Check for intermediate white lines
    white_line_indices = np.where(~row_density)[0]  # Rows with no text
    line_gaps = np.diff(white_line_indices)  # Gaps between white lines
    has_intermediate_white_lines = np.any(line_gaps >= line_gap_threshold)

    # Final conditions: must meet row and column thresholds and have intermediate white lines
    return num_rows >= row_threshold and num_cols >= col_threshold and has_intermediate_white_lines
```

2. Result and Discussion

The final output is saved in the "*Paragraphs*" folder, while column images extracted during processing are stored in the "*Columns*" folder. The "*Not Paragraphs*" folder contains images that do not meet the criteria for paragraphs (e.g. tables and photos).

The naming convention for images follows a structured format. It starts with the base name of the original image, followed by an underscore and C*x*, where *x* represents the column number. For paragraphs extracted from a column, an additional underscore and P*x* are appended, where *x* indicates the paragraph number.

For example, processing 007.png is as follows:

Input	**Extracted Columns**: C1 and C2
	

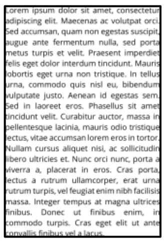
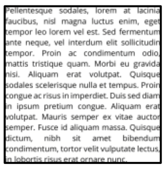
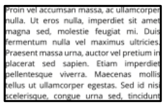
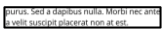
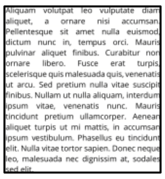
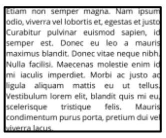
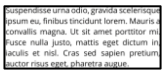
Final Output:		
Paragraphs from C1	Paragraphs from C2	Non-Paragraph Content
 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Maecenas ac volutpat orci. Sed accumsan, quam non egestas suscipit, augue ante fermentum nulla, sed porta metus turpis et velit. Praesent imperdiet felis eget dolor interdum tincidunt. Mauris lobortis eget urna non tristique. In tellus urna, commodo quis nisl eu, bibendum vulputate justo. Aenean id egestas sem. Sed in laoreet eros. Phasellus sit amet tincidunt velit. Curabitur auctor, massa in pellentesque lacinia, mauris odio tristique lectus, vitae accumsan lorem eros in tortor. Nullam cursus aliquet nisi, ac sollicitudin libero ultricies et. Nunc orci nunc, porta a viverra a, placerat in eros. Cras porta, lectus a rutrum ullamcorper, erat urna rutrum turpis, vel feugiat enim nibh facilisis massa. Integer tempus at magna ultrices finibus. Donec ut finibus enim, in commodo turpis. Cras eget elit ut ante convallis finibus vel a lacus.  Pellentesque sodales, lorem at lacinia faucibus, nisl magna luctus enim, eget tempor leo lorem vel est. Sed fermentum ante neque, vel interdum elit sollicitudin tempor. Proin ac condimentum odio, mattis tristique quam. Morbi eu gravida nisi. Aliquam erat volutpat. Quisque sodales scelerisque nulla et tempus. Proin congue ac risus in imperdiet. Duis sed diam in ipsum pretium congue. Aliquam erat volutpat. Mauris semper ex vitae auctor semper. Fusce id aliquam massa. Quisque dictum, nibh sit amet bibendum condimentum, tortor velit vulputate lectus, in lobortis risus erat ornare nunc.  Proin vel accumsan massa, ac ullamcorper nulla. Ut eros nulla, imperdiet sit amet magna sed, molestie feugiat mi. Duis fermentum nulla vel maximus ultricies. Praesent massa urna, auctor vel pretium in placerat sed sapien. Etiam imperdiet pellentesque viverra. Maecenas mollis tellus ut ullamcorper egestas. Sed id nisi scelerisque, congue urna sed, tincidunt	 purus. Sed a dapibus nulla. Morbi nec ante a velit suscipit placerat non at est.  Aliquam volutpat leo vulputate diam aliquet, a ornare nisi accumsan. Pellentesque sit amet nulla euismod, dictum nunc in, tempus orci. Mauris pulvinar aliquet finibus. Curabitur non ornare libero. Fusce erat turpis, scelerisque quis malesuada quis, venenatis ut arcu. Sed pretium nulla vitae suscipit finibus. Nullam ut nulla aliquam, interdum ipsum vitae, venenatis nunc. Mauris tincidunt pretium ullamcorper. Aenean aliquet turpis ut mi mattis, in accumsan ipsum vestibulum. Phasellus eu tincidunt elit. Nulla vitae tortor sapien. Donec neque leo, malesuada nec dignissim at, sodales sed elit.  Etiam non semper magna. Nam ipsum odio, viverra vel lobortis et, egestas et justo. Curabitur pulvinar euismod sapien, id semper est. Donec eu leo a mauris maximus blandit. Donec vitae neque nibh. Nulla facilisi. Maecenas molestie enim id mi iaculis imperdiet. Morbi ac justo ac ligula aliquam mattis eu ut tellus. Vestibulum lorem elit, blandit quis mi eu, scelerisque tristique felis. Mauris condimentum purus porta, pretium dui vel viverra lacus.  Suspendisse urna odio, gravida scelerisque ipsum eu, finibus tincidunt lorem. Mauris a convallis magna. Ut sit amet porttitor mi. Fusce nulla justo, mattis eget dictum in, iaculis et nisl. Cras sed sapien pretium, auctor risus eget, pharetra augue.	

Table 6. Result of 007.png after processed