EPFL

SCHOOL OF COMPUTER AND COMMUNICATION SCIENCES

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Computer Vision Laboratory
Unseen Spacecraft Pose Estimation

Baseline solution by implementing a machine learning
framework with target models included

Bachelor's Thesis in Computer Science

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I hereby confirm that I am the sole author of the written work here enclosed and that I have compiled it in my own words. Parts excepted are corrections of form and content by the advisors.

Lausanne, Switzerland, 05.01.24   Jérémy Chaverot

Acknowledgments

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Abstract

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1 Introduction

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1.1 Problem statement

1.1.1 The settings

1.1.2 The goal

1.2 The work environment: Scitas Izar

```bash
#!/bin/bash
#SBATCH --chdir /scratch/izar/jchavero
#SBATCH --partition=gpu
#SBATCH --qos=gpu_free
#SBATCH --gres=gpu:2
#SBATCH --nodes=1
#SBATCH --ntasks-per-node=1
#SBATCH --cpus-per-task=1
#SBATCH --mem 16G

echo STARTING AT `date`

echo "Loading modules"
module load gcc openmpi py-torch py-torchvision cuda

echo "Launching the Virtual Environment"
source ~/opt/izar1/venv-gcc/bin/activate

echo "Navigating to the directory and executing the task"
cd ~/Gen6D
python eval.py --cfg configs/gen6d_pretrain.yaml --object_name
    spacecraft/hubble

echo FINISHED AT `date`
```

Listing 1.1: Bash script `execute.sh` to run a machine learning model on Scitas Izar EPFL. While the overall structure remains consistent, this script is specific to Gen6D's architecture, further discussed later.

2 Scientific papers review

2.1 Some ML models

2.2 Gen6D: Pros and cons

3 Gen6D: formal description

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abstract base classes (ABC) each and every abstract method

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Rely more on the 3D model (for now only the size) and the segmented images, would optimize for symmetric and irregular shaped spacecrafts

6.3 Robustness to occlusion

7 Conclusion

Limitations Acknowledgments My personal contribution

Abbreviations

Appendix

```python
"""
Author:       Jeremy Chaverot
Date:         November 29, 2023
Description: Create the files val.txt, train.txt and test.txt
    according to a test percentage
"""

import os
import sys
import random


if __name__ == "__main__":

  # Check if the correct number of arguments is provided
    if len(sys.argv) != 3:
        print("Usage: python format.py <object_name> <
    test_percentage>")
        sys.exit(1)

    object = sys.argv[1]
    test_percentage = float(sys.argv[2])

    if (test_percentage < 0 or 1 < test_percentage):
        print("Wrong value for the variable <test_percentage>.
    Should be between 0 and 1 included.")
        sys.exit(1)

    # Get a list of all files in the folder
    all_files = os.listdir(f'data/SpaceCraft/{object}/images')

    # Filter the list to include only image files and exclude
    MacOS temporary files
    image_files = [file for file in all_files if file.lower().
    endswith(('.jpg')) and not file.startswith('._')]

    # Get the number of images in the folder
    num_images = len(image_files)

    # Iterate through each image and apply the transformation
```

```
36    with open(f'data/SpaceCraft/{object}/train.txt', 'w') as
      train, open(f'data/SpaceCraft/{object}/test.txt', 'w') as
      test:
37        for image_file in image_files:
38            rand = random.random()
39            image_path = 'SpaceCraft/hubble/images/' + image_file
40            if (rand < test_percentage):
41                test.write(image_path + '\n')
42            else: train.write(image_path + '\n')
43
44    print(f"Done splitting {num_images} images in train.txt and
      test.txt")
```

Listing A.1: Python script `format.py` to randomly generate the training set and the test set based on a specified probability. Should be run from Gen6D's root folder.

```
1  """
2  Author:      Jeremy Chaverot
3  Date:        November 20, 2023
4  Description: Transform every images of a folder into jpg format.
5  """
6
7  import os
8  import sys
9  from PIL import Image
10
11
12 def transform_image(image_path):
13     img = Image.open(image_path)
14     new_image_path = image_path.split('.')[0] + '.jpg'
15     img.save(new_image_path)
16
17
18 if __name__ == "__main__":
19
20   # Check if the correct number of arguments is provided
21     if len(sys.argv) != 2:
22         print("Usage: python to_jpg.py </path/to/your/images>")
23         sys.exit(1)
24
25     folder_path = sys.argv[1]
26
27     # Get a list of all files in the folder
28     all_files = os.listdir(folder_path)
29
30     # Filter the list to include only image files and exclude
       MacOS temporary files
31     image_files = [file for file in all_files if file.lower().
       endswith(('.png', '.jpg', '.jpeg', '.gif', '.bmp')) and not
```

```
        file.startswith('._')]
32
33   # Get the number of images in the folder
34   num_images = len(image_files)
35
36   # Iterate through each image and apply the transformation
37   for image_file in image_files:
38       image_path = os.path.join(folder_path, image_file)
39       transform_image(image_path)
40       os.remove(image_path)
41
42   print(f"Number of images transformed into .jpg: {num_images}"
        )
```

Listing A.2: Python script `to_jpg.py` to transform every images of a specified folder into jpg format.

```
1   """
2   Author:      Jeremy Chaverot
3   Date:        November 20, 2023
4   Description: Transform a txt file with quaternions and the
        translation vector into multiple npy files containing the
        rotation matrix augmented with the translation vector.
5   """
6
7   import numpy as np
8   import sys
9   import os
10
11
12  def quaternion_to_matrix(Q, translation):
13      """
14          Covert a quaternion and translation into a full three-
        dimensional augmented rotation matrix.
15
16          Input
17          :param Q: A 4 element array representing the quaternion (
        qw, qx, qy, qz).
18          :param translation: A 3 element array representing the
        translation (x, y, z).
19
20          Output
21          :return: A 3x4 element matrix representing the full 3D
        rotation matrix with
22                   translation. This rotation matrix converts a
        point in the local
23                   reference frame to a point in the global
        reference frame.
24      """
```

```python
    # Extract the values from Q
    qw = Q[0]
    qx = Q[1]
    qy = Q[2]
    qz = Q[3]

    # Extract the values from the translation vector
    x = translation[0]
    y = translation[1]
    z = translation[2]

    # First row of the rotation matrix
    r00 = 2 * (qw * qw + qx * qx) - 1
    r01 = 2 * (qx * qy - qw * qz)
    r02 = 2 * (qx * qz + qw * qy)

    # Second row of the rotation matrix
    r10 = 2 * (qx * qy + qw * qz)
    r11 = 2 * (qw * qw + qy * qy) - 1
    r12 = 2 * (qy * qz - qw * qx)

    # Third row of the rotation matrix
    r20 = 2 * (qx * qz - qw * qy)
    r21 = 2 * (qy * qz + qw * qx)
    r22 = 2 * (qw * qw + qz * qz) - 1

    # 3x3 rotation matrix
    rot_matrix_augm = np.array([[r00, r01, r02, x],
                                [r10, r11, r12, y],
                                [r20, r21, r22, z]])

    return rot_matrix_augm


if __name__ == "__main__":

    # Check if the correct number of arguments is provided
    if len(sys.argv) != 3:
        print("Usage: python quaternion_to_matrix.py </path/to/
    your/text/file> </path/to/the/pose/folder>")
        sys.exit(1)

    file_path = sys.argv[1]
    pose_folder_path = sys.argv[2]
    file_content = None

    try:
        with open(file_path, 'r') as file:
```

```
73              file_content = file.read()
74      except FileNotFoundError:
75          print(f"The file {file_path} was not found.")
76          sys.exit(1)
77      except Exception as e:
78          print(f"An error occurred: {e}")
79          sys.exit(1)
80
81      poses = file_content.split('\n')[:-1]
82
83      # Iterate through each pose and apply the transformation
84      for pose in poses:
85          image_id, obj_id, qw, qx, qy, qz, x, y, z = pose.split(',
        ')
86          Q = np.array([qw, qx, qy, qz], dtype=np.float32)
87          translation = np.array([x, y, z], dtype=np.float32)
88          matrix = quaternion_to_matrix(Q, translation)
89          np.save(pose_folder_path + '/pose' + str(int(image_id)),
        matrix)
90
91      print(f"Number of transformation processed: {len(poses)}")
```

Listing A.3: Python script `quaternion_to_matrix.py` to transform a txt file with quaternions and the translation vector into multiple npy files containing the rotation matrix augmented with the translation vector.

```
1  """
2  Author:      Jeremy Chaverot
3  Date:        December 10, 2023
4  Description: Invert the masks from a given folder.
5  """
6
7  import cv2
8  import os
9  import sys
10
11
12 def inverse_masks_in_folder(folder_path):
13   # Iterate through the list of files at the specified path
14     for filename in os.listdir(folder_path):
15       # Filter to include only png image files and exclude MacOS
       temporary files
16         if filename.endswith(".png") and not filename.startswith(
        '._'):
17             mask_path = os.path.join(folder_path, filename)
18             try:
19                 # Read the mask image
20                 mask = cv2.imread(mask_path, cv2.IMREAD_GRAYSCALE
        )
```

```python
21                    if mask is None:
22                        print(f"Failed to read image: {mask_path}")
23                        continue
24
25                    # Invert the mask
26                    inverted_mask = cv2.bitwise_not(mask)
27
28                    # Save the inverted mask with a temporary name
29                    temp_path = os.path.join(folder_path, "temp_" +
       filename)
30                    cv2.imwrite(temp_path, inverted_mask)
31
32                    # Delete the original mask
33                    os.remove(mask_path)
34
35                    # Rename the inverted mask to the original
       filename
36                    os.rename(temp_path, mask_path)
37                    print(f"Inverted and replaced mask for: {
       mask_path}")
38                except Exception as e:
39                    print(f"Error processing {mask_path}: {e}")
40
41
42 if __name__ == "__main__":
43
44    # Check if the correct number of arguments is provided
45     if len(sys.argv) != 2:
46         print("Usage: python invert_mask.py <folder_path>")
47         sys.exit(1)
48
49     folder_path = sys.argv[1]
50     inverse_masks_in_folder(folder_path)
```

Listing A.4: Python script `invert_mask.py` to invert the masks from a specified folder. We aim to have a black object set against a white background.

```python
1  """
2  Author:      Jeremy Chaverot
3  Date:        January 01, 2024
4  Description: Resize the images from a given folder.
5  """
6
7  import os
8  import sys
9  from PIL import Image
10
11
12 def resize_images(folder_path, resize_factor):
```

```python
13    # Iterate through the list of files at the specified path
14    for filename in os.listdir(folder_path):
15      # Filter to include only png image files and exclude MacOS
      temporary files
16        if filename.endswith(".png") and not filename.startswith(
      '._'):
17            img_path = os.path.join(folder_path, filename)
18            with Image.open(img_path) as img:
19                # Calculate new size
20                new_size = tuple([int(dim / resize_factor) for
      dim in img.size])
21                # Resize the image
22                resized_img = img.resize(new_size, Image.
      ANTIALIAS)
23                # Save the resized image with a different name
      temporarily
24                temp_path = os.path.join(folder_path, "temp_" +
      filename)
25                resized_img.save(temp_path)
26
27            # Delete the original image
28            os.remove(img_path)
29
30            # Rename the resized image to the original filename
31            os.rename(temp_path, img_path)
32
33
34 if __name__ == "__main__":
35
36    # Check if the correct number of arguments is provided
37    if len(sys.argv) != 3:
38        print("Usage: resize.py <folder_path> <resize_factor>")
39        sys.exit(1)
40
41    folder_path = sys.argv[1]
42    factor = int(sys.argv[2])
43
44    resize_images(folder_path, factor)
```

Listing A.5: Python script `resize.py` designed to alter an image's size with respect to a specified resize factor.