Contents

1 ex5/README

```
muaz.abdeen

files in the ZIP:
1- Ex5_results.pdf
2- IMPR_Ex5_Deep_Style_Image_Prior_2021_2022.ipynb
3- ./Deblurring/im1_k85_w0.001
   ./Deblurring/im2_k75_w0.1
   ./Deblurring/Yann LeCun
4- ./Colorization/im1_s900_w1
   ./Colorization/im2_s900_w1
   ./Colorization/Alan Turing
5- ./Inpainting/paint_im1_s1000_w0.2
   ./Inpainting/paint_im2_s1000_w0.2
   ./Inpainting/fei_fei_li

Each one of the 3-5 sub-folders contains 4 files:
1- inverted_latent.npz
2- original_image.png
3- original_degraded_image.png
4- final_inverted_image.png
```

67829 – Image Processing – Fall 2021

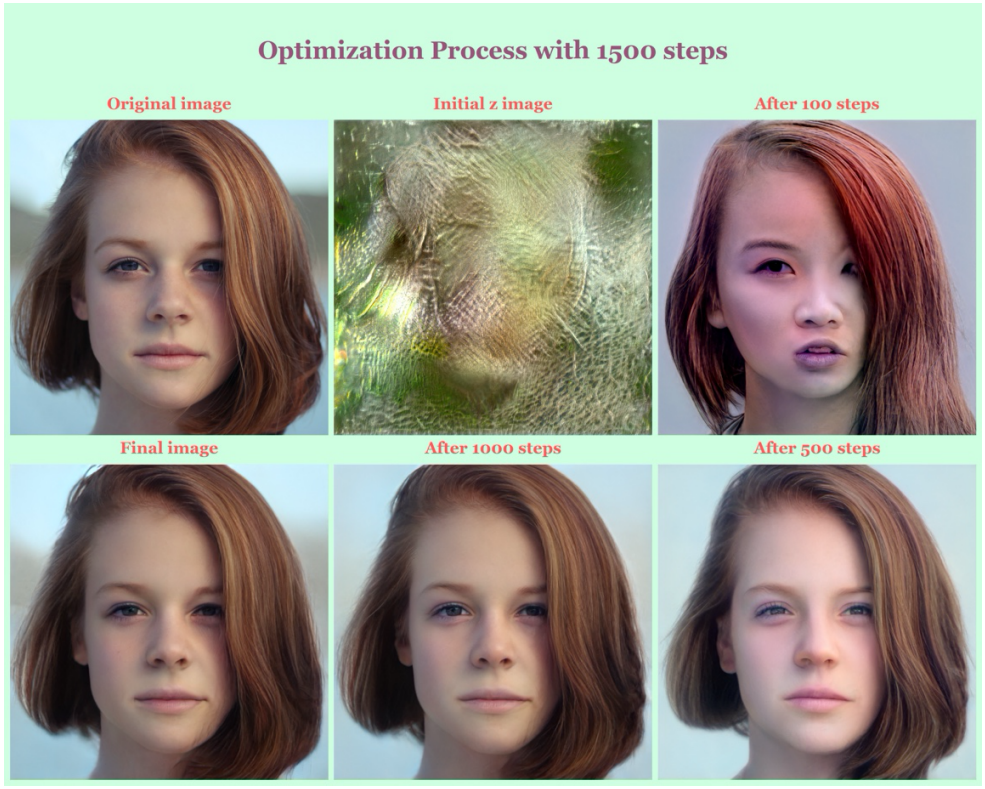
Exercise (5)

Muaz Abdeen – 300575297

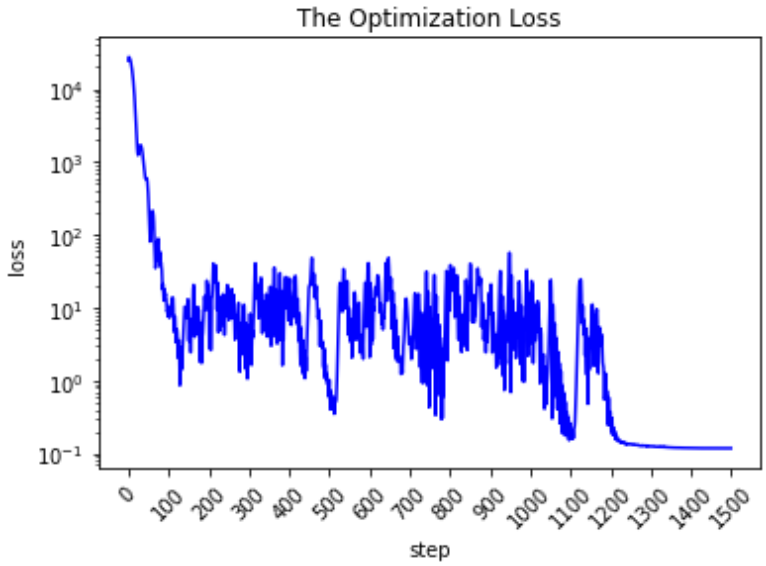
Image Alignment:

Before	After
	

The Optimization Progressions:



A Plot of the Optimization Loss:



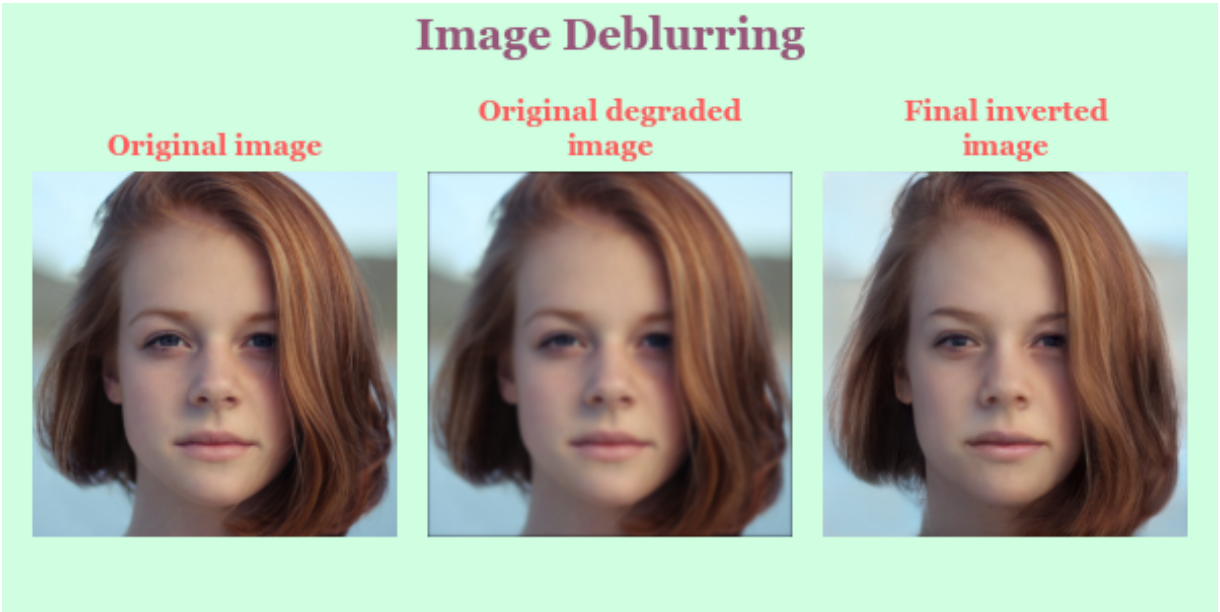
The effect of *latent_dist_reg_weight* and *num_steps* on the results:

I noticed that given a *num_steps*, increasing the *latent_dist_reg_weight* made the optimization process generates good results earlier, that is, closer images to the original one will start to show earlier.

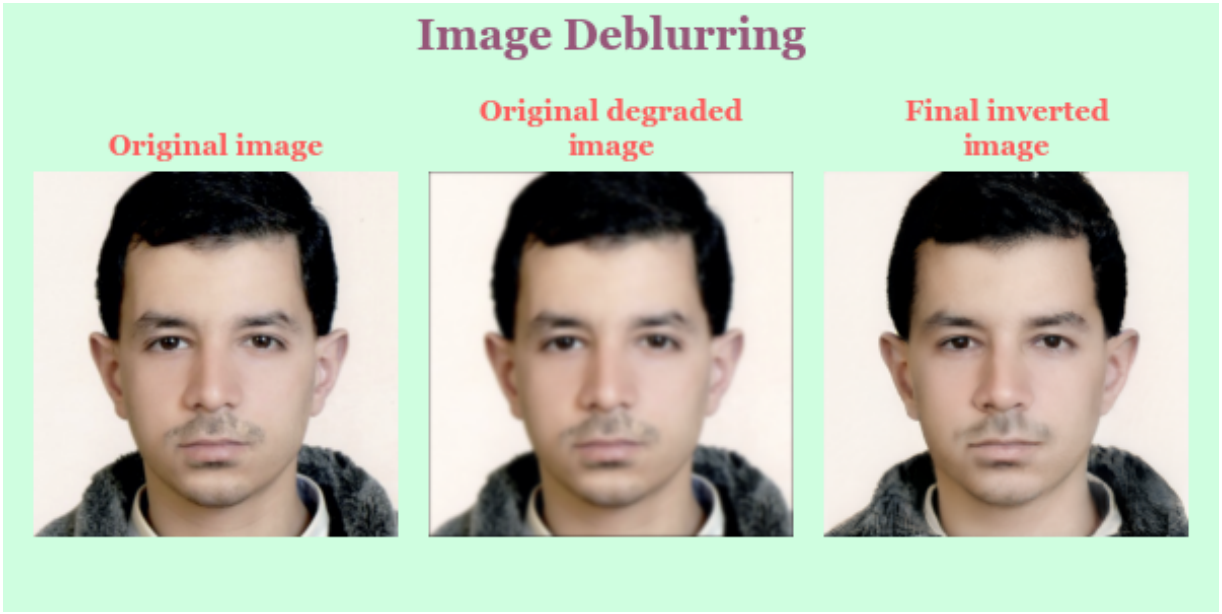
Also, increasing the *num_steps* will give us a better result, to some extent, that is after some threshold, there will be almost no improvement.

Image Deblurring:

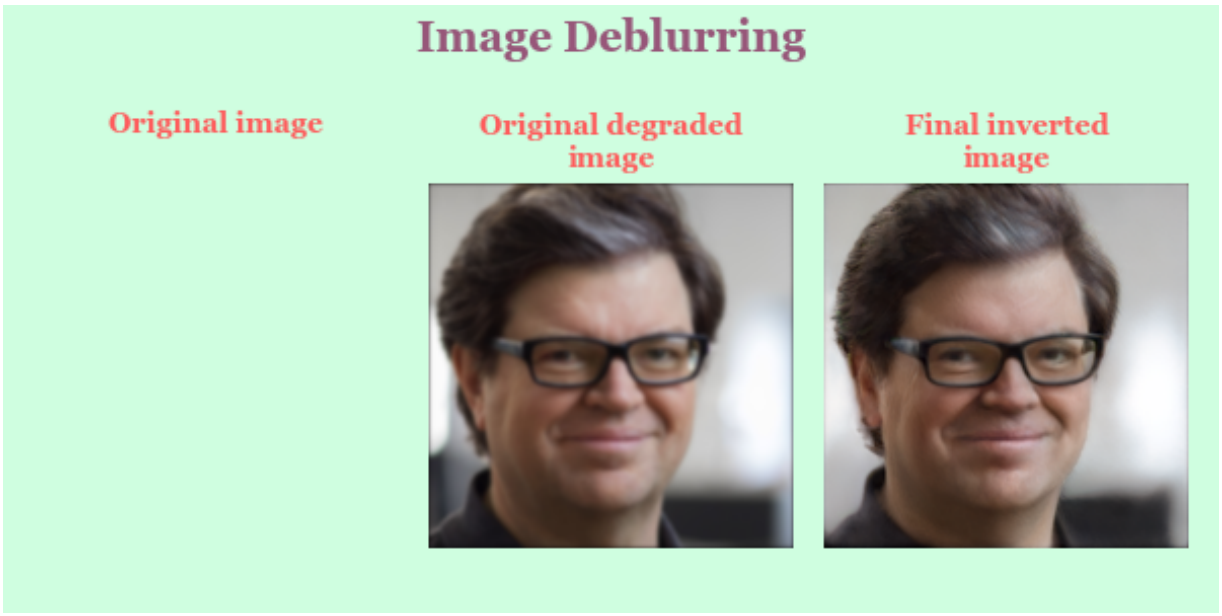
First image



Second image (my personal picture):



Yann LeCun



Solution Discussion:

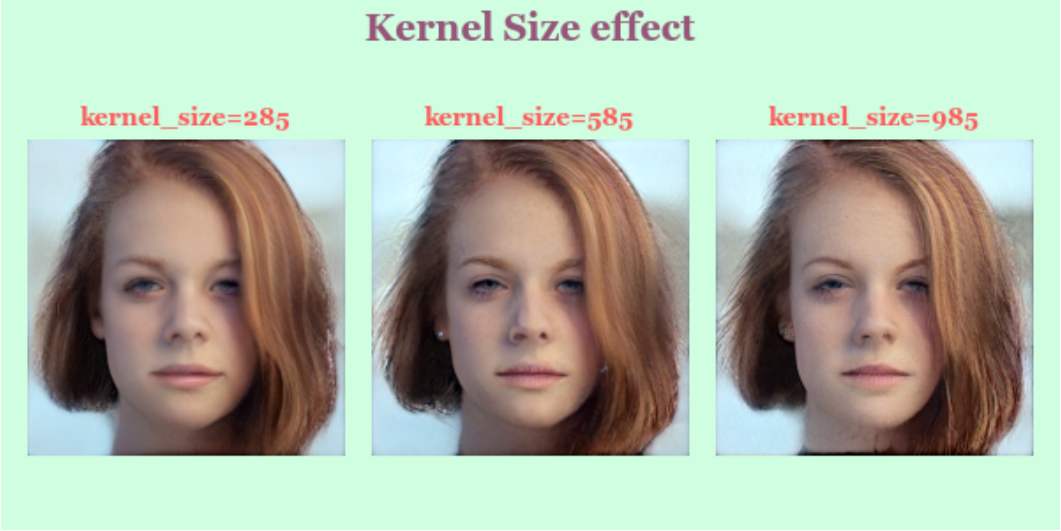
Hyperparameters: $kernel\_size = 85$, $num\_steps = 1000$,

$$latent\_dist\_reg\_weight = 0.001$$

I applied the degrading function on the generated image, that is, I blurred the generated image $G(z)$, before computing the loss.

I defined two functions to blur the image: *gaussian_kernel* and *blur_spatial*, the first one generates a gaussian kernel according to the size passed to it, the second blurs the image passed to it by convolve it with this kernel twice, horizontally and vertically, as we have learned in the class. I made some changes to the API; I passed the kernel to the *run_latent_optimization* function and use it to blur the generated image before computing the loss.

The kernel size affected the results; the smaller the kernel the less blurred the image, and we get a result like the one of undegraded image. Conversely, if we choose a big kernel, that is, more blurred image, the result will be less clear, many fine details will be lost, it will be somehow noisy.

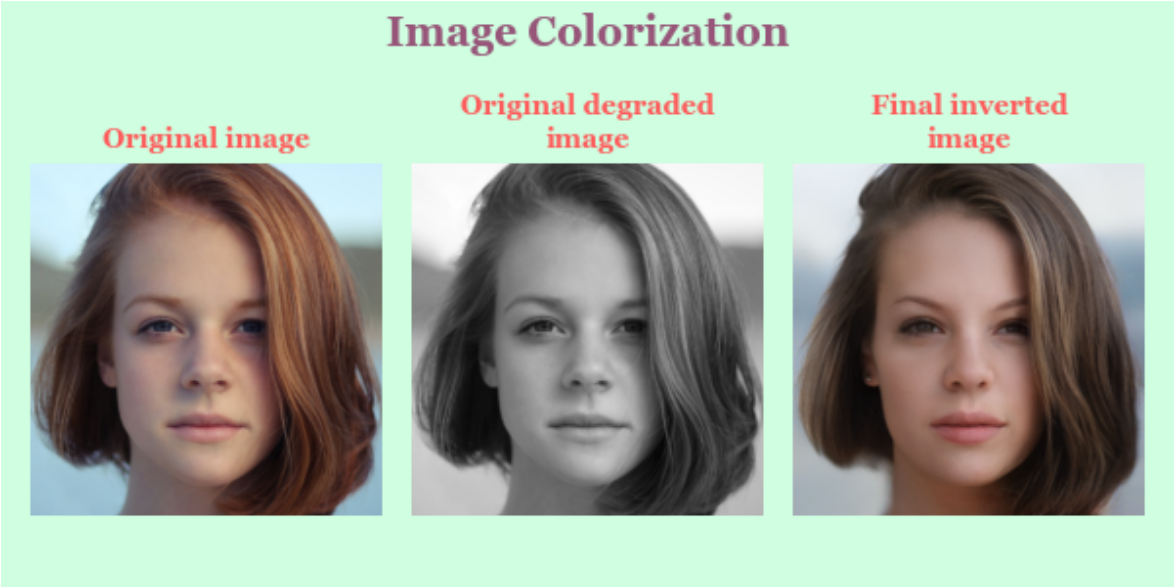


I noticed that after at most 1000 steps, the loss almost converged, and the result did not improve more. Also, and the bigger the *latent_dist_reg_weight* the closer the constructed image to the mean of natural images, and vice versa.

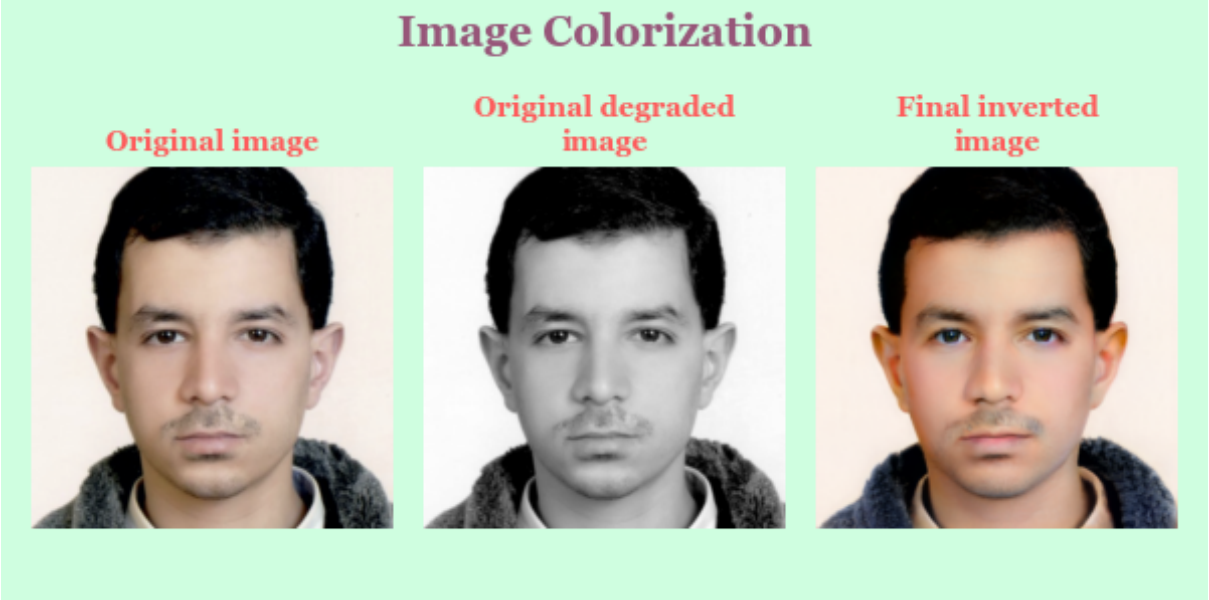
For example, a more blurred image (*kernel_size* = 195) with large *latent_dist_reg_weight* (= 0.2) will give a clear result but deviated relatively from the original one. In the other hand, small *latent_dist_reg_weight* (= 0.01) will give closer result to the original image, but less clear.

Image Colorization:

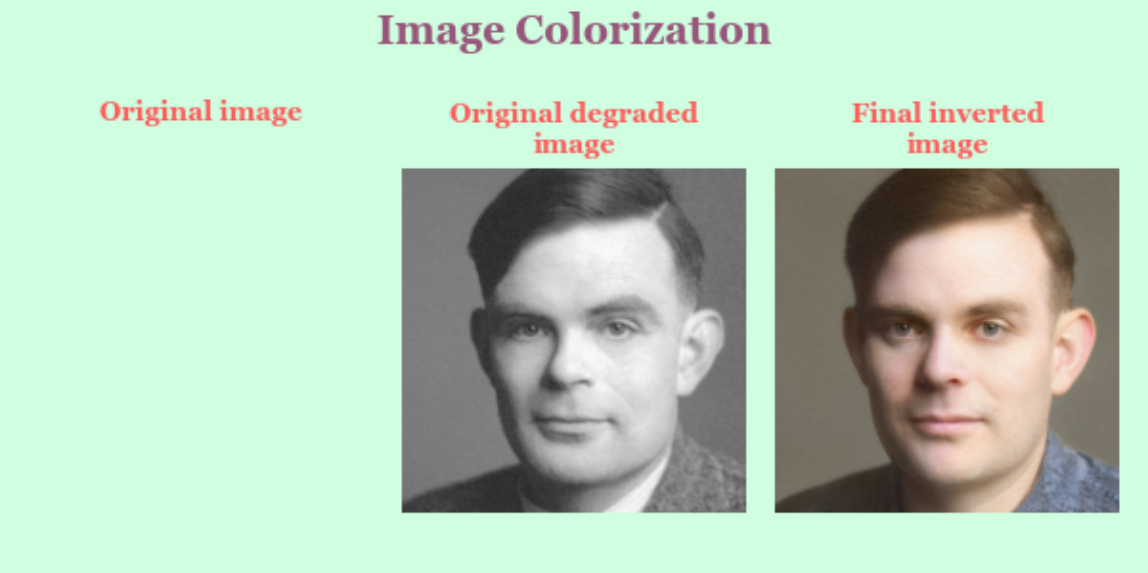
First image



Second image (my personal picture)



Alan Turing



Solution Discussion:

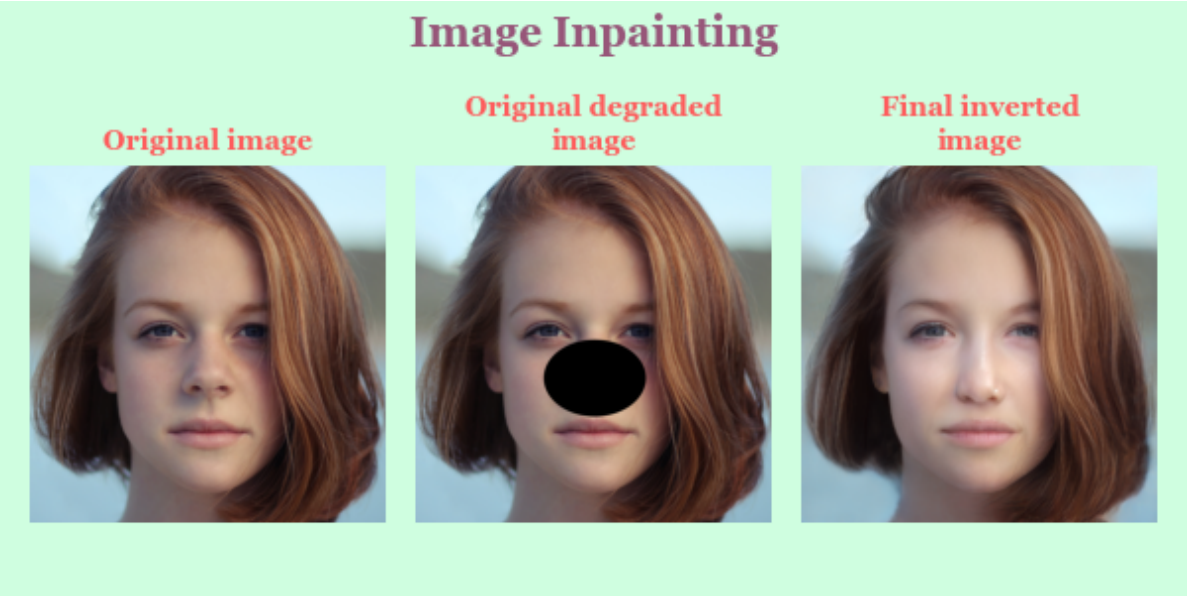
Hyperparameters: $num\_steps = 1000$, $latent\_dist\_reg\_weight = 1$

I applied the degrading function on the generated image, that is, I converted the generated image $G(z)$ to a grayscale one, before computing the loss. I used the `Grayscale` function from `torchvision.transforms` module to convert an image to grayscale mode.

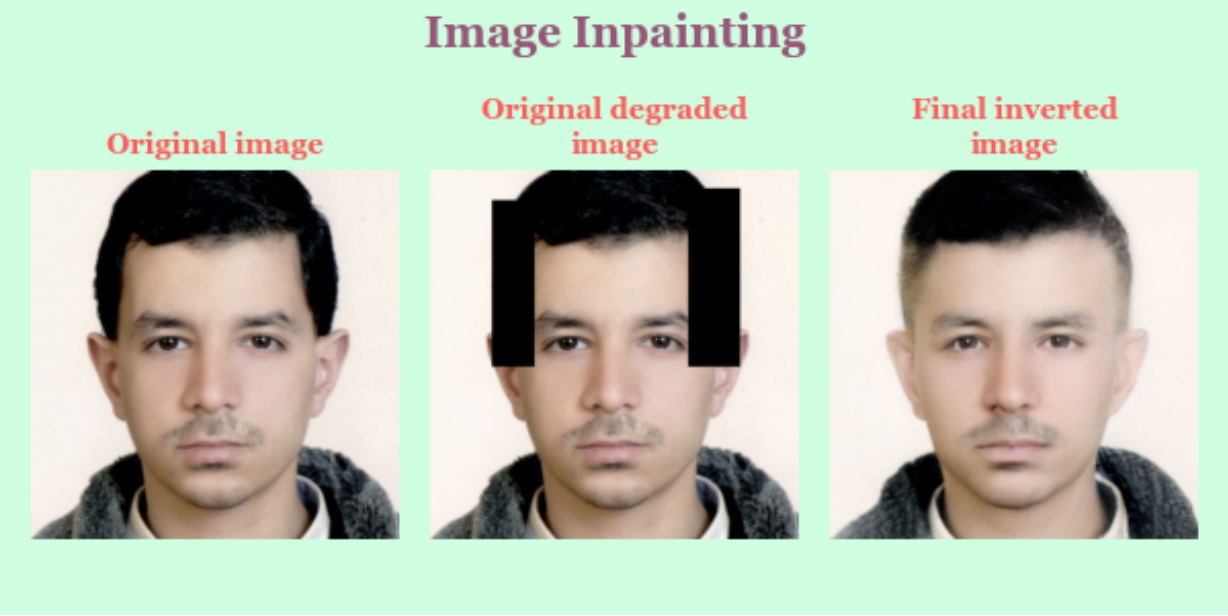
I noticed that a big $latent\_dist\_reg\_weight$ gives more realistic colorization, but with a little deviated image from the original one, I think the bigger the $latent\_dist\_reg\_weight$ the closer the constructed image to the mean of natural images, and vice versa. Moreover, after at most 1000 steps, the loss almost converged, and the result did not improve more.

Image Inpainting:

First image

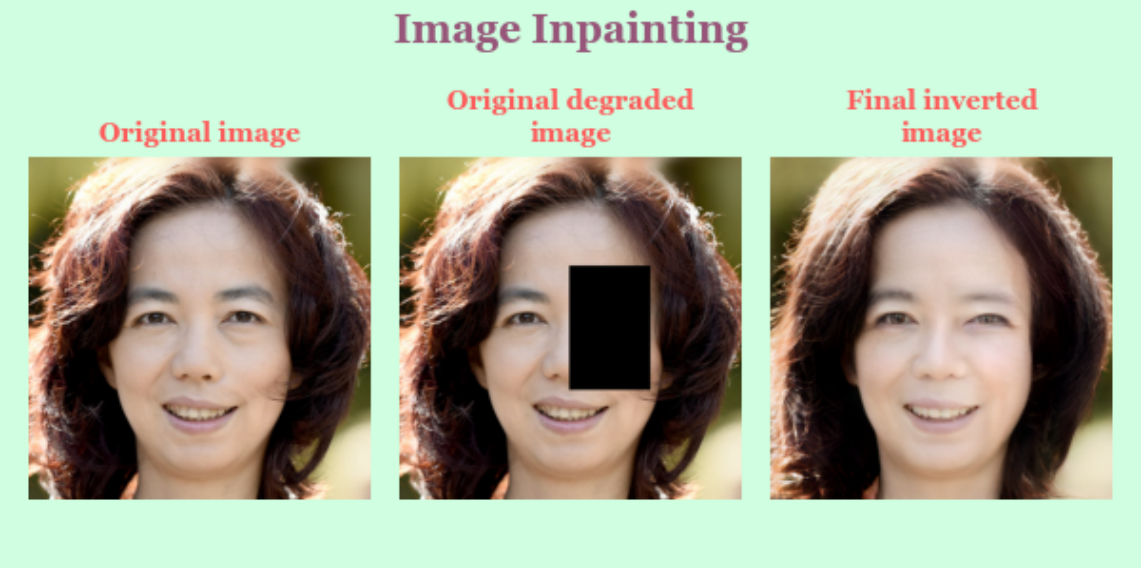


Second image (my personal picture)



* Here I think the difference in the sideburns is because the shape of the mask. *

Fei-Fei Li



Solution Discussion:

Hyperparameters: $num\_steps = 1000$, $latent\_dist\_reg\_weight = 0.2$

I applied the degrading function on the generated image, that is, I multiplied the generated image $G(z)$ with the mask, before computing the loss.

I made some changes to the API, I passed the mask path name ($mask\_fname$) to the $invert\_image$ function, then inside this function I read the mask file, converted it to a tensor, and multiply it with original image, then passed it to the $run\_latent\_optimization$ function and use it to multiply the generated image with it before computing the loss.

I noticed that after at most 1000 steps, the loss almost converged. The optimal $latent\_dist\_reg\_weight$ range for inpainting was between 0.1 – 0.3.

As the previous reconstruction problems, num_steps has improved the result up to 1000 steps, and the bigger the $latent\_dist\_reg\_weight$ the closer the constructed image to the mean of natural images, and vice versa.

3 ex5/IMPR Ex5 Deep Style Image Prior 2021 2022.ipynb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            "Requirement already satisfied: traitlets>=4.2 in /usr/local/lib/python3.7/dist-packages (from ipython->mediapy)
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        "from google.colab import drive\n",
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          "# It is advised that you save the files to google drive as restarting Colab will erase them.\n",
          "!python \"$ROOT_PATH/align_faces/align_faces.py\" '/content/gdrive/MyDrive/IMPRO_EX5_2021/input_images/my_face.png'
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        "    # ******************                  NEED TO ADD DEGRADATION FUNCTIONS               ******************\n",
        "    # ********************************************************************************************************\n",
        "\n",
        "    # I. GAUSSIAN_BLUR_DEGRADATION\n",
        "\n",
        "    def gaussian_kernel(filter_size):\n",
        "      basis = filter_vec = torch.tensor([0.5, 0.5], dtype=torch.float32).reshape(1, 1, 2)\n",
        "      for i in range(filter_size - 2):\n",
        "          filter_vec = conv1d(filter_vec, basis, padding=1)\n",
        "      return filter_vec\n",
        "      # return filter_vec / torch.sum(filter_vec)\n",
        "\n",
        "\n",
        "    def blur_spatial(im, filter_vec):\n",
        "        filter_vec = filter_vec.repeat(3, 1, 1, 1)\n",
        "        padding = filter_vec.shape[3]//2\n",
        "        blurred_im = conv2d(im, filter_vec , padding=[0,padding], groups=3)\n",
        "        blurred_im = conv2d(blurred_im, filter_vec.permute(0, 1, 3, 2), padding=[padding,0], groups=3)\n",
        "\n",
        "        return blurred_im\n",
        "\n",
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        "\n",
        "    # III. INPAINTING_DEGRADATION"
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        "def run_latent_optimization(outdir,\n",
```

```
"    degradation_mode,\n",
"    G,\n",
"    imgs_to_disply_dict,\n",
"    target: torch.Tensor, # [C,H,W] and dynamic range [0,255], W & H must match G output resolution\n",
"    *,\n",
"    num_steps                 = 1000,\n",
"    w_avg_samples             = 10000,\n",
"    initial_learning_rate     = 0.1,\n",
"    initial_noise_factor      = 0.05,\n",
"    lr_rampdown_length        = 0.25,\n",
"    lr_rampup_length          = 0.05,\n",
"    noise_ramp_length         = 0.75,\n",
"    regularize_noise_weight   = 1e5,\n",
"    latent_dist_reg_weight    = 0.001,\n",
"    blur_kernel               = None,\n",
"    mask                      = None,\n",
"    device: torch.device\n",
"    \n",
"):\n",
"    assert target.shape == (G.img_channels, G.img_resolution, G.img_resolution)\n",
"\n",
"    if degradation_mode == GAUSSIAN_BLUR_DEGRADATION:\n",
"      assert blur_kernel is not None\n",
"    if degradation_mode == INPAINTING_DEGRADATION:\n",
"      assert mask is not None\n",
"\n",
"    G = copy.deepcopy(G).eval().requires_grad_(False).to(device) # type: ignore\n",
"  \n",
"    # Compute w stats.\n",
"    print(f'Computing W midpoint and stddev using {w_avg_samples} samples...')\n",
"    z_samples = np.random.RandomState(123).randn(w_avg_samples, G.z_dim)\n",
"    w_samples = G.mapping(torch.from_numpy(z_samples).to(device), None)  # [N, L, C]\n",
"    w_samples = w_samples.cpu().numpy().astype(np.float32)\n",
"    w_avg = np.mean(w_samples, axis=0, keepdims=True)      # [1, 18, C]\n",
"    w_avg_original = torch.from_numpy(w_avg).to(device).float()\n",
"    w_std = (np.sum((w_samples - w_avg) ** 2) / w_avg_samples) ** 0.5\n",
"\n",
"    # Setup noise inputs.\n",
"    noise_bufs = { name: buf for (name, buf) in G.synthesis.named_buffers() if 'noise_const' in name }\n",
"\n",
"    # Load VGG16 feature detector.\n",
"    url = 'https://nvlabs-fi-cdn.nvidia.com/stylegan2-ada-pytorch/pretrained/metrics/vgg16.pt'\n",
"    with dnnlib.util.open_url(url) as f:\n",
"        vgg16 = torch.jit.load(f).eval().to(device)\n",
"    \n",
"    # Features for target image.\n",
"    target_images = target.unsqueeze(0).to(device).to(torch.float32)\n",
"\n",
"    if target_images.shape[2] > 256:\n",
"        target_images = F.interpolate(target_images, size=(256, 256), mode='area')\n",
"    target_features = vgg16(target_images, resize_images=False, return_lpips=True)\n",
"\n",
"    w_opt = torch.tensor(w_avg, dtype=torch.float32, device=device, requires_grad=True) \n",
"    w_out = torch.zeros([num_steps] + list(w_opt.shape[1:]), dtype=torch.float32, device=device)\n",
"    loss_out = torch.zeros([num_steps], dtype=torch.float32, device=device)\n",
"    optimizer = torch.optim.Adam([w_opt] + list(noise_bufs.values()), betas=(0.9, 0.999), lr=initial_learning_rate)\n",
"    \n",
"    # Init noise.\n",
"    for buf in noise_bufs.values():\n",
"        buf[:] = torch.randn_like(buf)\n",
"        buf.requires_grad = True\n",
"\n",
"    for step in range(num_steps):\n",
"        # Learning rate schedule.\n",
"        t = step / num_steps\n",
"        w_noise_scale = w_std * initial_noise_factor * max(0.0, 1.0 - t / noise_ramp_length) ** 2\n",
"        lr_ramp = min(1.0, (1.0 - t) / lr_rampdown_length)\n",
"        lr_ramp = 0.5 - 0.5 * np.cos(lr_ramp * np.pi)\n",
```

```
"        lr_ramp = lr_ramp * min(1.0, t / lr_rampup_length)\n",
"        lr = initial_learning_rate * lr_ramp\n",
"        for param_group in optimizer.param_groups:\n",
"            param_group['lr'] = lr\n",
"\n",
"        # Synth image from opt_w\n",
"        w_noise = torch.randn_like(w_opt) * w_noise_scale\n",
"        ws = w_opt + w_noise\n",
"        synth_images = G.synthesis(ws, noise_mode='const')\n",
"        \n",
"        # Prep to save synth image\n",
"        synth_image_save = (synth_images + 1) * (255/2)\n",
"        synth_image_save = synth_image_save.permute(0, 2, 3, 1).clamp(0, 255).to(torch.uint8)[0].cpu().numpy()\n",
"    \n",
"    \n",
"        # ************************************************************************************************************\
"        # ******************                    NEED TO FILL IN THE FOLLOWING CODE              ******************\
"        # ************************************************************************************************************\
"        if  degradation_mode == INPAINTING_DEGRADATION:\n",
"          assert mask.shape == synth_images.shape\n",
"          synth_images *= mask\n",
"        elif degradation_mode == GRAYSCALE_DEGRADATION:\n",
"          synth_images = Grayscale(num_output_channels=3)(synth_images)\n",
"        elif degradation_mode == GAUSSIAN_BLUR_DEGRADATION:\n",
"          synth_images = blur_spatial(synth_images, blur_kernel)\n",
"\n",
"        # ************************************************************************************************************\
"        # ******************                                END CODE TO ADD SECTION               ******************\
"        # ************************************************************************************************************\
"         \n",
"        \n",
"        # Prep to save and show images\n",
"        synth_image_degraded_save = (synth_images + 1) * (255/2)\n",
"        synth_image_degraded_save = synth_image_degraded_save.permute(0, 2, 3, 1).clamp(0, 255).to(torch.uint8)[0].
"        \n",
"        if step % 20 == 0:\n",
"          imgs_to_disply_dict[\"Generated Image\"]=synth_image_save\n",
"          imgs_to_disply_dict[\"Generated Degraded Image\"]=synth_image_degraded_save\n",
"          clear_output(wait=True)\n",
"          media.show_images(imgs_to_disply_dict,height=256)\n",
"        if step % 100 == 0:\n",
"          PIL.Image.fromarray(synth_image_save, 'RGB').save(f'{outdir}/intermidiate_%d_not_degraded.png'%step)\n",
"          PIL.Image.fromarray(synth_image_degraded_save, 'RGB').save(f'{outdir}/intermidiate_%d_degraded.png'%step)
"\n",
"\n",
"        # Noise regularization.\n",
"        reg_loss = 0.0\n",
"        for v in noise_bufs.values():\n",
"            noise = v[None,None,:,:] # must be [1,1,H,W] for F.avg_pool2d()\n",
"            while True:\n",
"                reg_loss += (noise*torch.roll(noise, shifts=1, dims=3)).mean()**2\n",
"                reg_loss += (noise*torch.roll(noise, shifts=1, dims=2)).mean()**2\n",
"                if noise.shape[2] <= 8:\n",
"                    break\n",
"                noise = F.avg_pool2d(noise, kernel_size=2)\n",
"\n",
"        # Downsample image to 256x256 if it's larger than that. VGG was built for 224x224 images.\n",
"        synth_images = (synth_images + 1) * (255/2)\n",
"        if synth_images.shape[2] > 256:\n",
"            synth_images = F.interpolate(synth_images, size=(256, 256), mode='area')\n",
"\n",
"        # Features for synth images.\n",
"        synth_features = vgg16(synth_images, resize_images=False, return_lpips=True)\n",
"        \n",
"        # Compute loss\n",
"        percep_loss = (target_features - synth_features).square().sum()\n",
"        latent_dist_reg = F.l1_loss(w_avg_original, w_opt)\n",
"        loss = percep_loss + reg_loss * regularize_noise_weight  + latent_dist_reg_weight * latent_dist_reg\n",
```

```
        "\n",
        "\n",
        "        # Step\n",
        "        optimizer.zero_grad(set_to_none=True)\n",
        "        loss.backward()\n",
        "        optimizer.step()\n",
        "\n",
        "        print(f'step {step+1:>4d}/{num_steps}: percep_loss {percep_loss:<4.2f} latent_dist_reg {latent_dist_reg:<4.
        "\n",
        "        # Save inverted latent for each optimization step.\n",
        "        w_out[step] = w_opt.detach()[0]\n",
        "        loss_out[step] = loss\n",
        "\n",
        "        # Normalize noise.\n",
        "        with torch.no_grad():\n",
        "            for buf in noise_bufs.values():\n",
        "                buf -= buf.mean()\n",
        "                buf *= buf.square().mean().rsqrt()\n",
        "    \n",
        "    return w_out, loss_out"
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        "                 outdir,\n",
        "                 mask_fname = None,\n",
        "                 seed=303,\n",
        "                 num_steps=1000,\n",
        "                 latent_dist_reg_weight=0.001):\n",
        "    np.random.seed(seed)\n",
        "    torch.manual_seed(seed)\n",
        "\n",
        "    # Load networks.\n",
        "    print('Loading networks from \"%s\"...' % CHECKPOINTS_PATH)\n",
        "    device = torch.device('cuda')\n",
        "    with dnnlib.util.open_url(CHECKPOINTS_PATH) as fp:\n",
        "        networks = legacy.load_network_pkl(fp)\n",
        "        G = networks['G_ema'].requires_grad_(False).to(device)\n",
        "        \n",
        "\n",
        "    # Load target image.\n",
        "    if not os.path.exists(outdir):\n",
        "      os.makedirs(outdir)\n",
        "    target_pil = PIL.Image.open(target_fname).convert('RGB')\n",
        "    w, h = target_pil.size\n",
        "    s = min(w, h)\n",
        "    target_pil = target_pil.crop(((w - s) // 2, (h - s) // 2, (w + s) // 2, (h + s) // 2))\n",
        "    target_pil = target_pil.resize((G.img_resolution, G.img_resolution), PIL.Image.LANCZOS)\n",
        "    target_uint8 = np.array(target_pil, dtype=np.uint8)\n",
        "    target = torch.tensor(target_uint8.transpose([2, 0, 1]), device=device), \n",
        "    target_images = target[0].unsqueeze(0).to(device).to(torch.float32)\n",
        "\n",
        "    # ************************************************************************************************\n",
        "    # ******************                    NEED TO FILL IN THE FOLLOWING CODE              ******************\n",
        "    # ************************************************************************************************\n",
        "    kernel = None\n",
        "    mask = None\n",
```

```
        "    if  degradation_mode == INPAINTING_DEGRADATION:\n",
        "      mask = PIL.Image.open(mask_fname).convert('RGB')\n",
        "      mask = torch.tensor(T.ToTensor()(mask), dtype=torch.float32, device=device).unsqueeze(0)\n",
        "      target_images *= mask\n",
        "    elif degradation_mode == GRAYSCALE_DEGRADATION:\n",
        "      target_images = Grayscale(num_output_channels=3)(target_images)\n",
        "    elif degradation_mode == GAUSSIAN_BLUR_DEGRADATION:\n",
        "      kernel = gaussian_kernel(85).to(device)\n",
        "      target_images = blur_spatial(target_images, kernel)\n",
        "      pass\n",
        "      \n",
        "    # ********************************************************************************************************\n",
        "    # ******************                              END CODE TO ADD SECTION                  ******************\n",
        "    # ********************************************************************************************************\n",
        "\n",
        "    #Save target image\n",
        "    target_to_save = target_images.permute(0, 2, 3, 1).clamp(0, 255).to(torch.uint8)[0].cpu().numpy()\n",
        "    PIL.Image.fromarray(target_to_save, 'RGB').save(f'{outdir}/original_degraded_image.png')\n",
        "    imgs_to_disply_dict = {\n",
        "        \"Original Image\":target_uint8,\n",
        "        \"Original Degraded Image\":target_to_save,\n",
        "              }\n",
        "\n",
        "    # Run latent optimization\n",
        "    print('Run latent optimization')\n",
        "    start_time = perf_counter()\n",
        "    optimization_steps, optimization_losses = run_latent_optimization(\n",
        "        outdir,\n",
        "        degradation_mode,\n",
        "        G,\n",
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        "        target_images[0],\n",
        "        num_steps=num_steps,\n",
        "        device=device,\n",
        "        latent_dist_reg_weight=latent_dist_reg_weight,\n",
        "        blur_kernel=kernel,\n",
        "        mask=mask\n",
        "    )\n",
        "\n",
        "    print (f'Elapsed: {(perf_counter()-start_time):.1f} s')\n",
        "    os.makedirs(outdir, exist_ok=True)\n",
        "\n",
        "    # Save final inverted image and latent vector.\n",
        "    inverted_latent = optimization_steps[-1]\n",
        "    synth_image = G.synthesis(inverted_latent.unsqueeze(0), noise_mode='const')\n",
        "    synth_image = (synth_image + 1) * (255/2)\n",
        "    synth_image = synth_image.permute(0, 2, 3, 1).clamp(0, 255).to(torch.uint8)[0].cpu().numpy()\n",
        "    PIL.Image.fromarray(synth_image, 'RGB').save(f'{outdir}/final_inverted_image.png')\n",
        "    np.savez(f'{outdir}/inverted_latent.npz', latent=inverted_latent.unsqueeze(0).cpu().numpy())\n",
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        "    return optimization_losses"
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        "    plt.plot(steps, loss.cpu().detach().numpy(), 'b-')\n",
        "    plt.xlabel('step')\n",
        "    plt.xticks(np.arange(0, len(loss) + 1, 100), rotation = (45), fontsize = 10)\n",
        "    plt.ylabel('loss')\n",
        "    plt.yscale('log')\n",
        "    plt.title('The Optimization Loss')\n",
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**********************************************
*** THIS FILE WAS TOO BIG AND WAS TRUNCATED ***
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4 ex5/unaligned images/Christopher Campbell.jpg

5 ex5/unaligned images/my face.png

6 ex5/Colorization/Alan Turing/alan turing grayscale.png

7 ex5/Colorization/Alan Turing/final inverted image.png

8 ex5/Colorization/Alan Turing/original degraded image.png

9 ex5/Colorization/im1 s900 w1/Christopher Campbell aligned.png

10 ex5/Colorization/im1 s900 w1/final inverted image.png

11 ex5/Colorization/im1 s900 w1/original degraded image.png

12 ex5/Colorization/im2 s900 w1/final inverted image.png

13 ex5/Colorization/im2 s900 w1/my face aligned.png

14 ex5/Colorization/im2 s900 w1/original degraded image.png

15 ex5/Deblurring/Yann LeCun/final inverted image.png

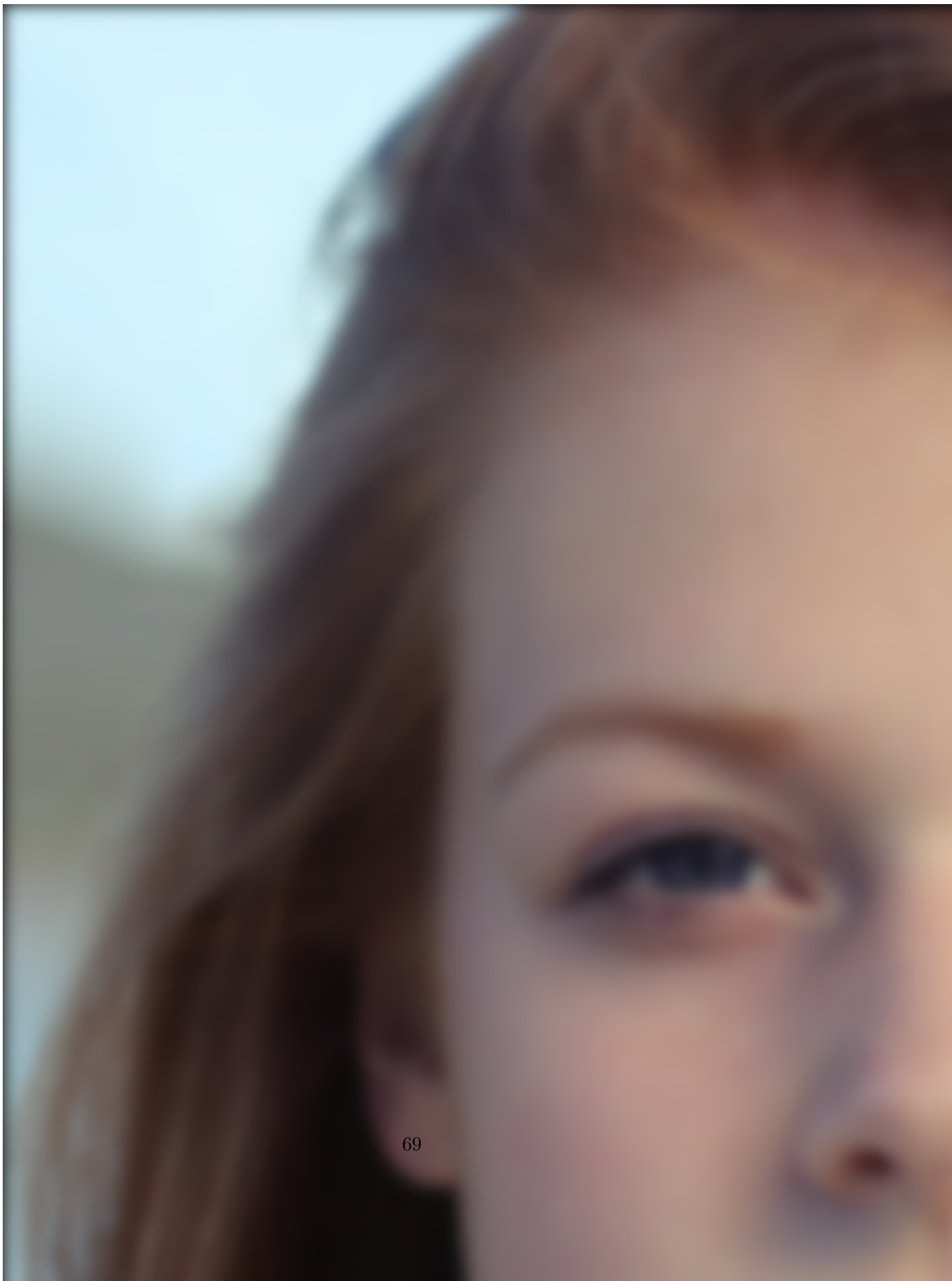
16 ex5/Deblurring/Yann LeCun/original degraded image.png

17 ex5/Deblurring/Yann LeCun/yann lecun blur.png

18 ex5/Deblurring/im1 k85 w0.001/Christopher Campbell aligned.png

19 ex5/Deblurring/im1 k85 w0.001/final inverted image.png

20 ex5/Deblurring/im1 k85 w0.001/original degraded image.png

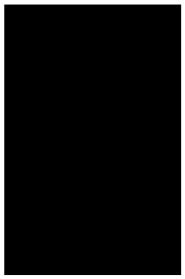


21 ex5/Deblurring/im2 k75 w0.1/final inverted image.png

22 ex5/Deblurring/im2 k75 w0.1/my face aligned.png

23 ex5/Deblurring/im2 k75 w0.1/original degraded image.png

24 ex5/Inpainting/fei fei li/fei fei li inpainting mask.png



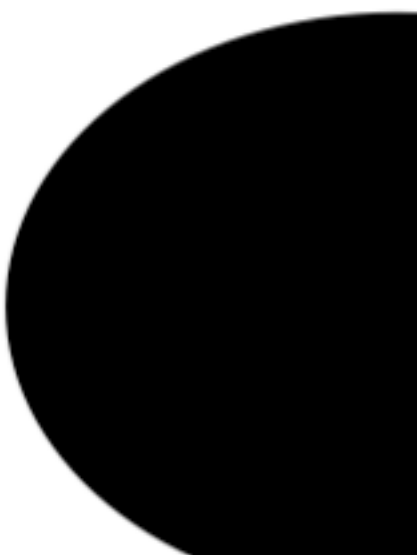
25 ex5/Inpainting/fei fei li/fei fei li original.png

26 ex5/Inpainting/fei fei li/final inverted image.png

27 ex5/Inpainting/fei fei li/original degraded image.png

28 ex5/Inpainting/paint im1 s1000 w0.2/Christopher Campbell aligned.png

29 ex5/Inpainting/paint im1 s1000 w0.2/Christopher Campbell mask.png



30 ex5/Inpainting/paint im1 s1000 w0.2/final inverted image.png

31 ex5/Inpainting/paint im1 s1000 w0.2/original degraded image.png

32 ex5/Inpainting/paint im2 s1000 w0.2/final inverted image.png

33 ex5/Inpainting/paint im2 s1000 w0.2/my face aligned.png

34 ex5/Inpainting/paint im2 s1000 w0.2/my face mask.png

35 ex5/Inpainting/paint im2 s1000 w0.2/original degraded image.png