

Light Field Messaging with Deep Photographic Steganography

Supplementary Material

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1. Additional Example Results

In this section, we show additional examples of original, embedded, and recovered images and messages. See Figures 1 and 2.

1.1. Video Examples

There are also several video examples. The attached videos are MPEG-4 files with H.264 encoding.

- **kayak_original.mp4** is an unmodified video.
- **kayak_embedded_lowVis_example.mp4** contains a message embedded using a network tuned for few visual artifacts.
- **kayak_embedded_lowBER_example.mp4** contains a message embedded using a network tuned for low BER (bit error rate).

Notice that there are minimal visible artifacts in both of the embedded videos.

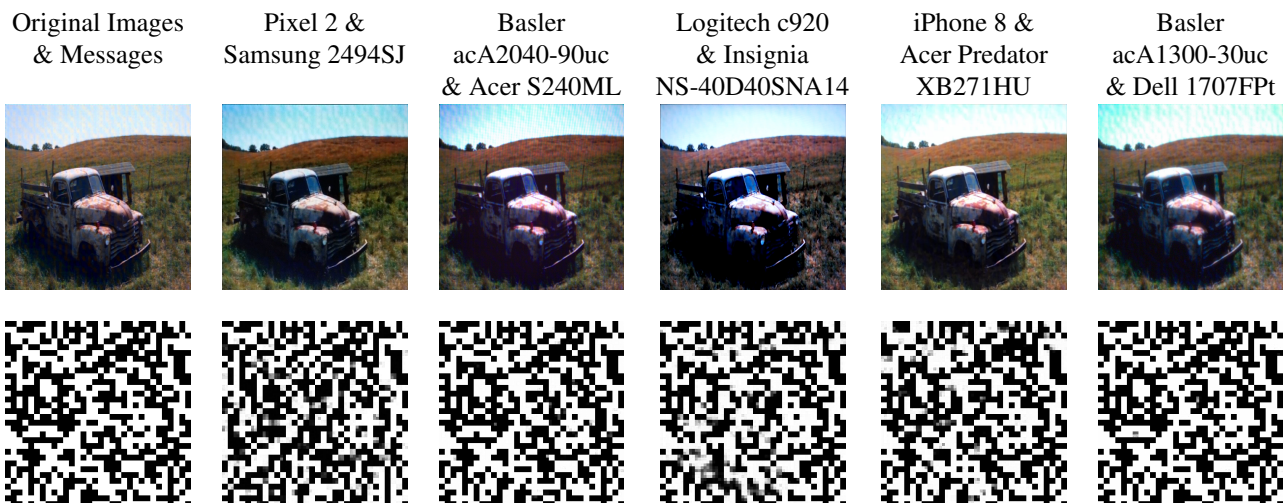


Figure 1. Examples of original and camera captured images, and camera-recovered messages. These images, messages, and camera-display hardware were used in the BER evaluations in the main paper.

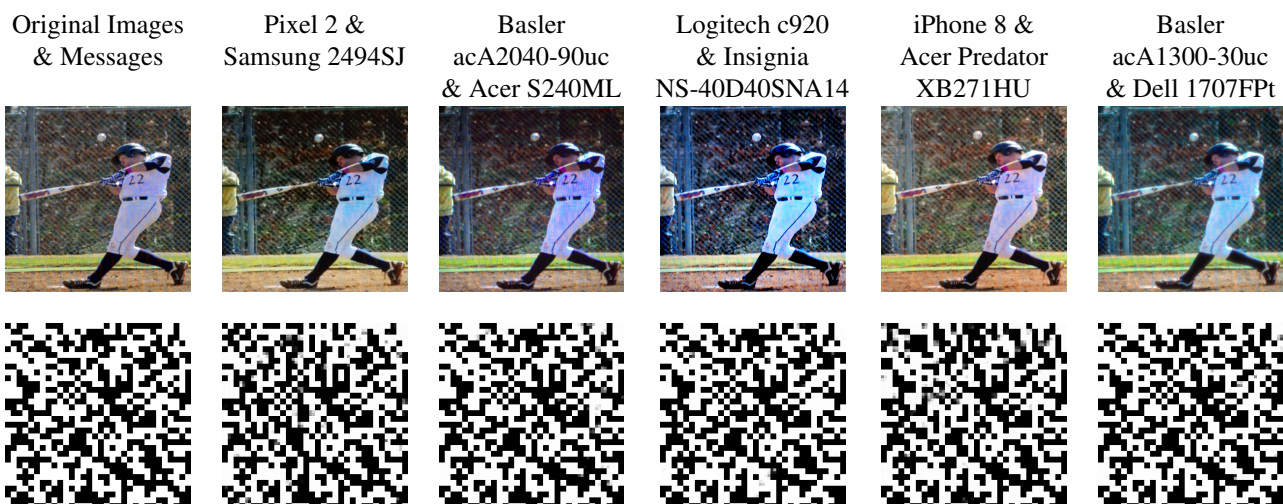


Figure 2. Additional examples of original and camera captured images, and camera-recovered messages. These images, messages, and camera-display hardware were used in the BER evaluations in the main paper.

2. Network Architecture Details

This section contains a detailed description of the network architectures of $E()$, $R()$, and $T()$. This is the output as generated with a Python script that interfaces with the PyTorch library. It can be used as a full description for replicating the exact architecture.

2.1. Embed Net $E()$

```
SiameseDenseNet(
  (denseImageUNet): SiameseDenseUNets(
    (initial): Sequential(
      (conv0): Conv2d (3, 16, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (norm0): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
      (relu0): LeakyReLU(0.01, inplace)
    )
    (encode_block0): _DenseBlock2D(
      (denselayer1): _DenseLayer2D(
        (norm.1): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
        (conv.1): Conv2d (16, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer2): _DenseLayer2D(
        (norm.1): BatchNorm2d(20, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
        (conv.1): Conv2d (20, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer3): _DenseLayer2D(
        (norm.1): BatchNorm2d(24, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
        (conv.1): Conv2d (24, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
    )
    (encode_trans0): _DownsampleTransition2D(
      (norm): BatchNorm2d(28, eps=1e-05, momentum=0.1, affine=True)
      (relu): LeakyReLU(0.01, inplace)
      (conv): Conv2d (28, 28, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))
    )
    (encode_block1): _DenseBlock2D(
      (denselayer1): _DenseLayer2D(
        (norm.1): BatchNorm2d(28, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
        (conv.1): Conv2d (28, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer2): _DenseLayer2D(
        (norm.1): BatchNorm2d(32, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
```

```

        (conv.1): Conv2d (32, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
    (denselayer3): _DenseLayer2D(
        (norm.1): BatchNorm2d(36, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
        (conv.1): Conv2d (36, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
)
(encode_trans1): _DownsampleTransition2D(
    (norm): BatchNorm2d(40, eps=1e-05, momentum=0.1, affine=True)
    (relu): LeakyReLU(0.01, inplace)
    (conv): Conv2d (40, 40, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))
)
(encode_block2): _DenseBlock2D(
    (denselayer1): _DenseLayer2D(
        (norm.1): BatchNorm2d(40, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
        (conv.1): Conv2d (40, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
    (denselayer2): _DenseLayer2D(
        (norm.1): BatchNorm2d(44, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
        (conv.1): Conv2d (44, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
    (denselayer3): _DenseLayer2D(
        (norm.1): BatchNorm2d(48, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
        (conv.1): Conv2d (48, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
)
(encode_trans2): _DownsampleTransition2D(
    (norm): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
    (relu): LeakyReLU(0.01, inplace)
    (conv): Conv2d (52, 52, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))
)
(bottom_block): Sequential(
    (conv0): Conv2d (52, 52, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (norm0): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
    (relu0): LeakyReLU(0.01, inplace)
)
(decode_trans0): _UpsampleTransition2D(

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(norm): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
(rel): LeakyReLU(0.01, inplace)
(deconv): ConvTranspose2d (52, 26, kernel_size=(2, 2), stride=(2, 2))
)
(decode_block0): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(78, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (78, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(82, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (82, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(86, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (86, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
)
(unpool0): Sequential(
  (conv0): Conv2d (90, 3, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (relu0): LeakyReLU(0.01, inplace)
  (pool0): ConvTranspose2d (3, 3, kernel_size=(4, 4), stride=(4, 4))
)
(decode_trans1): _UpsampleTransition2D(
  (norm): BatchNorm2d(90, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (deconv): ConvTranspose2d (90, 45, kernel_size=(2, 2), stride=(2, 2))
)
(decode_block1): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(85, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (85, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(89, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (89, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(

```

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        (norm.1): BatchNorm2d(93, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
        (conv.1): Conv2d (93, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
)
(unpool1): Sequential(
  (conv0): Conv2d (97, 3, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (relu0): LeakyReLU(0.01, inplace)
  (pool0): ConvTranspose2d (3, 3, kernel_size=(2, 2), stride=(2, 2))
)
(decode_trans2): _UpsampleTransition2D(
  (norm): BatchNorm2d(97, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (deconv): ConvTranspose2d (97, 48, kernel_size=(2, 2), stride=(2, 2))
)
(decode_block2): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(76, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (76, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(80, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (80, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(84, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (84, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
)
(unpool2): Sequential(
  (conv0): Conv2d (88, 3, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (relu0): LeakyReLU(0.01, inplace)
  (pool0): ConvTranspose2d (3, 3, kernel_size=(1, 1), stride=(1, 1))
)
(final_conv_1x1): Sequential(
  (conv0): ConvTranspose2d (6, 3, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
)
(thresh): Sequential(
  (0): Threshold (0.5, 0.0)
)
)
(denseMessageUNet): SiameseDenseUNets(
  (initial): Sequential(

```

```

(conv0): Conv2d (1, 16, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
(norm0): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
(rel0): LeakyReLU(0.01, inplace)
)
(encode_block0): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (16, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(20, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (20, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(24, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (24, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
)
(encode_trans0): _DownsampleTransition2D(
  (norm): BatchNorm2d(28, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (conv): Conv2d (28, 28, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))
)
(encode_block1): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(28, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (28, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(32, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (32, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(36, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (36, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)

```

```

        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
)
(encode_trans1): _DownsampleTransition2D(
  (norm): BatchNorm2d(40, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (conv): Conv2d (40, 40, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))
)
(encode_block2): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(40, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (40, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(44, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (44, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(48, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (48, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
)
(encode_trans2): _DownsampleTransition2D(
  (norm): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (conv): Conv2d (52, 52, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))
)
(bottom_block): Sequential(
  (conv0): Conv2d (52, 52, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (norm0): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
  (relu0): LeakyReLU(0.01, inplace)
)
(decode_trans0): _UpsampleTransition2D(
  (norm): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (deconv): ConvTranspose2d (52, 26, kernel_size=(2, 2), stride=(2, 2))
)
(decode_block0): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(78, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (78, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)

```



```

        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
    (denselayer2): _DenseLayer2D(
        (norm.1): BatchNorm2d(82, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
        (conv.1): Conv2d (82, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
    (denselayer3): _DenseLayer2D(
        (norm.1): BatchNorm2d(86, eps=1e-05, momentum=0.1, affine=True)
        (relu.1): LeakyReLU(0.01, inplace)
        (conv.1): Conv2d (86, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
        (relu.2): LeakyReLU(0.01, inplace)
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
    (unpool0): Sequential(
        (conv0): Conv2d (90, 3, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (relu0): LeakyReLU(0.01, inplace)
        (pool0): ConvTranspose2d (3, 3, kernel_size=(4, 4), stride=(4, 4))
    )
    (decode_trans1): _UpsampleTransition2D(
        (norm): BatchNorm2d(90, eps=1e-05, momentum=0.1, affine=True)
        (relu): LeakyReLU(0.01, inplace)
        (deconv): ConvTranspose2d (90, 45, kernel_size=(2, 2), stride=(2, 2))
    )
    (decode_block1): _DenseBlock2D(
        (denselayer1): _DenseLayer2D(
            (norm.1): BatchNorm2d(85, eps=1e-05, momentum=0.1, affine=True)
            (relu.1): LeakyReLU(0.01, inplace)
            (conv.1): Conv2d (85, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
            (relu.2): LeakyReLU(0.01, inplace)
            (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        )
        (denselayer2): _DenseLayer2D(
            (norm.1): BatchNorm2d(89, eps=1e-05, momentum=0.1, affine=True)
            (relu.1): LeakyReLU(0.01, inplace)
            (conv.1): Conv2d (89, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
            (relu.2): LeakyReLU(0.01, inplace)
            (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        )
        (denselayer3): _DenseLayer2D(
            (norm.1): BatchNorm2d(93, eps=1e-05, momentum=0.1, affine=True)
            (relu.1): LeakyReLU(0.01, inplace)
            (conv.1): Conv2d (93, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
            (relu.2): LeakyReLU(0.01, inplace)
            (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        )
    )
    (unpool1): Sequential(
        (conv0): Conv2d (97, 3, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)

```

```

    (relu0): LeakyReLU(0.01, inplace)
    (pool0): ConvTranspose2d (3, 3, kernel_size=(2, 2), stride=(2, 2))
)
(decode_trans2): _UpsampleTransition2D(
  (norm): BatchNorm2d(97, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (deconv): ConvTranspose2d (97, 48, kernel_size=(2, 2), stride=(2, 2))
)
(decode_block2): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(76, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (76, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(80, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (80, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(84, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (84, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
)
(unpool2): Sequential(
  (conv0): Conv2d (88, 3, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (relu0): LeakyReLU(0.01, inplace)
  (pool0): ConvTranspose2d (3, 3, kernel_size=(1, 1), stride=(1, 1))
)
)
)
Total number of parameters: 216666

```

2.2. Recover Net $R()$

```
DenseNetMessageRecovery(  
  (denseUNet): SiameseDenseUNets(  
    (initial): Sequential(  
      (conv0): Conv2d (3, 16, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      (norm0): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
      (relu0): LeakyReLU(0.01, inplace)  
    )  
    (encode_block0): _DenseBlock2D(  
      (denselayer1): _DenseLayer2D(  
        (norm.1): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.1): LeakyReLU(0.01, inplace)  
        (conv.1): Conv2d (16, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)  
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.2): LeakyReLU(0.01, inplace)  
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      )  
      (denselayer2): _DenseLayer2D(  
        (norm.1): BatchNorm2d(20, eps=1e-05, momentum=0.1, affine=True)  
        (relu.1): LeakyReLU(0.01, inplace)  
        (conv.1): Conv2d (20, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)  
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.2): LeakyReLU(0.01, inplace)  
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      )  
      (denselayer3): _DenseLayer2D(  
        (norm.1): BatchNorm2d(24, eps=1e-05, momentum=0.1, affine=True)  
        (relu.1): LeakyReLU(0.01, inplace)  
        (conv.1): Conv2d (24, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)  
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.2): LeakyReLU(0.01, inplace)  
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      )  
    )  
    (encode_trans0): _DownsampleTransition2D(  
      (norm): BatchNorm2d(28, eps=1e-05, momentum=0.1, affine=True)  
      (relu): LeakyReLU(0.01, inplace)  
      (conv): Conv2d (28, 28, kernel_size=(1, 1), stride=(1, 1), bias=False)  
      (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))  
    )  
    (encode_block1): _DenseBlock2D(  
      (denselayer1): _DenseLayer2D(  
        (norm.1): BatchNorm2d(28, eps=1e-05, momentum=0.1, affine=True)  
        (relu.1): LeakyReLU(0.01, inplace)  
        (conv.1): Conv2d (28, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)  
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.2): LeakyReLU(0.01, inplace)  
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      )  
      (denselayer2): _DenseLayer2D(  
        (norm.1): BatchNorm2d(32, eps=1e-05, momentum=0.1, affine=True)  
        (relu.1): LeakyReLU(0.01, inplace)  
        (conv.1): Conv2d (32, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)  
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.2): LeakyReLU(0.01, inplace)  
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      )  
    )  
  )  
)
```

```

(denselayer3): _DenseLayer2D(
  (norm.1): BatchNorm2d(36, eps=1e-05, momentum=0.1, affine=True)
  (relu.1): LeakyReLU(0.01, inplace)
  (conv.1): Conv2d (36, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
  (relu.2): LeakyReLU(0.01, inplace)
  (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
)
)
(encode_trans1): _DownsampleTransition2D(
  (norm): BatchNorm2d(40, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (conv): Conv2d (40, 40, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))
)
(encode_block2): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(40, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (40, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(44, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (44, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(48, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (48, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
)
)
(encode_trans2): _DownsampleTransition2D(
  (norm): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (conv): Conv2d (52, 52, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))
)
)
(bottom_block): Sequential(
  (conv0): Conv2d (52, 52, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (norm0): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
  (relu0): LeakyReLU(0.01, inplace)
)
)
(decode_trans0): _UpsampleTransition2D(
  (norm): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (deconv): ConvTranspose2d (52, 26, kernel_size=(2, 2), stride=(2, 2))
)
)
(decode_block0): _DenseBlock2D(

```

```

(denselayer1): _DenseLayer2D(
  (norm.1): BatchNorm2d(78, eps=1e-05, momentum=0.1, affine=True)
  (relu.1): LeakyReLU(0.01, inplace)
  (conv.1): Conv2d (78, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
  (relu.2): LeakyReLU(0.01, inplace)
  (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
)
(denselayer2): _DenseLayer2D(
  (norm.1): BatchNorm2d(82, eps=1e-05, momentum=0.1, affine=True)
  (relu.1): LeakyReLU(0.01, inplace)
  (conv.1): Conv2d (82, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
  (relu.2): LeakyReLU(0.01, inplace)
  (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
)
(denselayer3): _DenseLayer2D(
  (norm.1): BatchNorm2d(86, eps=1e-05, momentum=0.1, affine=True)
  (relu.1): LeakyReLU(0.01, inplace)
  (conv.1): Conv2d (86, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
  (relu.2): LeakyReLU(0.01, inplace)
  (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
)
)
(unpool0): Sequential(
  (conv0): Conv2d (90, 1, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (relu0): LeakyReLU(0.01, inplace)
  (pool0): ConvTranspose2d (1, 1, kernel_size=(4, 4), stride=(4, 4))
)
(decode_trans1): _UpsampleTransition2D(
  (norm): BatchNorm2d(90, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (deconv): ConvTranspose2d (90, 45, kernel_size=(2, 2), stride=(2, 2))
)
(decode_block1): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(85, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (85, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(89, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (89, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(93, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (93, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
  )
)

```

```

        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
)
(unpool1): Sequential(
  (conv0): Conv2d (97, 1, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (relu0): LeakyReLU(0.01, inplace)
  (pool0): ConvTranspose2d (1, 1, kernel_size=(2, 2), stride=(2, 2))
)
(decode_trans2): _UpsampleTransition2D(
  (norm): BatchNorm2d(97, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (deconv): ConvTranspose2d (97, 48, kernel_size=(2, 2), stride=(2, 2))
)
(decode_block2): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(76, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (76, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(80, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (80, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(84, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (84, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
)
)
(unpool2): Sequential(
  (conv0): Conv2d (88, 1, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (relu0): LeakyReLU(0.01, inplace)
  (pool0): ConvTranspose2d (1, 1, kernel_size=(1, 1), stride=(1, 1))
)
)
)
Total number of parameters: 103297

```

2.3. Camera-Display Transfer Net $T()$

```
DenseNetMessageRecovery(  
  (denseUNet): SiameseDenseUNets(  
    (initial): Sequential(  
      (conv0): Conv2d (3, 16, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      (norm0): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
      (relu0): LeakyReLU(0.01, inplace)  
    )  
    (encode_block0): _DenseBlock2D(  
      (denselayer1): _DenseLayer2D(  
        (norm.1): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.1): LeakyReLU(0.01, inplace)  
        (conv.1): Conv2d (16, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)  
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.2): LeakyReLU(0.01, inplace)  
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      )  
      (denselayer2): _DenseLayer2D(  
        (norm.1): BatchNorm2d(20, eps=1e-05, momentum=0.1, affine=True)  
        (relu.1): LeakyReLU(0.01, inplace)  
        (conv.1): Conv2d (20, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)  
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.2): LeakyReLU(0.01, inplace)  
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      )  
      (denselayer3): _DenseLayer2D(  
        (norm.1): BatchNorm2d(24, eps=1e-05, momentum=0.1, affine=True)  
        (relu.1): LeakyReLU(0.01, inplace)  
        (conv.1): Conv2d (24, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)  
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.2): LeakyReLU(0.01, inplace)  
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      )  
    )  
    (encode_trans0): _DownsampleTransition2D(  
      (norm): BatchNorm2d(28, eps=1e-05, momentum=0.1, affine=True)  
      (relu): LeakyReLU(0.01, inplace)  
      (conv): Conv2d (28, 28, kernel_size=(1, 1), stride=(1, 1), bias=False)  
      (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))  
    )  
    (encode_block1): _DenseBlock2D(  
      (denselayer1): _DenseLayer2D(  
        (norm.1): BatchNorm2d(28, eps=1e-05, momentum=0.1, affine=True)  
        (relu.1): LeakyReLU(0.01, inplace)  
        (conv.1): Conv2d (28, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)  
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.2): LeakyReLU(0.01, inplace)  
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      )  
      (denselayer2): _DenseLayer2D(  
        (norm.1): BatchNorm2d(32, eps=1e-05, momentum=0.1, affine=True)  
        (relu.1): LeakyReLU(0.01, inplace)  
        (conv.1): Conv2d (32, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)  
        (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)  
        (relu.2): LeakyReLU(0.01, inplace)  
        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)  
      )  
    )  
  )  
)
```

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(denselayer3): _DenseLayer2D(
  (norm.1): BatchNorm2d(36, eps=1e-05, momentum=0.1, affine=True)
  (relu.1): LeakyReLU(0.01, inplace)
  (conv.1): Conv2d (36, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
  (relu.2): LeakyReLU(0.01, inplace)
  (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
)
)
(encode_trans1): _DownsampleTransition2D(
  (norm): BatchNorm2d(40, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (conv): Conv2d (40, 40, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))
)
(encode_block2): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(40, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (40, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(44, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (44, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(48, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (48, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
)
(encode_trans2): _DownsampleTransition2D(
  (norm): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (conv): Conv2d (52, 52, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (pool): MaxPool2d(kernel_size=(2, 2), stride=(2, 2), dilation=(1, 1))
)
(bottom_block): Sequential(
  (conv0): Conv2d (52, 52, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (norm0): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
  (relu0): LeakyReLU(0.01, inplace)
)
(decode_trans0): _UpsampleTransition2D(
  (norm): BatchNorm2d(52, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (deconv): ConvTranspose2d (52, 26, kernel_size=(2, 2), stride=(2, 2))
)
(decode_block0): _DenseBlock2D(

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(denselayer1): _DenseLayer2D(
  (norm.1): BatchNorm2d(78, eps=1e-05, momentum=0.1, affine=True)
  (relu.1): LeakyReLU(0.01, inplace)
  (conv.1): Conv2d (78, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
  (relu.2): LeakyReLU(0.01, inplace)
  (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
)
(denselayer2): _DenseLayer2D(
  (norm.1): BatchNorm2d(82, eps=1e-05, momentum=0.1, affine=True)
  (relu.1): LeakyReLU(0.01, inplace)
  (conv.1): Conv2d (82, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
  (relu.2): LeakyReLU(0.01, inplace)
  (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
)
(denselayer3): _DenseLayer2D(
  (norm.1): BatchNorm2d(86, eps=1e-05, momentum=0.1, affine=True)
  (relu.1): LeakyReLU(0.01, inplace)
  (conv.1): Conv2d (86, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
  (relu.2): LeakyReLU(0.01, inplace)
  (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
)
)
(unpool0): Sequential(
  (conv0): Conv2d (90, 1, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (relu0): LeakyReLU(0.01, inplace)
  (pool0): ConvTranspose2d (1, 1, kernel_size=(4, 4), stride=(4, 4))
)
(decode_trans1): _UpsampleTransition2D(
  (norm): BatchNorm2d(90, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (deconv): ConvTranspose2d (90, 45, kernel_size=(2, 2), stride=(2, 2))
)
(decode_block1): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(85, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (85, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(89, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (89, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(93, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (93, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
  )
)

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        (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    )
)
(unpool1): Sequential(
  (conv0): Conv2d (97, 1, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (relu0): LeakyReLU(0.01, inplace)
  (pool0): ConvTranspose2d (1, 1, kernel_size=(2, 2), stride=(2, 2))
)
(decode_trans2): _UpsampleTransition2D(
  (norm): BatchNorm2d(97, eps=1e-05, momentum=0.1, affine=True)
  (relu): LeakyReLU(0.01, inplace)
  (deconv): ConvTranspose2d (97, 48, kernel_size=(2, 2), stride=(2, 2))
)
(decode_block2): _DenseBlock2D(
  (denselayer1): _DenseLayer2D(
    (norm.1): BatchNorm2d(76, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (76, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer2): _DenseLayer2D(
    (norm.1): BatchNorm2d(80, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (80, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
  (denselayer3): _DenseLayer2D(
    (norm.1): BatchNorm2d(84, eps=1e-05, momentum=0.1, affine=True)
    (relu.1): LeakyReLU(0.01, inplace)
    (conv.1): Conv2d (84, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (norm.2): BatchNorm2d(16, eps=1e-05, momentum=0.1, affine=True)
    (relu.2): LeakyReLU(0.01, inplace)
    (conv.2): Conv2d (16, 4, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  )
)
)
(unpool2): Sequential(
  (conv0): Conv2d (88, 1, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (relu0): LeakyReLU(0.01, inplace)
  (pool0): ConvTranspose2d (1, 1, kernel_size=(1, 1), stride=(1, 1))
)
)
)
Total number of parameters: 103297

```