Dheeraj Agarwal

16UCS059

Assignment 9 – Blackboard Mosaic

CODE :

```
//DHEERAJ AGARWAL
//16UCS059

//compilation command: g++ -std=c++11 -g mosac.cpp -o mosac.out -lopencv_core -lopencv_imgproc -lopencv_highgui -lopencv_imgcodecs -lopencv_calib3d
//execution command: ./mosac.out

#include <stdio.h>
#include <iostream>

#include "opencv2/highgui/highgui.hpp"
#include "opencv2/imgproc/imgproc.hpp"
#include "opencv2/imgcodecs/imgcodecs.hpp"
#include "opencv2/core/core.hpp"
#include "opencv2/features2d/features2d.hpp"
#include "opencv2/calib3d/calib3d.hpp"
#include "opencv2/opencv.hpp"
```

```
using namespace cv;
using namespace std;


//for finding the offset required for each image and also the max and min offset value to decide the dimension of stitched image
void findDim(Mat img,int &gmaxrow,int &gmaxcol,int &gminrow,int &gmincol,Mat homography){
	for(int a=0;a<5;a++){
		double H[3][3];

		//taking the values of homography in a matrix from a Mat object
		for(int we=0,k=0;we<3;we++)
			for(int j=0;j<3&&k<8;j++)
				H[we][j]= homography.at<double>(k++);
		H[2][2]=1;

		int maxrow=INT_MIN,maxcol=INT_MIN,minrow=INT_MAX,mincol=INT_MAX;

		//finding value of each pixel to get max and min offset value and select the global value
		for(int we=0;we<img.rows;we++){
			for(int j=0;j<img.cols;j++){

				double k= H[2][0]*we + H[2][1]*j + H[2][2];
				int inew= (H[0][0]*we + H[0][1]*j + H[0][2])/k;
				int jnew= (H[1][0]*we + H[1][1]*j + H[1][2])/k;
```

```
                    gmaxrow= max(gmaxrow,inew);
                    gmaxcol= max(gmaxcol,jnew);
                    gminrow= min(gminrow,inew);
                    gmincol= min(gmincol,jnew);
                }
            }
        }
}

//function to remove projective distortion and plotting the points in res accordingly
void removeProjection(Mat img,Mat homography,int maxrow,int maxcol,int minrow,int mincol,Mat &res){

    double H[3][3];

    //taking the values of homography in a matrix from a Mat object
    for(int we=0,k=0;we<3;we++)
        for(int j=0;j<3&&k<8;j++)
            H[we][j]= homography.at<double>(k++);
    H[2][2]=1;

    //finding value of each pixel after removing distortion and plotting it in res
    for(int we=0;we<img.rows;we++){
        for(int j=0;j<img.cols;j++){
            double k= H[2][0]*we + H[2][1]*j + H[2][2];
            int inew= (H[0][0]*we + H[0][1]*j + H[0][2])/k;
            int jnew= (H[1][0]*we + H[1][1]*j + H[1][2])/k;
```

```
                    //using reverse mapping
                    res.at<Vec3b>(inew-minrow,jnew-mincol) = img.at<Vec3b>(we,j);
                }
        }
}


int main( int argc, const char** argv ){

        //corresponding points in reference and given images
        vector<Point2d> Ref0 = { Point2d(542.91,87.901), Point2d(547.41,375.99),
Point2d(942.03,32.385), Point2d(1035.1,194.43), Point2d(1095.1,718.09),
Point2d(868.51,725.59), Point2d( 496.4,680.58), Point2d( 500.9,1048.2), Point2d(545.91,1372.3),
Point2d(733.47,701.59), Point2d(976.54,1196.7), Point2d(1044.1,1073.7),
Point2d(1120.6,893.64), Point2d(802.49,33.885), Point2d(886.52,592.05), Point2d(   834,260.45),
Point2d(520.41,1681.4), Point2d( 514.4,1953 ), Point2d(734.97,1948.5), Point2d(1154.3,1684.3),
Point2d(854.25,1666.3), Point2d(1007.3,1702.3), Point2d(794.99,1445.8),
Point2d(667.45,1109.7), Point2d(808.49,974.67)};
        vector<Point2d> Img0 = { Point2d(899.79,1003.8), Point2d(929.25,1303.3),
Point2d(1503.8,964.25), Point2d(1619.3,1153.3), Point2d(1635.8,1651.3),
Point2d(1349.3,1637.8), Point2d(882.01,1577.8), Point2d(901.52,1856.9), Point2d(969.04,
2082), Point2d(1174.6,1615.4), Point2d(1454.3,2006.8), Point2d(1544.3,1931.8),
Point2d(1655.3,1802.8), Point2d(1285.6,955.16), Point2d(1377.8,1528.3),
Point2d(1325.3,1210.3), Point2d(953.25,2267.8), Point2d(956.25,2411.8),
Point2d(1173.8,2429.8), Point2d(1616.3,2321.8), Point2d(1296.8,2284.3),
Point2d(1455.8,2323.3), Point2d(1234.6,2149.5), Point2d(1098.1, 1917),
Point2d(1266.1,1834.4)};
        vector<Point2d> Ref1 = { Point2d(553.42,372.99), Point2d(701.96,284.46),
Point2d(886.52,589.05), Point2d( 499.4,685.08), Point2d(632.94,718.09),
Point2d(793.49,724.09), Point2d(972.04,725.59), Point2d(1104.1,973.17),
Point2d(1047.1,1073.7), Point2d(862.51,958.16), Point2d(691.79,999.72),
Point2d(592.43,971.67), Point2d( 499.4,1001.7), Point2d(527.91,1163.7),
Point2d(622.44,1265.8), Point2d(773.98,1207.2), Point2d(885.02,1243.2),
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Point2d(1288.6,1685.9), Point2d(994.55,1720.4), Point2d(739.47,1681.4),
Point2d(524.91,1826.9), Point2d(526.41,2095.5), Point2d(731.97, 2106), Point2d(1173.1,1861.4),
Point2d(957.04,2056.5)} ;

        vector<Point2d> Img1 = { Point2d(1347.8,112.25), Point2d(1649.3,125.75),
Point2d(1604.3,734.75), Point2d(1014.1,503.53), Point2d(1155.1,671.58),
Point2d(1353.2,820.12), Point2d(1583.3,980.75), Point2d(1536.8,1424.8),
Point2d(1373.3,1489.2), Point2d(1242.1,1175.7), Point2d(1002.1,1064.7),
Point2d(898.52,952.16), Point2d(763.48,904.15), Point2d(682.45,1120.2),
Point2d(721.47,1313.8), Point2d(949.54,1369.3), Point2d(1029.1,1522.3),
Point2d(1163.3,2336.8), Point2d(815.25,2113.3), Point2d(553.42,1841.9),
Point2d(242.82,1804.4), Point2d(101.78,2056.5), Point2d(296.84,2242.5),
Point2d(906.02,2398.6), Point2d(542.91,2383.6)};

        vector<Point2d> Ref2 = { Point2d(529.41,2092.5), Point2d(518.91,1945.5),
Point2d(524.91,1831.4), Point2d( 515.9,1685.9), Point2d(739.47,  2031), Point2d(737.97,1738.4),
Point2d(866.25,1856.8), Point2d(996.75,1726.3), Point2d(905.25,2344.3),
Point2d(1070.3,2101.3), Point2d(1137.8,1808.8), Point2d(550.42,1376.8),
Point2d(616.44,1162.2), Point2d(524.91,899.65), Point2d(686.96,1067.7),
Point2d(770.98,974.67), Point2d(872.25,1036.3), Point2d(1002.8,1075.3),
Point2d(1089.8,1207.3), Point2d(1137.1,1618.4), Point2d(1210.6,1261.3),
Point2d(1252.6,1163.7), Point2d(888.02,1387.3), Point2d(856.51,1661.9),
Point2d(999.05,2209.5)};

        vector<Point2d> Img2 = { Point2d(764.25,1478.8), Point2d(722.25,1273.3),
Point2d(699.75,1103.8), Point2d(675.75,910.25), Point2d(1071.8,1312.3),
Point2d(995.25,907.25), Point2d(1209.8,1024.2), Point2d(1374.2,806.62),
Point2d(1418.3,1742.8), Point2d(1614.8,1313.8), Point2d(1622.3,874.25),
Point2d(655.45,538.04), Point2d(707.96,273.96), Point2d(544.41,32.385),
Point2d(785.99,144.92), Point2d(873.01,26.383), Point2d(1017.1,51.89), Point2d(1198.6,57.892),
Point2d(1336.7,161.42), Point2d(1536.8,629.75), Point2d(1529.3,182.75), Point2d(1568.3,65.75),
Point2d(1118.3,449.75), Point2d(1143.8,787.25), Point2d(1539.8,1496.8)};

        vector<Point2d> Ref3 = { Point2d(1310.3,2359.3), Point2d(1274.3,2186.8),
Point2d(1262.3,1904.8), Point2d(1293.1,1678.4), Point2d(1113.1,1678.4),
Point2d(1104.8,2129.8), Point2d(995.25,2207.8), Point2d(983.25,2444.8),
Point2d(867.75,1852.3), Point2d(996.75,1718.8), Point2d(888.75,2336.8),
Point2d(737.97,1685.9), Point2d(736.47,  2103), Point2d(520.41,1832.9), Point2d(635.94, 2055),
Point2d(1252.6,1166.7), Point2d(1087.6,1204.2), Point2d(1000.6,1078.2),
Point2d(883.52,1244.7), Point2d(772.48,1384.3), Point2d(548.91,1376.8),
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```
Point2d(619.44,1154.7), Point2d(775.48,1127.7), Point2d(954.75,2021.8),
Point2d(1092.8,1951.3)};

        vector<Point2d> Img3 = { Point2d(1243.6,1750.4), Point2d(1183.6,1475.8),
Point2d(1167.1,1046.7), Point2d(1212.8,739.25), Point2d(948.75,734.75),
Point2d(909.75,1375.3), Point2d(737.25,1484.8), Point2d(680.25,1873.3),
Point2d(557.92,950.66), Point2d(769.48,782.61), Point2d(540.75,1687.3),
Point2d(391.37,721.09), Point2d(329.85,1307.8), Point2d(55.266,908.65), Point2d(
179.8,1231.2), Point2d(1168.6,95.404), Point2d(928.53,143.42), Point2d( 820.5,0.8751),
Point2d(644.94,197.43), Point2d( 487.4,347.48), Point2d( 169.3,335.48), Point2d(295.34,90.902),
Point2d( 511.4,54.891), Point2d(684.75,1204.3), Point2d(905.25,1112.8)};

        vector<Point2d> Ref4 = { Point2d(547.41,80.399), Point2d(379.36,89.402), Point2d(611.93,
404.5), Point2d(692.96,113.41), Point2d(   831,126.91), Point2d(981.04,212.44),
Point2d(1128.8,221.75), Point2d(1098.1,716.59), Point2d(897.02, 992.67),
Point2d(878.25,725.75), Point2d(755.25,764.75), Point2d(774.75,1124.8),
Point2d(618.75,823.25), Point2d(531.75,838.25), Point2d(614.25,1127.8),
Point2d(516.75,1105.3), Point2d(1091.3,1198.3), Point2d(1104.8,971.75),
Point2d(1253.3,1160.8), Point2d(945.03,26.383), Point2d(1096.6,32.385),
Point2d(1364.3,196.25), Point2d(1382.3,745.25), Point2d(876.01,559.04),
Point2d(766.48,329.47)};

        vector<Point2d> Img4 = { Point2d(232.32,1127.7), Point2d(31.259,1198.2),
Point2d(391.37,1498.3), Point2d(418.38,1121.7), Point2d(601.43,1096.2),
Point2d(806.99,1148.7), Point2d(992.25,1112.8), Point2d(1111.6,1738.4), Point2d(948.03,
2172), Point2d(836.25,1823.8), Point2d(683.25,1915.3), Point2d(818.25,2396.8),
Point2d(522.75,2033.8), Point2d(402.75,2086.3), Point2d(602.25,2453.8),
Point2d(470.25,2462.8), Point2d(1272.1,2407.6), Point2d(1216.6,2080.5),
Point2d(1492.7,2284.6), Point2d(713.96,950.66), Point2d(892.52,902.65),
Point2d(1277.3,1007.8), Point2d(1497.8,1685.8), Point2d(779.98,1618.4),
Point2d(575.92,1348.3)};


        //vector for storing the homography matrix for each image relative to corresponding
image

        vector<Mat> homography;

        homography.push_back(findHomography(Img0,Ref0));

        homography.push_back(findHomography(Img1,Ref1));
```

```
homography.push_back(findHomography(Img2,Ref2));
homography.push_back(findHomography(Img3,Ref3));
homography.push_back(findHomography(Img4,Ref4));

//reading the reference image
Mat ref = imread("ref.jpg",CV_LOAD_IMAGE_UNCHANGED);
assert(&ref);

//for storing all the given images
Mat img[5];

//will be used to find the dimension of result image
int gmaxrow=INT_MIN,gmaxcol=INT_MIN,gminrow=INT_MAX,gmincol=INT_MAX;

//reading all given images
for(int we=0;we<5;we++){
        string name="m"+to_string(we)+".jpg";
        img[we]= imread(name,CV_LOAD_IMAGE_UNCHANGED);
        assert(&img[we]);
}

//creating a window named Image
namedWindow("Image", CV_WINDOW_NORMAL);
resizeWindow("Image",1200,1200);

//calling findDim function for each image
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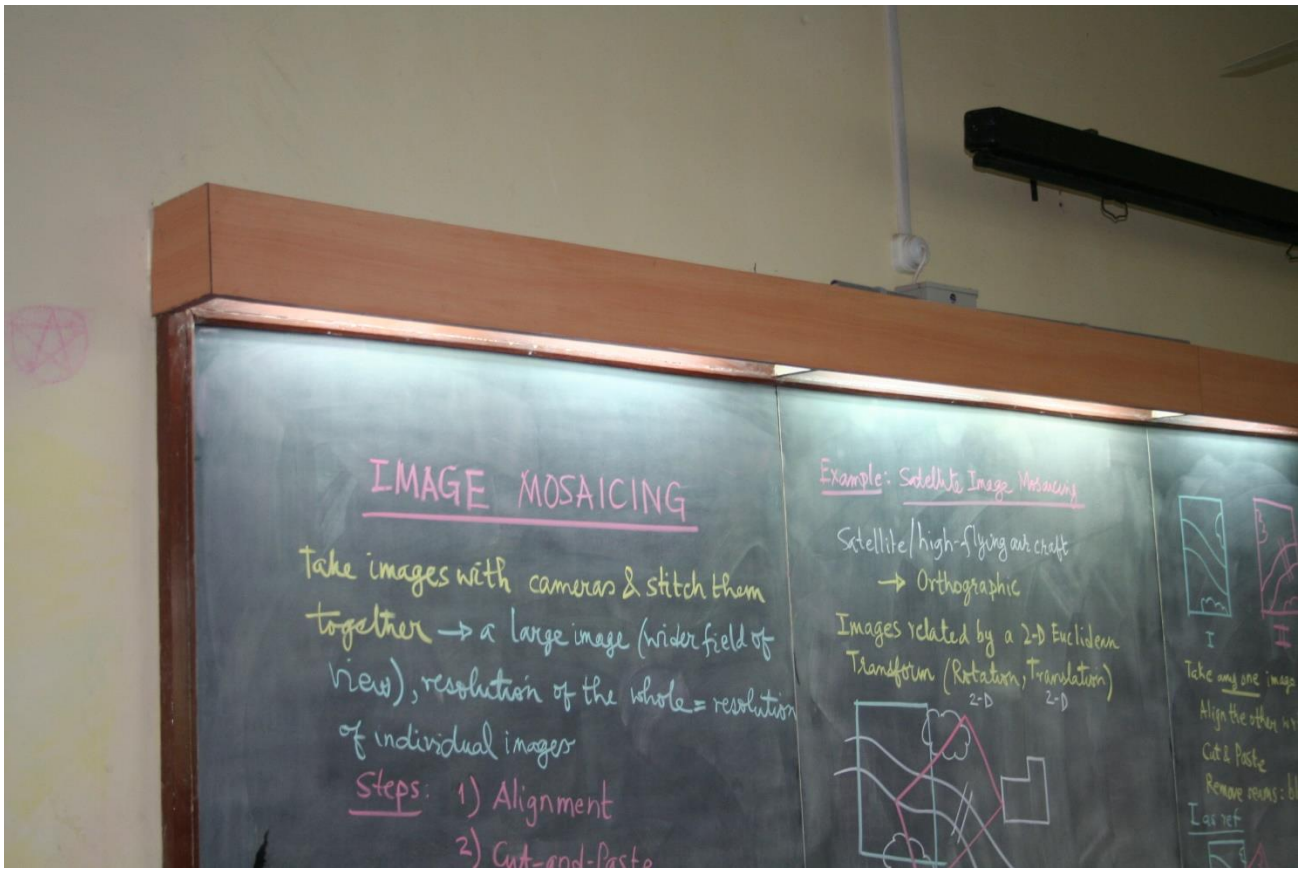
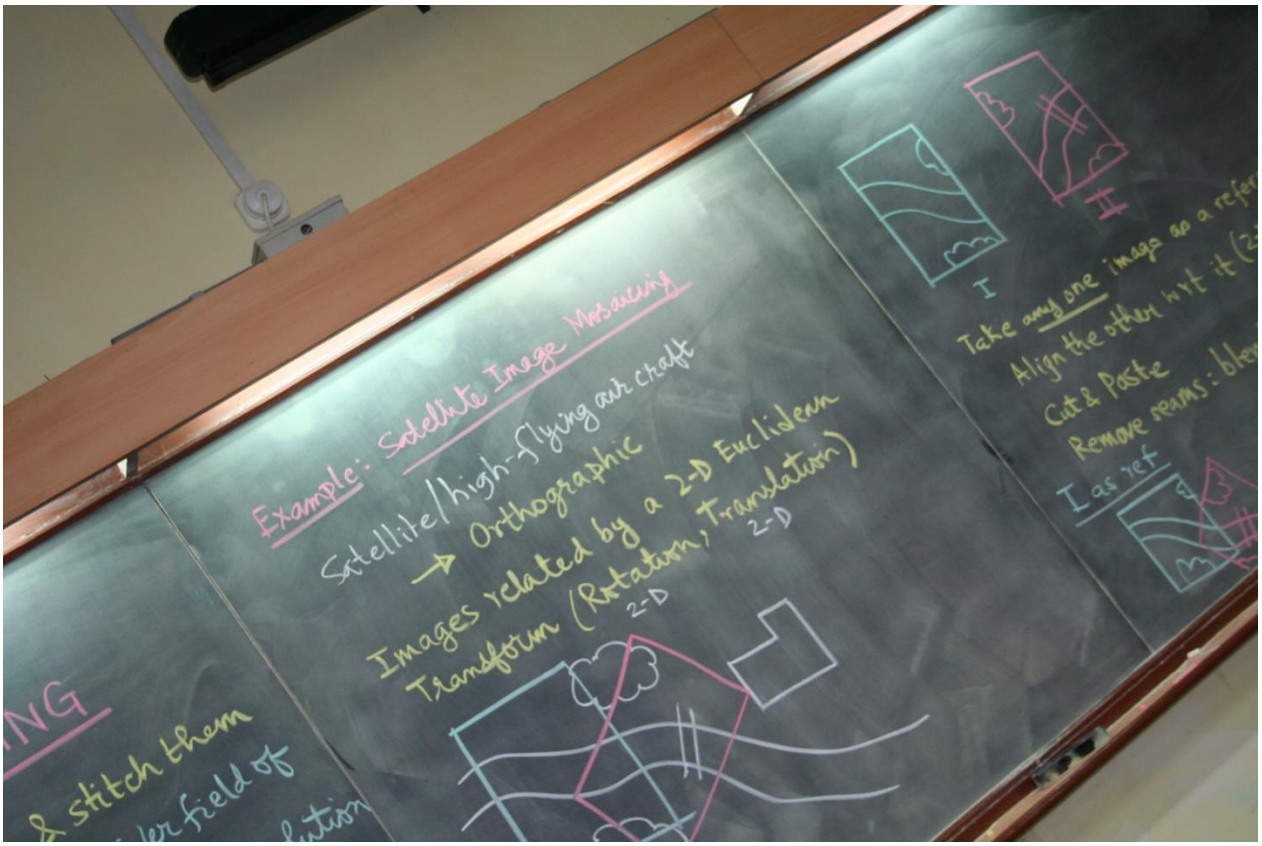
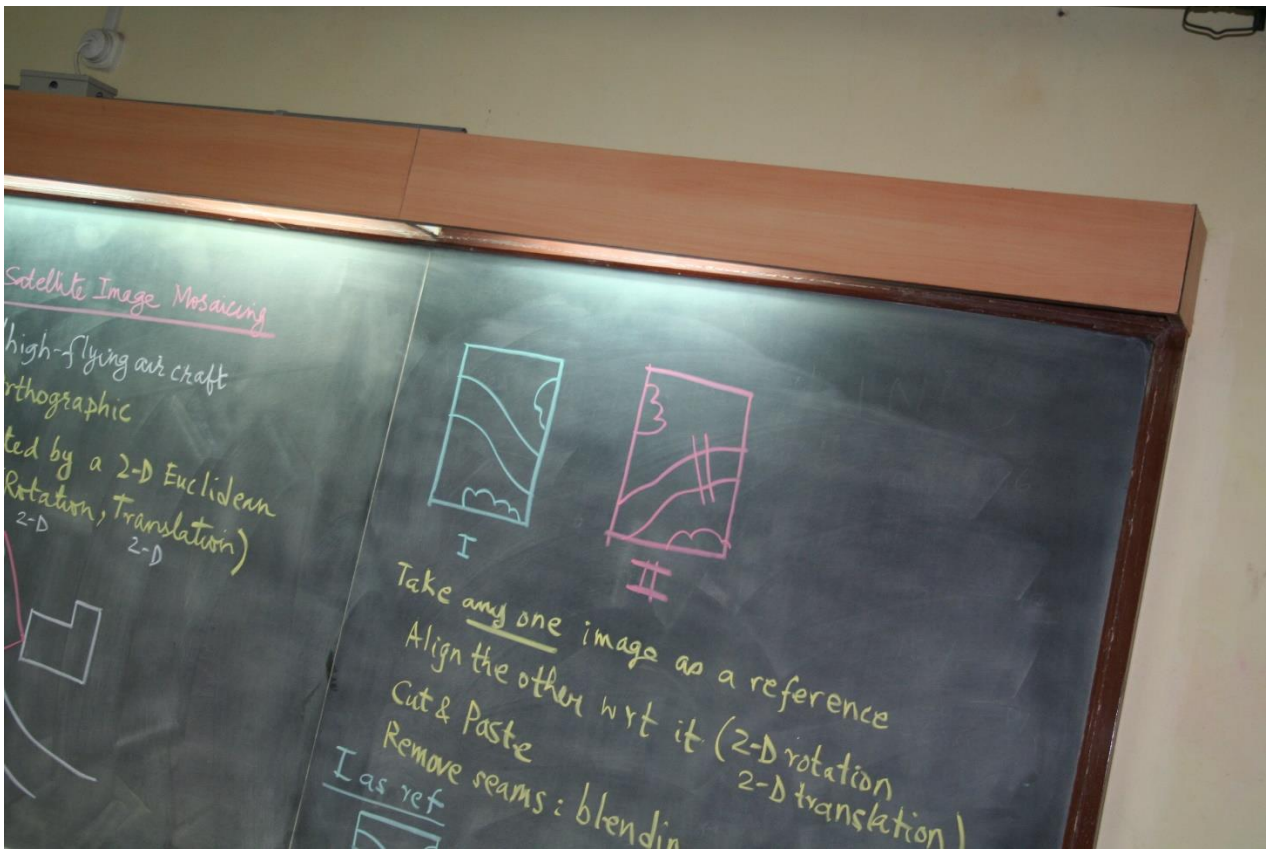
```
for(int a=0;a<5;a++)
        findDim(img[a],gmaxrow,gmaxcol,gminrow,gmincol,homography[a]);

//wether global max values are less than reference image row and cols if not then update
it
gmaxrow = max(gmaxrow,ref.rows);
gmaxcol = max(gmaxcol,ref.cols);

//object res is created using global max and min values
Mat res(gmaxrow-gminrow+1, gmaxcol-gmincol+1, CV_8UC3, Scalar(0,0,0));

//loop for all the given images
for(int a=0;a<5;a++){
        string name="mnew"+to_string(a)+".jpg";
        //calling removeProjection function
        removeProjection(img[a],homography[a],gmaxrow,gmaxcol,gminrow,gmincol,res);
        imwrite(name,res);
        imshow("Image", res);
        waitKey(0);
}

//plotting the points of reference image as it was for better image
for(int we=0;we<ref.rows;we++)
        for(int j=0;j<ref.cols;j++)
                res.at<Vec3b>(we-gminrow,j-gmincol) = ref.at<Vec3b>(we,j);

imshow("Image",res);
```

```
        waitKey(0);
        imwrite("result.jpg",res);

        return 0;
}
```

Input images




Example: Satellite Image Mosaicing
Satellite/high-flying aircraft
→ Orthographic
Images related by a 2-D Euclidean
Transform (Rotation, Translation)
2-D
2-D
I
II
Take any one image as a reference
Align the other wrt it (2-
Cut & Paste
Remove seams : ble
I as ref


Satellite Image Mosaicing
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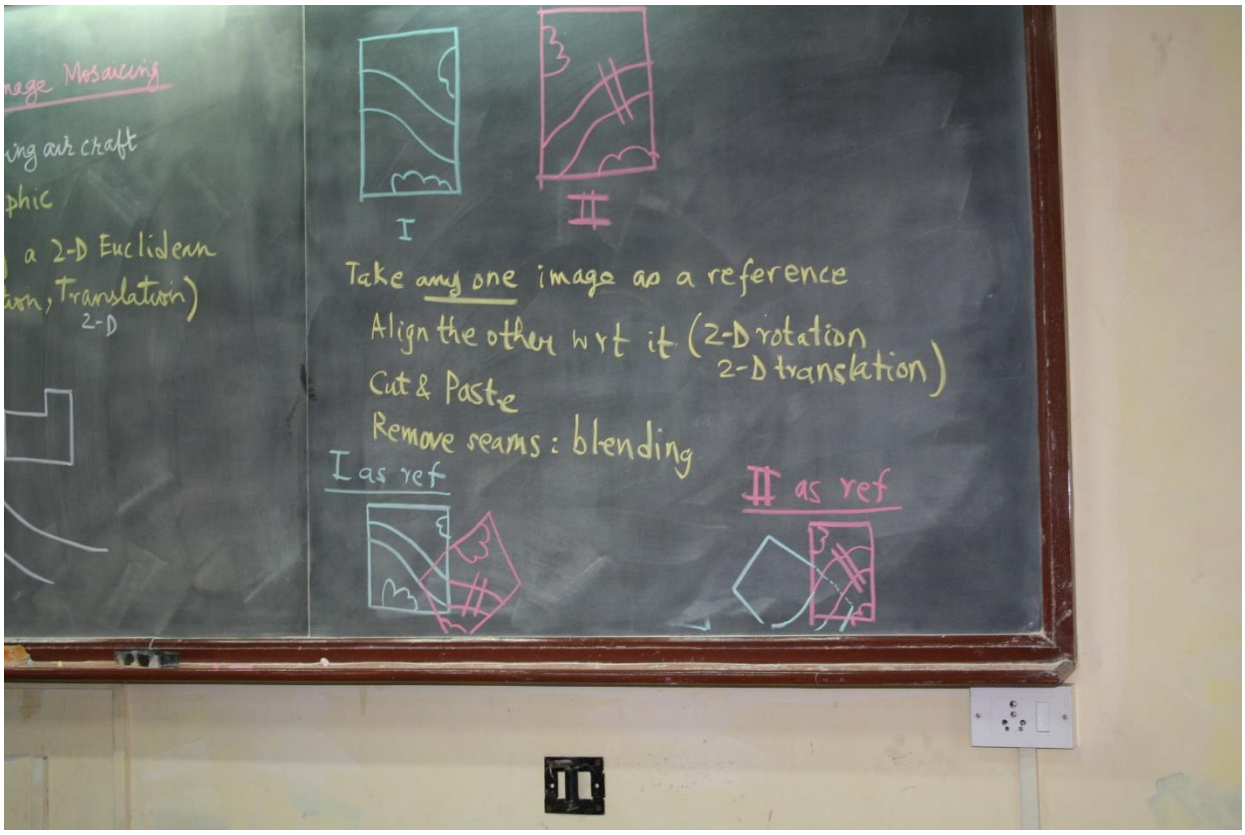
Take any one image as a reference
Align the other wrt it (2-D rotation
2-D translation)
Cut & Paste
Remove seams : blendin
I as ref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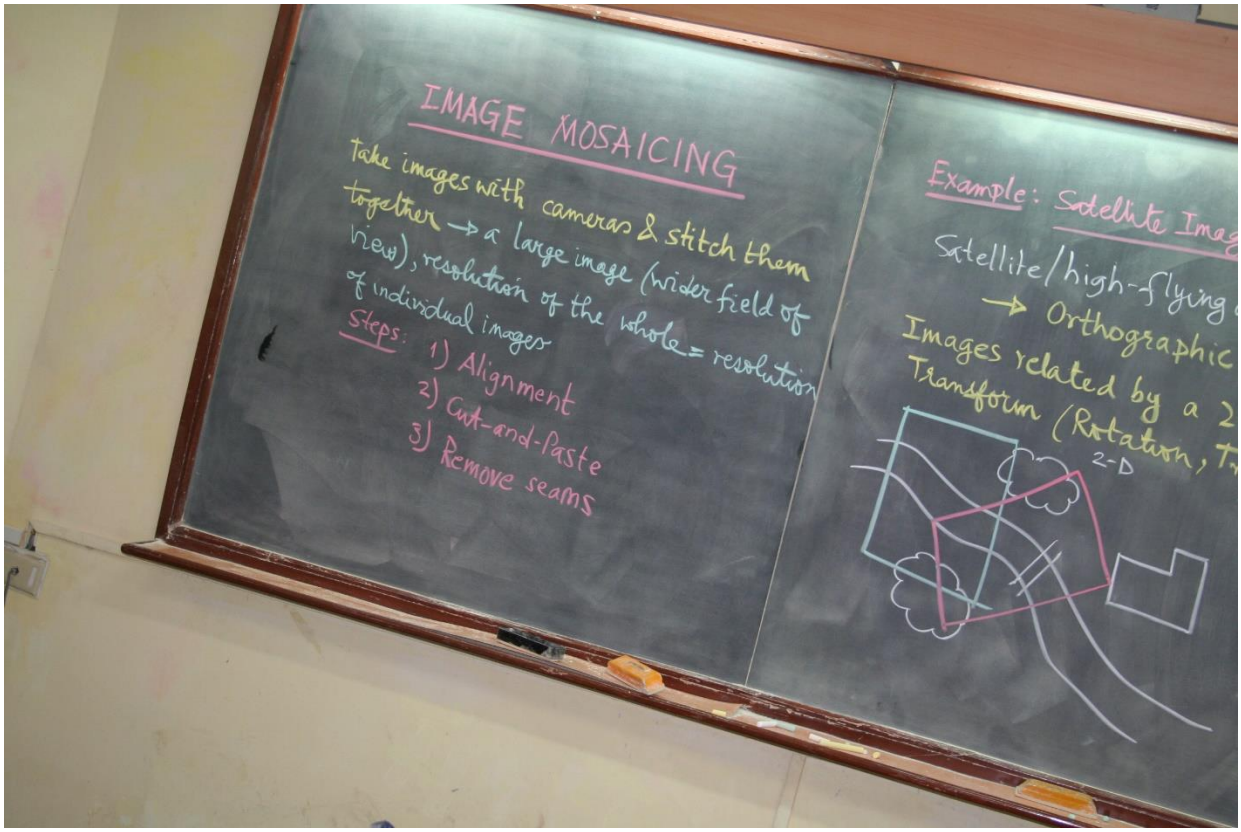
IMAGE MOSAICING
Take images with cameras & stitch them
together → a large image (wider field of
view), resolution of the whole = resolution
of individual images
Steps: 1) Alignment
2) Cut-and-Paste
3) Remove seams
Example: Satellite Imag
Satellite/high-flying
→ Orthographic
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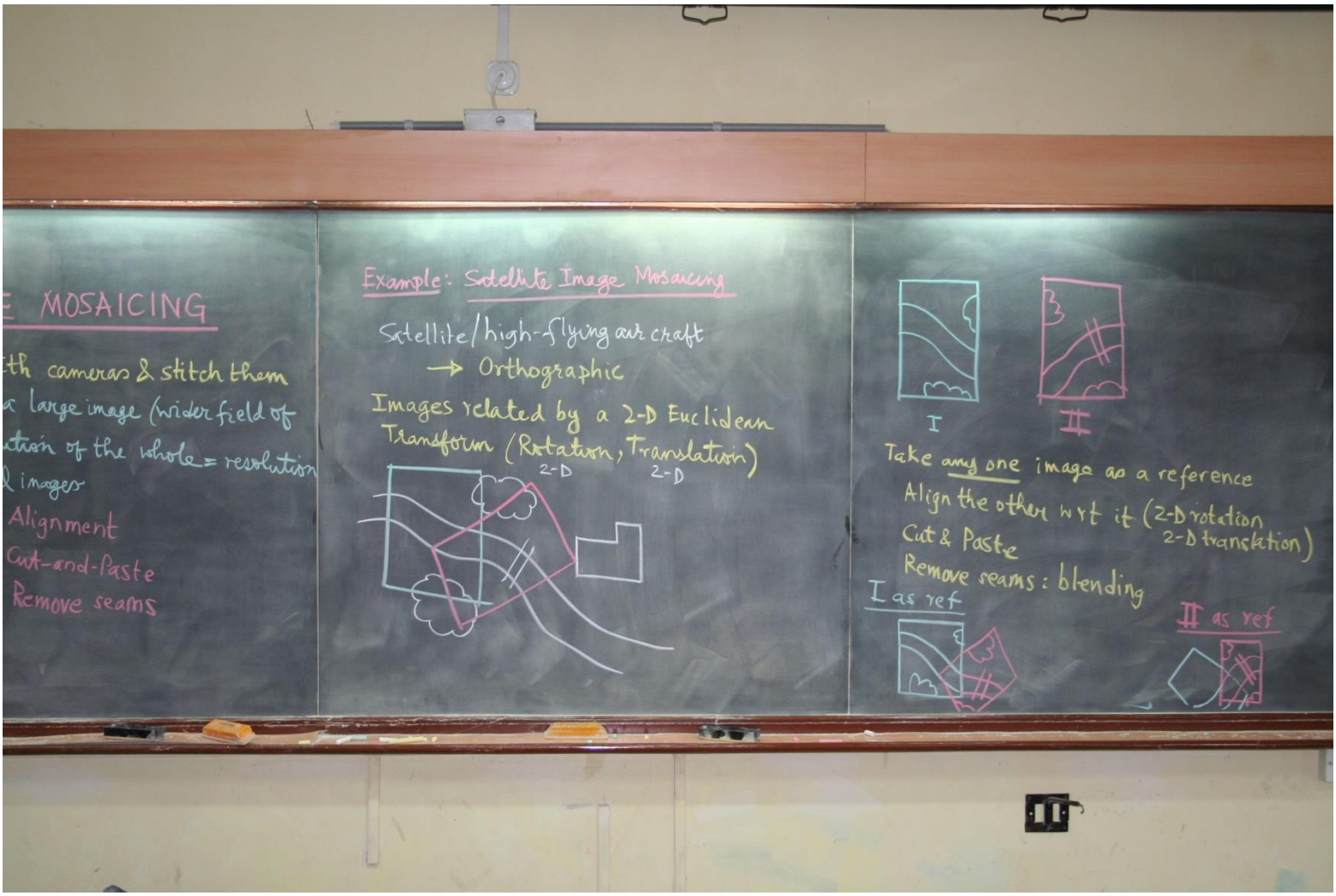
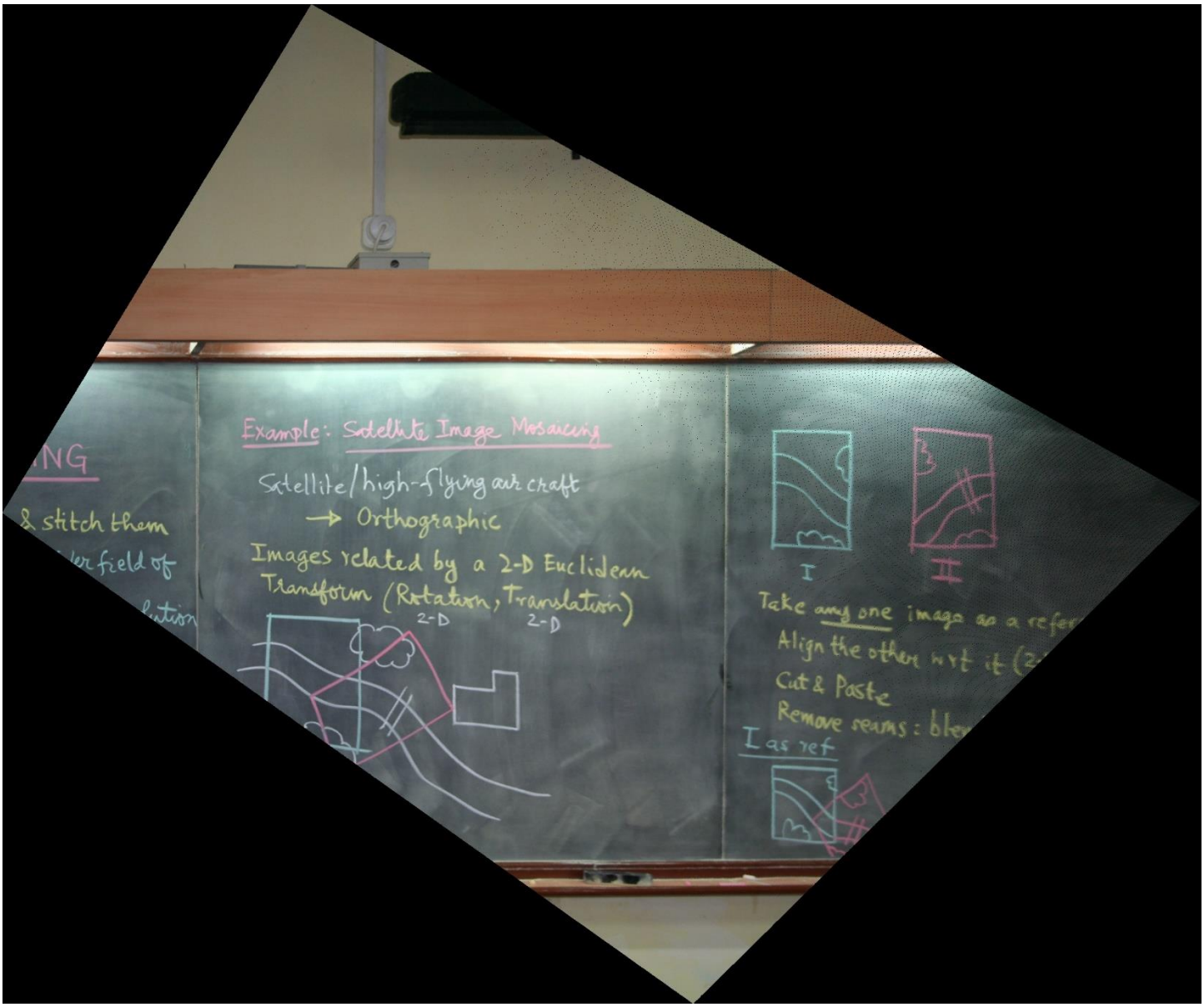
Reference Image



Images after removing Projective Distortion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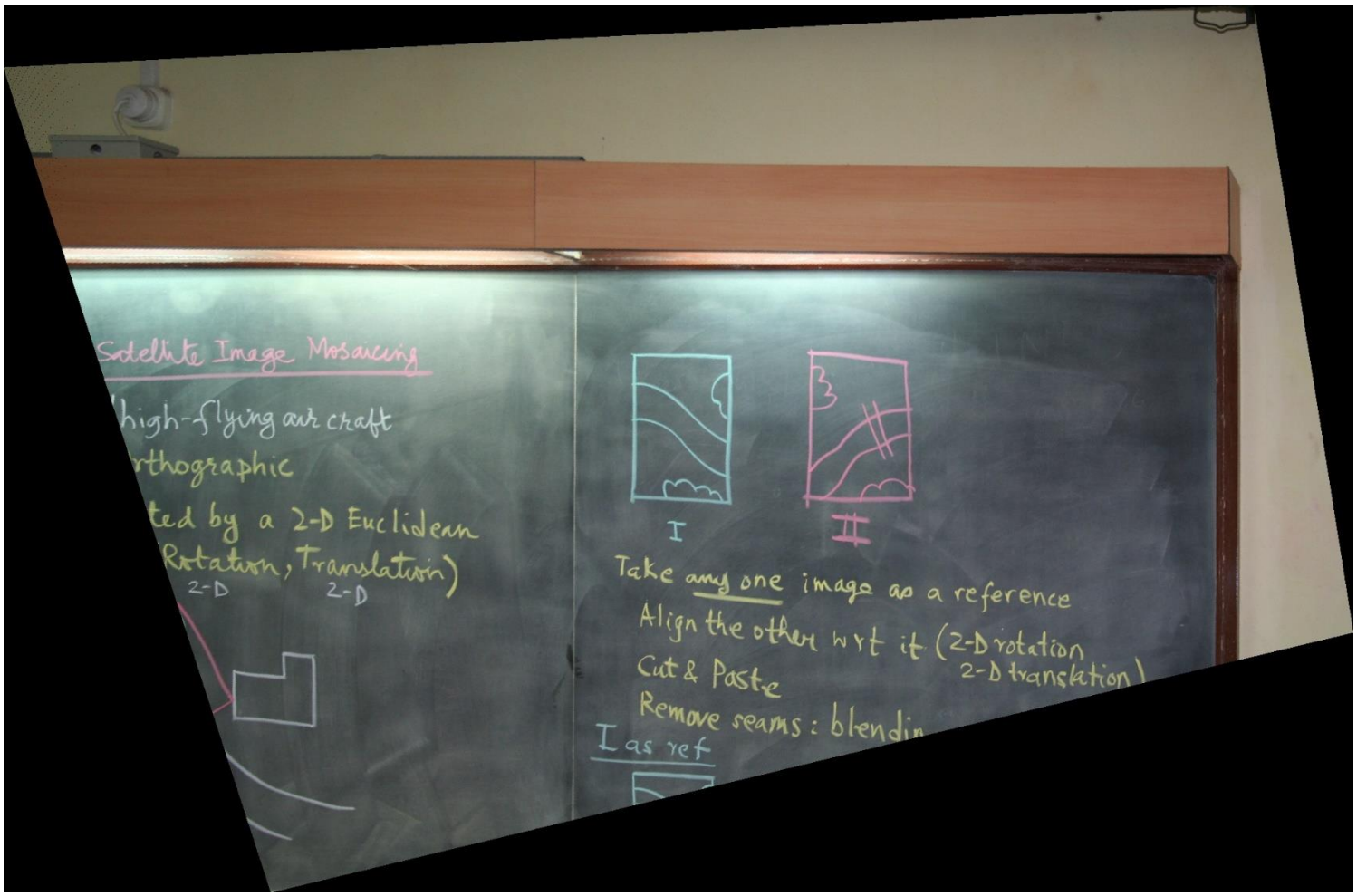
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Remove seams : blending

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II as ref

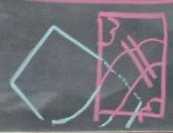


IMAGE MOSAICING

Take images with cameras & stitch them together → a large image (wider field of view), resolution of the whole = resolution of individual images

Steps: 1) Alignment
2) Cut-and-Paste
3) Remove seams

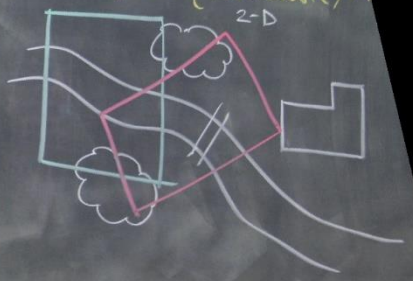
Example: Satellite Imag

Satellite/high-flying

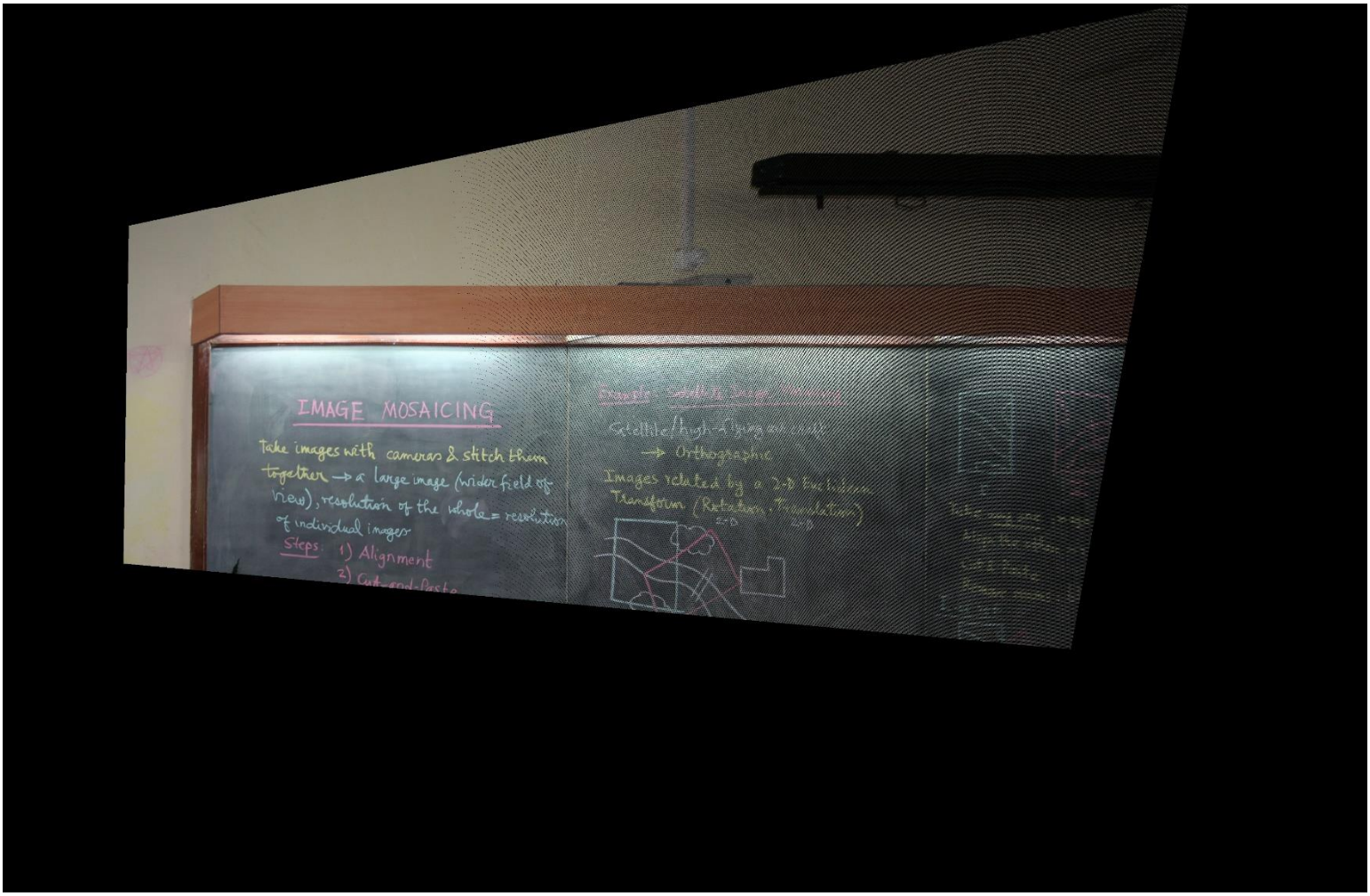
→ Orthographic

Images related by a 2

Transform (Rotation, T



Output Images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Steps: 1) Alignment
Images related by a 2-D Euclidean Transform (Rotation, Translation)


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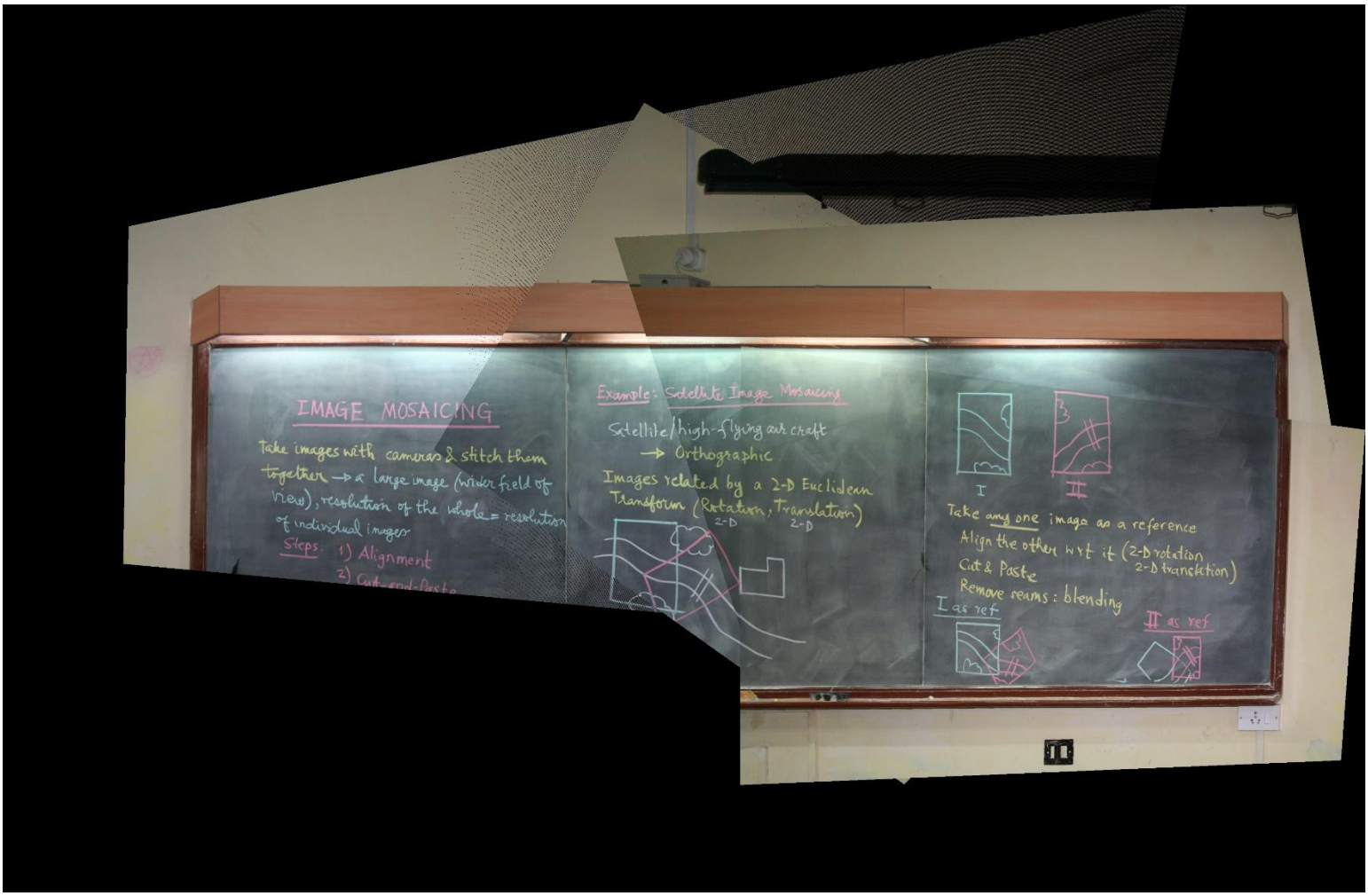
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II as ref

IMAGE MOSAICING

Take images with cameras & stitch them together → a large image (wider field of view), resolution of the whole = resolution of individual images

Steps:
1) Alignment
2) Cut-and-Paste
3) Remove seams

Example: Satellite Image Mosaicing

Satellite/high-flying aircraft
→ Orthographic

Images related by a 2-D Euclidean Transform (Rotation, Translation)
2-D 2-D

Take any one image as a reference
Align the other wrt it (2-D rotation 2-D translation)
Cut & Paste
Remove seams: blending

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Observations:

- **To remove projective distortion, we first need a reference image and corresponding points of other images to that image.**
- **Then we calculated the homography and find undistorted image using it.**
- **We also needed to find the dimension of the image that is to be produced after stitching these undistorted images to each other. For that we find the global max and min value rows and columns of each image after removing distortion and make a black image with these dimension for result.**
- **Then We mapped the images accordingly using reverse mapping and no point will be out as we have already accounted for the offset. As we plot the image points from which we have removed distortion according to the reference image, the points overlap each other accordingly and a clear image with all the parts of the blackboard is obtained with almost perfect alignment.**
- **We have used 25 reference points in place of 4 to get more accurate homography matrix.**
- **We used Mat objects for storing images and vector<Point2d> to store the points.**