CS 445: Computational Photography

Programming Project #3: Gradient Domain Fusion

In [2]:

```
# from google.colab import drive
# drive.mount('/content/drive')
```

In [1]:

```
import cv2
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import os
from random import random
import time
import scipy
import scipy as sc
import scipy.sparse.linalg
from scipy.sparse import *
from scipy.sparse.linalg import lsqr
from utils import *

# modify to where you store your project data including utils.py
# datadir = "/content/drive/My Drive/cs445_projects/proj3/"

# utilfn = datadir + "utils.py"
# !cp "$utilfn" .
# samplesfn = datadir + "samples"
# !cp -r "$samplesfn" .
import utils
```

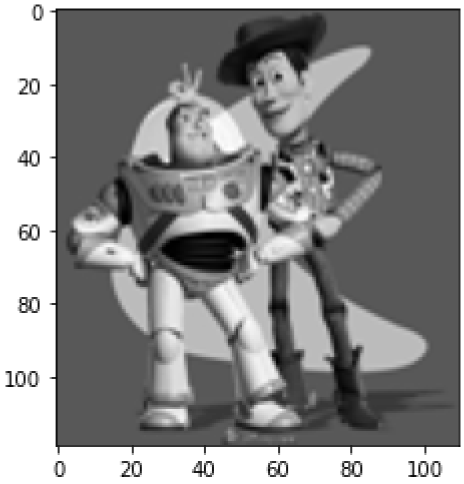
Part 1 Toy Problem (20 pts)

In [2]:

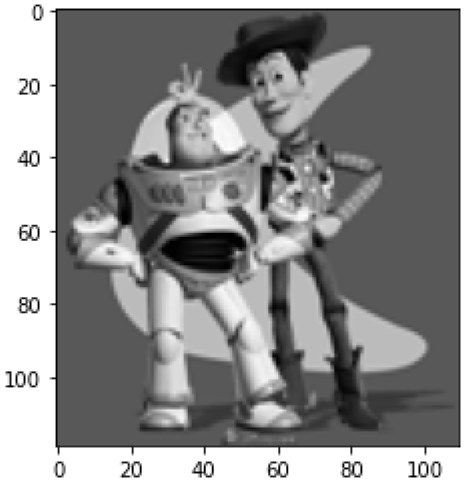
```
def toy_reconstruct(img):
    """
    The implementation for gradient domain processing is not complicated, but it
is easy to make a mistake, so let's start with a toy example. Reconstruct this i
mage from its gradient values, plus one pixel intensity. Denote the intensity of
the source image at (x, y) as s(x,y) and the value to solve for as v(x,y). For e
ach pixel, then, we have two objectives:
    1. minimize (v(x+1,y)-v(x,y) - (s(x+1,y)-s(x,y)))^2
    2. minimize (v(x,y+1)-v(x,y) - (s(x,y+1)-s(x,y)))^2
    Note that these could be solved while adding any constant value to v, so we
 will add one more objective:
    3. minimize (v(1,1)-s(1,1))^2
    :param toy_img: numpy.ndarray
    """

    img_h = img.shape[0]
    img_w = img.shape[1]
    #create a np array with shape of 1 * (img_h * img_w)
    im2var = np.arange(img_h * img_w)
    #reshape the single row array into the shape we want
    im2var = im2var.reshape(img_h, img_w)
#     print(im2var)
    #we use im2var to locate the pixel in original img


#     h = img_h *(img_w - 1) + (img_h - 1) * img_w+1
    h = img_h * img_w * 2 #26180
#     print("h" , h) #h 25952

    w = img_h * img_w
#     print("w" , w) #w 13090

#   A has size of :
    #h: # of formulas/constraints
    #w: # of values we want to resolve, which is the # of pixels in our target l
ocation, which is img
    #check 5.1.3 ~13mins for more details
#     A = np.zeros([h,w])
    A = scipy.sparse.lil_matrix((h, w), dtype='double')
    b = np.zeros((A.shape[0],1), dtype = 'double')
    e = 0

#     A[e, im2var[y][x]] not A[e][im2var[y][x]]
    A[e, im2var[0][0]] = 1
    b[e] = img[0][0]
    e = e+1
    A[e, im2var[0][0]] = 1
    b[e] = img[0][0]

    print(im2var.shape)
    for y in range(img_h - 1):
        for x in range(img_w - 1):
            #copy from tips, obj1
            A[e, im2var[y][x+1]] = 1 #the coefficient for variables v, and b is
 the constant from original image
            A[e, im2var[y][x]] = -1
            b[e] = img[y][x+1] - img[y][x]
            e = e + 1
            #obj2
            A[e, im2var[y+1][x]] = 1
            A[e, im2var[y][x]] = -1
            b[e] = img[y+1][x] - img[y][x]
            e = e + 1
    A[e, im2var[y+1][x+1]] = 1
    b[e] = img[y+1][x+1]



    print("A.shape",A.shape)
    print("b.shape", b.shape)
#     A_spa = csr_matrix(A)
#     v = lsqr(A_spa, b)
    v = scipy.sparse.linalg.lsqr(A.tocsr(), b);
#https://stackoverflow.com/questions/48621407/python-equivalent-of-matlabs-lsqr-with-first-argument-a-function
#https://het.as.utexas.edu/HET/Software/Scipy/generated/scipy.sparse.linalg.lsqr.html
#     v = scipy.sparse.linalg.lsqr(A.tocsr(), b)
#     print("A_csr.shape",A_csr.shape)
#     print("A.shape",A.shape)
#     print(v)
    return v[0].reshape(img_h, img_w)
#     return img
```

```
In [3]:
```

```
toy_img = cv2.cvtColor(cv2.imread('samples/toy_problem.png'), cv2.COLOR_BGR2GRAY
).astype('double') / 255.0
plt.imshow(toy_img, cmap="gray")
plt.show()

im_out = toy_reconstruct(toy_img)
plt.imshow(im_out, cmap="gray")
plt.show()
print("Max error is: ", np.sqrt(((im_out - toy_img)**2).max()))
```



```
(119, 110)
A.shape (26180, 13090)
b.shape (26180, 1)
```

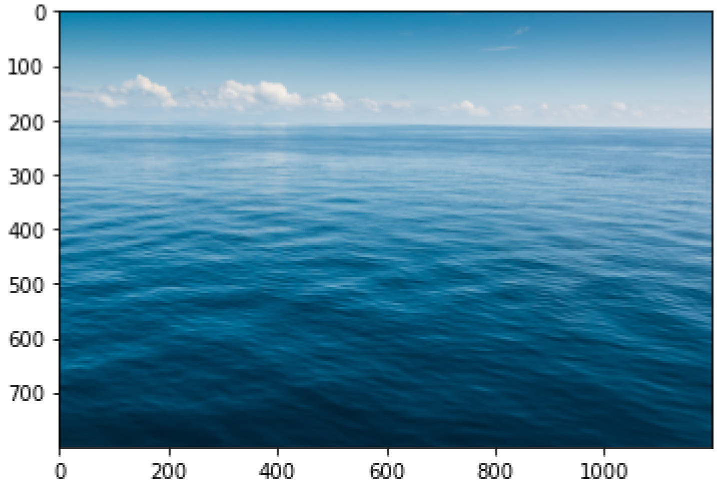


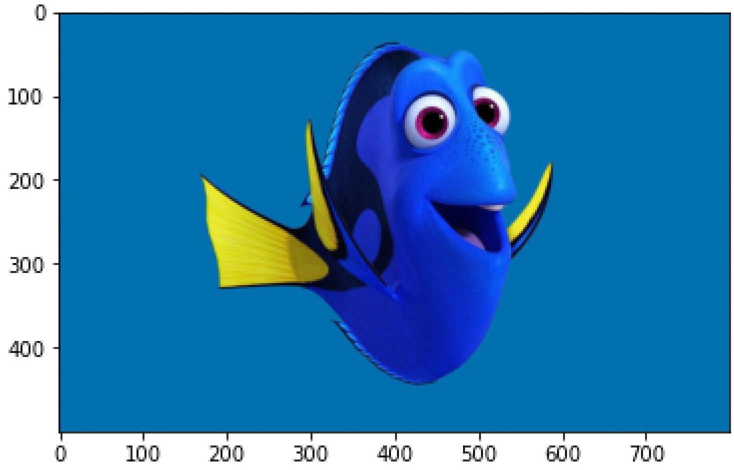
```
Max error is:  8.932118298277114e-06
```

Preparation

In [4]:

```
background_img = cv2.cvtColor(cv2.imread('samples/comb1_1.jpeg'), cv2.COLOR_BGR2
RGB).astype('double') / 255.0
plt.figure()
plt.imshow(background_img)
plt.show()
object_img = cv2.cvtColor(cv2.imread('samples/comb1_2.jpeg'), cv2.COLOR_BGR2RGB)
.astype('double') / 255.0
plt.imshow(object_img)
plt.show()

use_interface = True  # set to true if you want to use the interface to choose p
oints (might not work in Colab)
if not use_interface:
    xs = (65, 359, 359, 65)
    ys = (24, 24, 457, 457)
    object_mask = utils.get_mask(ys, xs, object_img)
    bottom_center = (500, 2500) # (x,y)

    object_img, object_mask = utils.crop_object_img(object_img, object_mask)
    bg_ul = utils.upper_left_background_rc(object_mask, bottom_center)
    plt.imshow(utils.get_combined_img(background_img, object_img, object_mask, b
g_ul))
```

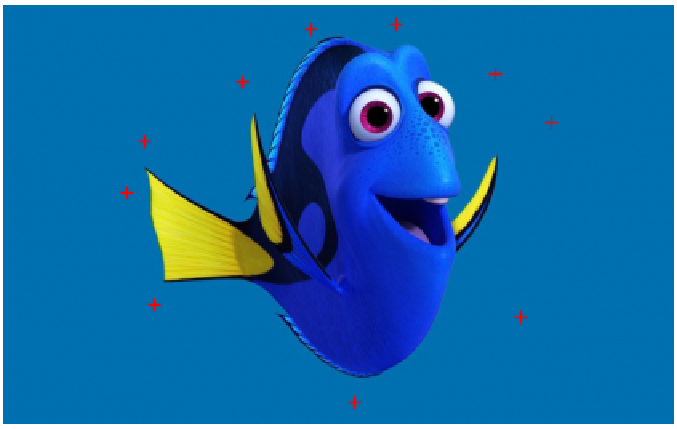




In [6]:

```
if use_interface:
    import matplotlib.pyplot as plt
    %matplotlib notebook
    mask_coords = specify_mask(object_img)
```

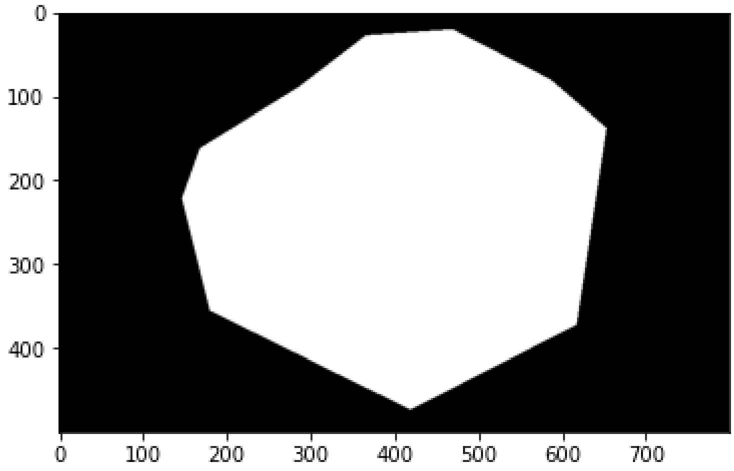
```
If it doesn't get you to the drawing mode, then rerun this function
again.
```



In [7]:

```
if use_interface:
    xs = mask_coords[0]
    ys = mask_coords[1]
    %matplotlib inline
    import matplotlib.pyplot as plt
    plt.figure()
    object_mask = get_mask(ys, xs, object_img)
```

```
<Figure size 432x288 with 0 Axes>
```



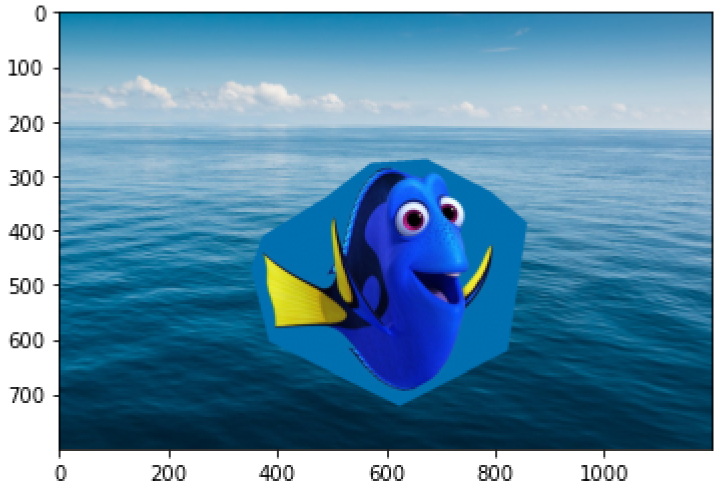
In [8]:

```
if use_interface:
    %matplotlib notebook
    import matplotlib.pyplot as plt
    bottom_center = specify_bottom_center(background_img)
#     bottom_center = background_img.shape[0],background_img.shape[1]
```

```
If it doesn't get you to the drawing mode, then rerun this function
again. Also, make sure the object fill fit into the background imag
e. Otherwise it will crash
```

In [9]:

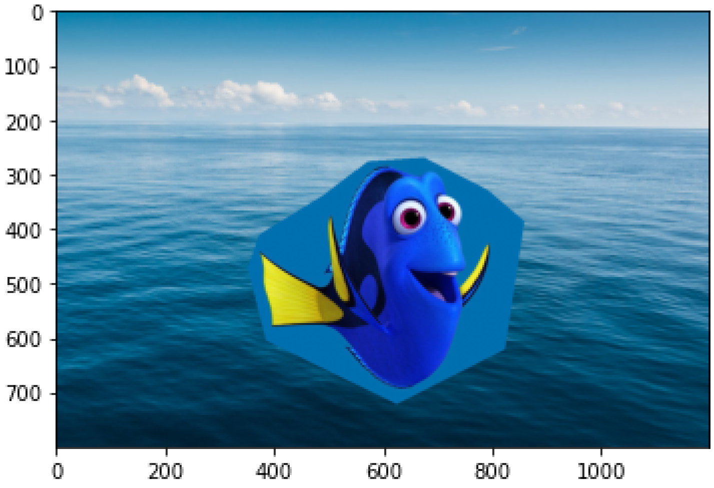
```
# print(bottom_center)
if use_interface:
    %matplotlib inline
    import matplotlib.pyplot as plt

    object_img, object_mask = utils.crop_object_img(object_img, object_mask)
    bg_ul = utils.upper_left_background_rc(object_mask, bottom_center)
    plt.imshow(utils.get_combined_img(background_img, object_img, object_mask, b
g_ul))
#     plt.savefig('comb3_direct.jpg')
```



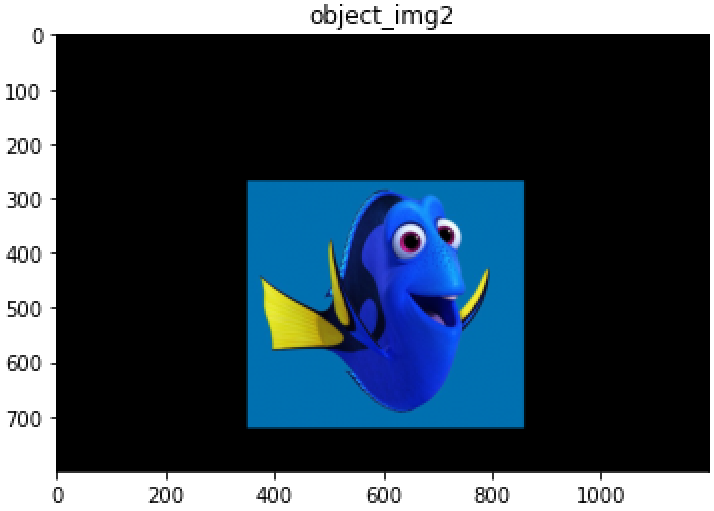
Part 2 Poisson Blending (50 pts)

In [10]:

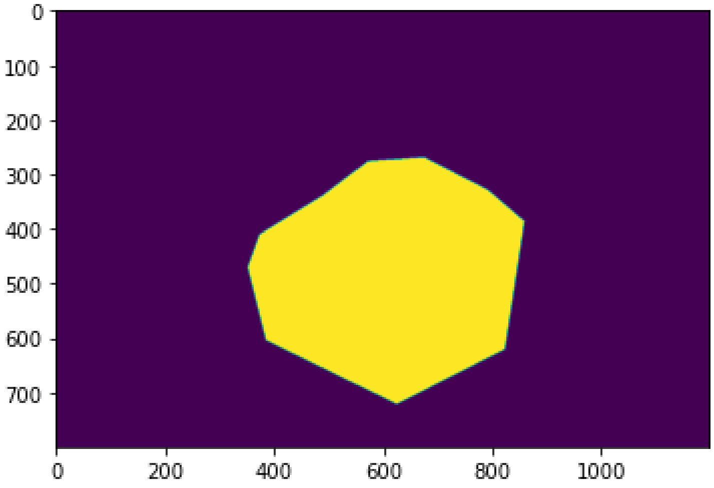
```
object_img2, mask = align_source(object_img, object_mask, background_img, bottom_center)
object_img3, mask2 = align_source(object_img, mask, background_img, bottom_center)
plt.imshow(object_img2)
plt.title('object_img2')
plt.show()
plt.imshow(mask2)
plt.title('mask2')
plt.show()
```



object_img2

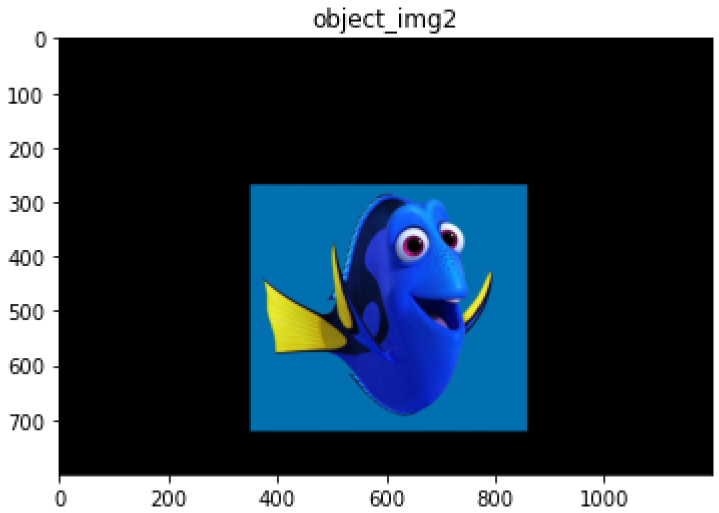


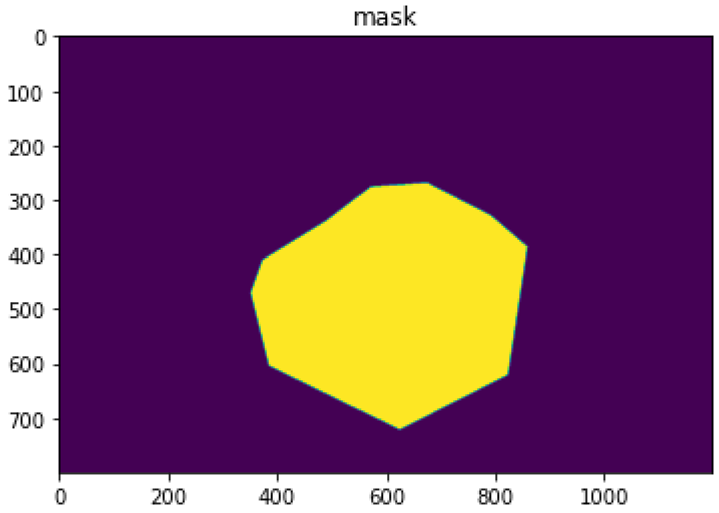
mask2

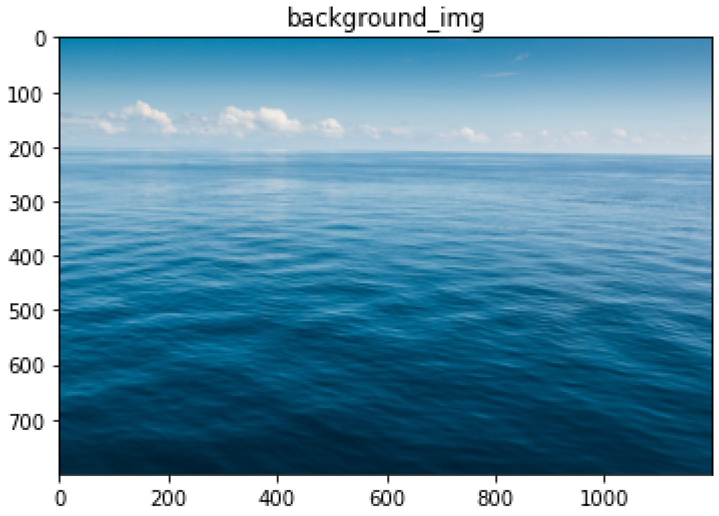


In [11]:

```
plt.imshow(object_img2)
plt.title("object_img2")
plt.show()
plt.imshow(mask)
plt.title("mask")
plt.show()
plt.imshow(background_img)
plt.title("background_img")
plt.show()
```


object_img2
0
100
200
300
400
500
600
700
0
200
400
600
800
1000


mask
0
100
200
300
400
500
600
700
0
200
400
600
800
1000


background_img
0
100
200
300
400
500
600
700
0
200
400
600
800
1000

In [12]:

```
def poisson_blend(object_img2, mask2, bg_img, bg_ul):
    """
    Returns a Poisson blended image with masked object_img over the bg_img at po
sition specified by bg_ul.
    Can be implemented to operate on a single channel or multiple channels
    :param object_img: the image containing the foreground object
    :param object_mask: the mask of the foreground object in object_img
    :param background_img: the background image
    :param bg_ul: position (row, col) in background image corresponding to (0,0)
of object_img
    reference:
    https://cs.brown.edu/courses/csci1950-g/results/proj2/edwallac/
    http://cs.brown.edu/courses/cs129/results/proj2/taox/

    """
    non_zero_x, non_zero_y = np.where(mask2 == 1)

    img_h = object_img2.shape[0]
    img_w = object_img2.shape[1]
    im2var = np.arange(img_h*img_w).reshape(img_h, img_w)
    result = bg_img
    e = 0
#     h = img_h * img_w * 4 # is this varibale setup right? does it matter?
    h = len(non_zero_x) * 4 # is this varibale setup right? does it matter?
    print(h)
    w = img_h * img_w
#     A = np.zeros((h,w), dtype = np.float64)
#     A = scipy.sparse.lil_matrix((neq, nr*nc), dtype='double') # init lil
    A = scipy.sparse.lil_matrix((h,w),dtype=np.float64)

    b = np.zeros((A.shape[0],1), dtype = np.float64)
#     print(im2var.shape)


    print("checkpoint 1")
#     A[e, im2var[y][x]] not A[e][im2var[y][x]]
    for y in range(img_h):
        for x in range(img_w):
            if mask2[y][x] == 0:
                continue
            else:
                result[y][x] = 0
                if mask2[y][x+1] == 1:
                    A[e, im2var[y][x+1]] = -1
                    A[e, im2var[y][x]] = 1
                    b[e] = object_img2[y][x] - object_img2[y][x+1]
                    e = e + 1
                else:
                    A[e, im2var[y][x]] = 1
                    b[e] = object_img2[y][x] - object_img2[y][x+1] + bg_img[y][x
+1]
                    e = e + 1
################################################################
                if mask2[y][x-1] == 1:
                    A[e, im2var[y][x-1]] = -1
                    A[e, im2var[y][x]] = 1
                    b[e] = object_img2[y][x] - object_img2[y][x-1]
                    e = e + 1
                else:
                    A[e, im2var[y][x]] = 1
                    b[e] = object_img2[y][x] - object_img2[y][x-1] + bg_img[y][x-1]
                    e = e + 1
###############################################################
                if mask2[y+1][x] == 1:
                    A[e, im2var[y+1][x]] = -1
                    A[e, im2var[y][x]] = 1
                    b[e] = object_img2[y][x] - object_img2[y+1][x]
                    e = e + 1
                else:
                    A[e, im2var[y][x]] = 1
                    b[e] = object_img2[y][x] - object_img2[y+1][x] + bg_img[y+1][x]
                    e = e + 1
###############################################################
                if mask2[y-1][x] == 1:
                    A[e, im2var[y-1][x]] = -1
                    A[e, im2var[y][x]] = 1
                    b[e] = object_img2[y][x] - object_img2[y-1][x]
                    e = e + 1
                else:
                    A[e, im2var[y][x]] = 1
                    b[e] = object_img2[y][x] - object_img2[y-1][x] + bg_img[y-1][x]
                    e = e + 1
    print("calculating V ")
#     print(A.shape)
#     print(b.shape)

#computer dies while runing the A_spa and calculate v
#     A_spa = csr_matrix(A)
#     v = lsqr(A_spa, b)
    v = scipy.sparse.linalg.lsqr(A.tocsr(), b);
    print("v calculate complete")
#     print("len(v)", len(v))
#     print("len(v[0])", len(v[0]))

    result = result + v[0].reshape(img_h, img_w)



#     return v[0].reshape(img_h, img_w)
    return result
```

In [13]:

```
im_blend = np.zeros(background_img.shape)
# plt.imshow(mask2)
# plt.title('mask2')
# plt.show()
# plt.imshow(background_img)
# plt.title('background_img')
# plt.show()
# plt.imshow(object_img2)
# plt.title('object_img2')
# plt.show()

for b in np.arange(3):
    im_blend[:,:,b] = poisson_blend(object_img2[:,:,b], mask, background_img
[:,:,b].copy(), bg_ul)

plt.figure(figsize=(10,10))
plt.imshow(im_blend)

# plt.savefig('comb3_poi.jpg')
```

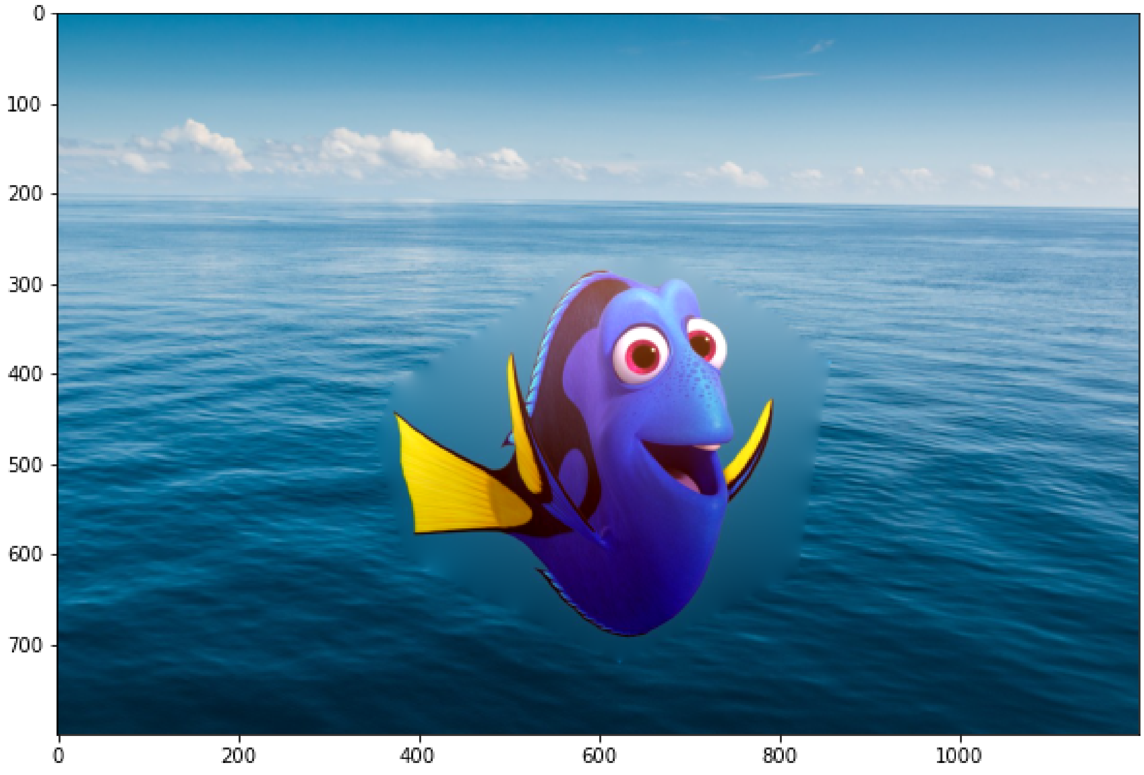
```
648004
checkpoint 1
calculating V
v calculate complete
648004
checkpoint 1
calculating V
v calculate complete
648004
checkpoint 1
calculating V
```

```
Clipping input data to the valid range for imshow with RGB data
([0..1] for floats or [0..255] for integers).
```

```
v calculate complete
```

Out[13]:

```
<matplotlib.image.AxesImage at 0xa202519b0>
```



Part 3 Mixed Gradients (20 pts)

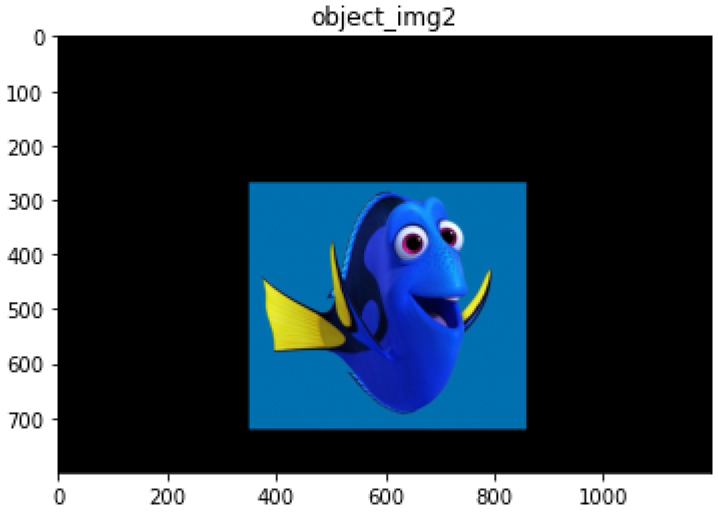
In [15]:

```python
def greater(input1, input2):
    if abs(input1) > abs(input2):
        return input1
    else:
        return input2
print(greater(-20, 9))
```

```
-20
```

In [16]:

```
plt.imshow(object_img2)
plt.title('object_img2')
plt.show()
```



In [17]:

```
def mixed_blend(object_img2, mask2, bg_img, bg_ul):
    """
    Returns a mixed gradient blended image with masked object_img over the bg_img at position specified by bg_ul.
    Can be implemented to operate on a single channel or multiple channels
    :param object_img: the image containing the foreground object
    :param object_mask: the mask of the foreground object in object_img
    :param background_img: the background image
    :param bg_ul: position (row, col) in background image corresponding to (0,0) of object_img
    """
    non_zero_x, non_zero_y = np.where(mask2 == 1)

    img_h = object_img2.shape[0]
    img_w = object_img2.shape[1]
    im2var = np.arange(img_h*img_w).reshape(img_h, img_w)
#     result = bg_img
    result = np.zeros((bg_img.shape),dtype='double')
    result = (1-mask2) * bg_img

    e = 0
    h = len(non_zero_x) * 4

    w = img_h * img_w
    A = scipy.sparse.lil_matrix((h,w),dtype=np.float64)
    b = np.zeros((A.shape[0],1), dtype = np.float64)

    print("checkpoint 1")
    for y in range(img_h):
        for x in range(img_w):
            if mask2[y][x] == 0:
                continue
            else:
#                 result[y][x] = 0



                if mask2[y][x+1] == 1:
                    A[e, im2var[y][x+1]] = -1
                    A[e, im2var[y][x]] = 1
#                     b[e] = object_img2[y][x] - object_img2[y][x+1]
                    b[e] = compare(object_img2[y][x] - object_img2[y][x+1], bg_img[y][x] - bg_img[y][x+1])
                    e = e + 1
                else:
                    A[e, im2var[y][x]] = 1
#                     b[e] = object_img2[y][x] - object_img2[y][x+1] + bg_img[y][x+1]
                    b[e] = compare(object_img2[y][x] - object_img2[y][x+1], bg_img[y][x] - bg_img[y][x+1]) + bg_img[y][x+1]
                    e = e + 1
###############################################################
                if mask2[y][x-1] == 1:
                    A[e, im2var[y][x-1]] = -1
                    A[e, im2var[y][x]] = 1
                    b[e] = object_img2[y][x] - object_img2[y][x-1]
#                     b[e] = compare(object_img2[y][x] - object_img2[y][x-1],bg_img[y][x] - bg_img[y][x-1])
                    e = e + 1
                else:
                    A[e, im2var[y][x]] = 1
#                     b[e] = object_img2[y][x] - object_img2[y][x-1] + bg_img[y]
[x-1]
                    b[e] = compare(object_img2[y][x] - object_img2[y][x-1],bg_im
g[y][x] - bg_img[y][x-1]) + bg_img[y][x-1]
                    e = e + 1
################################################################
                if mask2[y+1][x] == 1:
                    A[e, im2var[y+1][x]] = -1
                    A[e, im2var[y][x]] = 1

                    b[e] = compare(object_img2[y][x] - object_img2[y+1][x], bg_i
mg[y][x] - bg_img[y+1][x])
                    e = e + 1
                else:
                    A[e, im2var[y][x]] = 1
                    b[e] = compare(object_img2[y][x] - object_img2[y+1][x], bg_i
mg[y][x] - bg_img[y+1][x]) + bg_img[y+1][x]
                    e = e + 1
################################################################
                if mask2[y-1][x] == 1:
                    A[e, im2var[y-1][x]] = -1
                    A[e, im2var[y][x]] = 1
                    b[e] = compare(object_img2[y][x] - object_img2[y-1][x],bg_im
g[y][x] - bg_img[y-1][x])
                    e = e + 1
                else:
                    A[e, im2var[y][x]] = 1
                    b[e] = compare(object_img2[y][x] - object_img2[y-1][x], bg_i
mg[y][x] - bg_img[y-1][x]) + bg_img[y-1][x]
                    e = e + 1
    print("calculating V ")
#     print(A.shape)
#     print(b.shape)


    v = scipy.sparse.linalg.lsqr(A.tocsr(), b);
    print("v calculate complete")
    result = result + v[0].reshape(img_h, img_w)
    return result
```

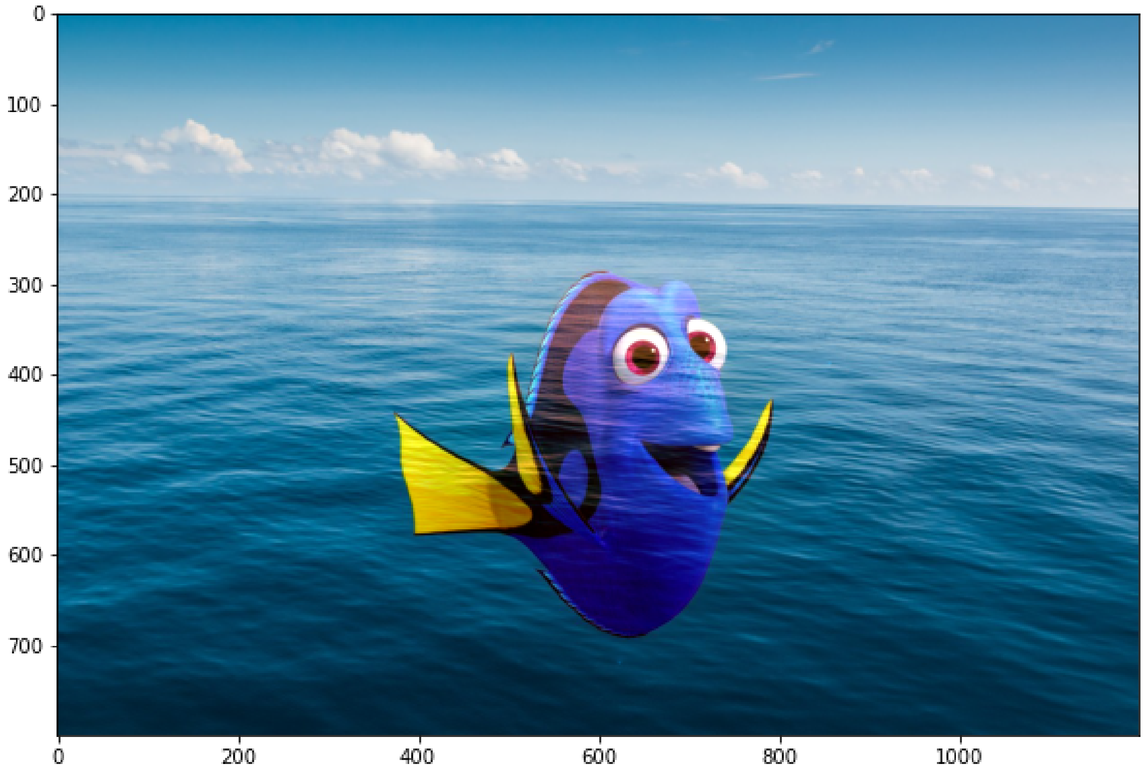
In [18]:

```
im_mix = np.zeros(background_img.shape)
for b in np.arange(3):
    im_mix[:,:,b] = mixed_blend(object_img2[:,:,b], mask, background_img[:,:,b].
copy(), bg_ul)

plt.figure(figsize=(10,10))
plt.imshow(im_mix)
```

```
checkpoint 1
calculating V
v calculate complete
checkpoint 1
calculating V
v calculate complete
checkpoint 1
calculating V

Clipping input data to the valid range for imshow with RGB data
([0..1] for floats or [0..255] for integers).

v calculate complete
```

Out[18]:

```
<matplotlib.image.AxesImage at 0xa2056ff60>
```



Bells & Whistles (Extra Points)

Color2Gray (20 pts)

In [ ]:

```
def color2gray(img):
    pass
```

Laplacian pyramid blending (20 pts)

In [ ]:

```
def laplacian_blend(object_img, object_mask, bg_img, bg_ul):
  # feel free to change input parameters
    pass
```

More gradient domain processing (up to 20 pts)

In [ ]:

```

```