Color Recovery of IR Image for Tele-Operated Robot

Suthawan Jirandorn  
Faculty of Engineering  
Thai-Nichi Institute of Technology

Kosuke Sato  
School of Engineering Science  
Osaka University

Abstract

Tele-operated inspection robots have the potential to reduce workers various risks. One of the major problems is low visibility of grayscale images taken when the robot is exploring in a dark environment. The main purpose in this research is to extend the existing colorization method which generates colorized images from grayscale images using manually-given color cues.

Our method consists of the following two phases. The first is pre-acquisition of environmental landmarks and their colors as prior knowledge in a bright condition. In the second phase, in a dark condition during blackout, the feature points corresponding to the landmarks are detected in acquired frames and the frames are colorized with the landmarks colors. Then using the colorization algorithm to propagate colors based on the pattern of input grayscale image.

In the experiment, we used a grayscale image converted from the ground truth color image and the color marks provided by an open source SLAM software, PTAM were given to the input image at the landmark positions.

Keywords: colorization, SLAM, PTAM, color marks

Introduction

Robot is a virtual intelligent agent which can perform complicated tasks automatically or by remote control such as tele-operated robot which is controlled from a distance. Various types of robots were invented in order to support different purposes. One of the various purposes is to reduce workers risks for example in the industry field, the inspection robots were built to inspect the specific area. However a major difficulty with inspection task is low visibility of grayscale images which occurs when the robot operates in a light-deficient area. This problem cause low performance in controlling task that is the main problem in tele-operated robot.

One of several approaches to resolve low visibility of grayscale image is through recovery the color of grayscale image by using colorization method. In this paper we used colorization using optimization [Levin at al.,2004], a simple but effective method, which requires a few color scribbles as cues from user input. Then the scribbled colors are automatically propagated in both space and time to produce a fully colorized image. Nevertheless this colorization method remains human labour requirement and time-consumption from manually-inputting task. Therefore rather than acquisition color cues from user scribbles, we exploit SLAM (Simultaneous Localization and MAppling) algorithm for automatic acquisition. However SLAM algorithm has never been used for colorization task before thus this contribution is a novel automatic colorization technique which relieve user’s task and reduce time-consumption.

SLAM Algorithm

SLAM (Simultaneous Localization and Mapping) is a technique for robots to create a map without a prior knowledge or improve an existing map within a known environment, while keeping track of their current location at the same time. In this work we exploit one of SLAM techniques called PTAM (Parallel Tracking and Mapping) which is split tracking and mapping into two separate tasks, process in two parallel threads.

PTAM works by detecting environmental landmarks from video frames which denoted as edge of objects and feature points in the frames. The color information and position in 3-D coordinates of each landmarks are gathered. These landmarks are represented as color dots.
Figure 1: A video frame with feature points at landmarks are shown as color dots

Then generates a map in 3-D coordinate system. This map consists of feature points and the current camera position from the landmarks which is updated in real-time.

Figure 2: 3-D map with feature points and camera position from the landmarks

In our experiment we used two still images which taken from different angles. One of the images was converted from color image to grayscale image.

Figure 3: Color image (left) and grayscale image (right) taken from different angles

At first, to acquire prior knowledge we used PTAM to detect the landmarks from two images. Then, we find corresponding positions between feature points in color image and feature points which correspond to the landmarks in grayscale image. From the test 294 corresponding points were detected and collected in 2-D format.

After we obtained corresponding points between two images, color marks were generated and given as color cues at the corresponding points to grayscale image. By testing with different size of color marks, 3x3 pixel of color marks are optimal and provided the best result.

Figure 4: Grayscale image with 3x3 pixel of color marks

**Colorization Method**

We used colorization using optimization method proposed by Anat Levin. This method works in YUV color space where Y is the monochromatic luminance channel, which simply mentioned as intensity, while U and V are the chrominance channels.

This algorithm requires an intensity volume Y as input to produce outputs two color volume U and V. The principle of this algorithm is noted as two neighboring pixels should have similar colors if their intensities are similar. Therefore, we have to find the minimum result of the difference between the color in channel U at pixel r, U(r), and the weighted average of the colors at neighboring pixels r,s. This principle depicts the following equation.

$$J(U) = \sum_r (U(r) - \sum_{s \in N(r)} w_{rs} U(s))^2$$  \hspace{1cm} (1)

Where $w_{rs}$ denotes weighting function which becomes larger when an intensity at pixel r, $Y(r)$, is similar to an intensity at pixel s, $Y(s)$.

$$w_{rs} \propto e^{-(Y(r) - Y(s))^2/2\sigma_r^2}$$  \hspace{1cm} (2)

Where $\sigma_r$ is an variance of the intensities in a window around pixel r.

This method needs some of color scribbles as cues, then the indicated color are automatically propagated until an intensity boundary is found. In the
experiment color marks provided by PTAM were given as color cues. Then, by using colorization using optimization method the colors from color marks are propagated within each intensity boundary.

Figure 5: Grayscale image with color marks provided by PTAM (left) and Colorized image based on colorization using optimization method (right)

Result

We experimented colorizing grayscale image with 3 different sizes of color marks 1x1 pixel, 3x3 pixel and 5x5 pixel. The result show that 3x3 pixel of color marks provided the best quality of colorized image.

Figure 6: Colorized image generated by using 1x1 pixel (a), 3x3 pixel (b) and 5x5 pixel (c) color marks size. And compare the result to groundtruth (d)

Moreover, we evaluated the quality of colorized image by comparing the result image with groundtruth. To compare the quality we computed the difference between two images and indicated with pseudo color.

Figure 7: Pseudo color chart indicates difference between colorized image and groundtruth, where red denotes maximum difference and blue denotes minimum difference

Conclusion

The result demonstrates that the colorized image is similar to the one in reality and the colors are close to the ground truth.

This result indicates SLAM algorithms can be employed to give color marks automatically for the colorization task. However, the quality of the colorized image was not enough depens on quantity and position of color mark provided by PTAM. In addition, there were a number of parts with noticeable incorrect colors.

And the remarkable limitation of our framework is regarding the prior knowledge. Our method needs information of landmarks from the first phase, in bright condition, to give color marks to the frame from second phase, in dark condition. It imply this framework cannot be used under unknown environment.

Future Work

Our future work is to augment the quality of colorized image by considering where and how to pick up the original colors and draw them as cues on the inputs grayscale image. Furthermore, improving colorization algorithm which is able to produce more effective result.

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