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5—4 A Way to Exploit Highlights in Metallic Environment for Pipes Localization.

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Abstract

Reprocessing cells of nuclear plants are constituted by a great number of specular metallic pipes. When they are illuminated, this kind of pipes generates areas of high light intensity, called highlights. The latter can produce erroneous results, especially in edge detection. The matter of this paper is to suppress and further to exploit the highlight effects. With this aim in view, we propose a system based on the polarization of light, which not only suppresses highlights in the scene but also uses them to extract relevant information like the pipes axes at the video rate.

1. Introduction

Interventions in reprocessing cells of nuclear plants are often performed by teleoperated robots equipped with a camera and a light source. It is difficult for the operator to steer itself in this kind of cell, because it is constituted of a great number of repetitive structures of pipes. Our work aims at providing a system able to localize the robot inside the cell at any time to help the operator. A database of the cell is provided (Fig. 1), it may be incomplete – some pipes may be missing in the database, or on the contrary some pipes of the database may not exist in the real cell – or imperfect – the position or the orientation of some pipes in the database may differ from these of the corresponding pipes in the real cell -.

The detection of the pipes is a crucial part of all the treatment. So, we were first interested in providing an as much performing as possible low level part.

In addition, the pipes in the cell are metallic. Thus, the pipe illumination by a light source brings areas of high light intensity, called highlights. Highlights often cause image processing failures, which lead to image misinterpretation.

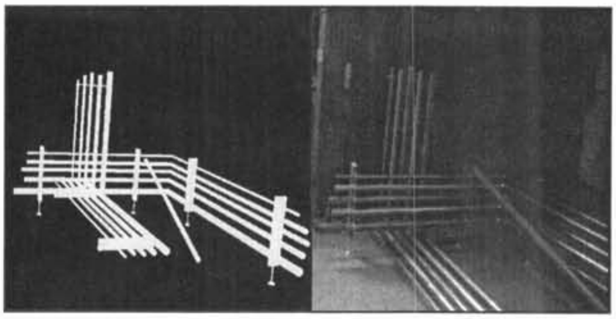

Figure 1 : Database and real scene.

For example, in edge detection, highlights bring virtual edges which can be taken for the real pipe edges (Fig. 2).

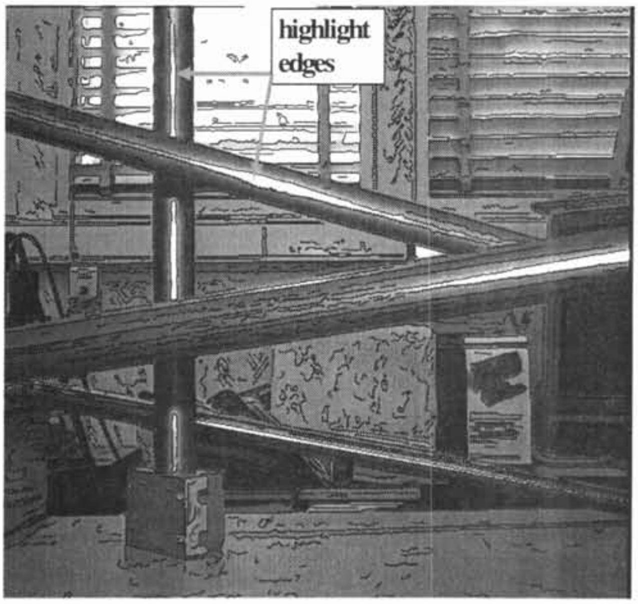

Figure 2 : Canny gradient image : virtual edges created by highlights.

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Our concern is to tackle these artifacts problem. For this purpose, we propose a polarization based system, which suppresses highlights and exploits them to extract the axes of the pipes, by discriminating the scene from the background. This system is described in [2].
At first, we will present some theoretical notions on the polarization of light. Then, we will quickly describe the system and show images to illustrate the method to extract the axes of the pipes. And, we will conclude with the advantages and the limits of the system, and possible usages of the system.

2. Polarization of light properties

Ordinary light consists of a mixture of waves vibrating randomly in all directions perpendicular to its direction of propagation. Polarized light is a light, in which the vibration of the electric or magnetic field is confined to one plane. It can be obtained to a varying extent (depending on the angle of incidence) by reflection. It can also be obtained by double refraction on certain crystals, such as calcite. These crystals have the property of refracting unpolarized light in two different directions, the ordinary ray and the extraordinary ray ; both are polarized in direction perpendicular to each other.
In our case, we use linear polarizers. They transmit a beam of light whose electric field vector vibrates in a plane that contains the beam axis. Because of this, such devices are sometimes called plane polarizers. The orientation of this plane in space can be varied by rotating the polarizer about the beam axis. Incident light whose electric field has a component perpendicular to the transmission direction of the polarizer have that component absorbed, reflected or deflected depending on what scheme is used. Two perfect polarizers placed behind one another, with theirs transmission axes perpendicular - they are then said to be crossed -, totally stop any light beam, whatever its polarization.
The polarization [1] [7] of light is used in computer vision since the eighties. The aim was generally to separate the specular part from the diffuse part of the light after reflection on an object [9] [10]. The objects studied were dielectric, which strongly polarize the light [8]. In 1991, Wolff and Boult [12] have proposed a method to distinguish dielectrics from metals in black and white images, thanks to theirs polarization capacities. All of them use the polarization of light caused by reflection on an object. As for us, we choose to polarize the light source [2]. We used a pair of polarizers, one placed in front of the light source oriented so as to maximize specularities and the other placed in front of the camera crossed with the first one, in order to minimize specularities in the image (Fig. 2). The difference between these images will be exploited to extract further information.

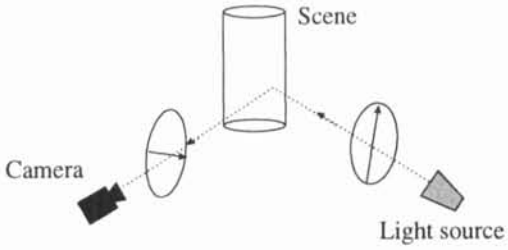

Figure 3 : Usage of a pair of polarizers crossed to minimize specularities.

3. Suppression and usage of highlights

As it was mentioned above, the system is precisely described in [2]. Just remember, we take two images, one, called Im_{max}, which maximizes specularities (Fig. 3) and the other called Im_{min}, which minimizes specularities (Fig. 4).

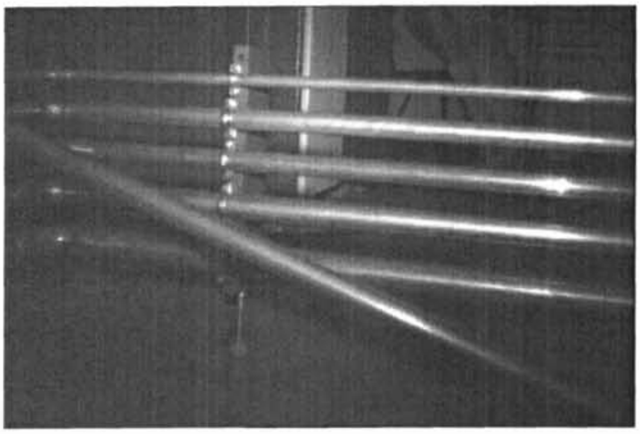

Figure 4 : Luminance image when polarizers are parallel.

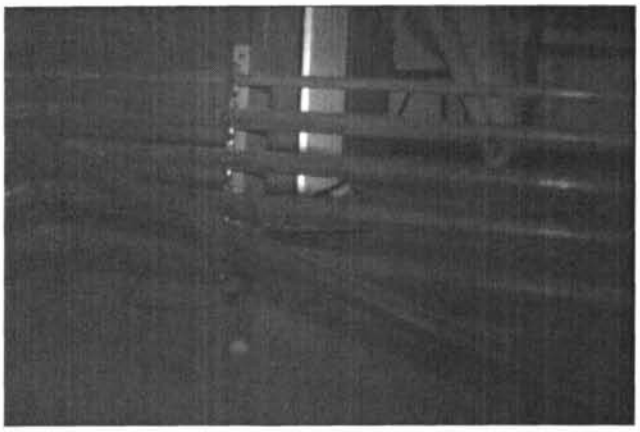

Figure 5 : Luminance image when polarizers are crossed.

Notices

- An edge detection in Im_{min} is more robust than in Im_{max} because highlights caused by the light source were removed.
- When Im_{max} is divided by Im_{min}, the strong ratios correspond to highlights caused by the light source. On the opposite, the background and the other highlights stay at the same intensity range, so their ratios are close to unity.
- It is obvious that if the view point is shifted between the two shots, the strong ratios do not correspond anymore to highlight zones. So, the above system does not work when the robot moves. We have then patented a simple system which allows to take two orthogonally polarized images without stopping the robot [2]. It is based on a Thompson prism which provides a simple way to split a beam of light into two mutually orthogonal linearly polarized beams, convenient for double imaging of a single source.

By dividing the first image by the second one, highlight zones correspond to strong ratios. Thus, thanks to a simple thresholding (Fig. 5), these zones can be easily extracted from the ratio image. On the opposite, the background and the other highlights stay at the same intensity range, so their ratios are close to one. This operation permits to discriminate the scene from the background.

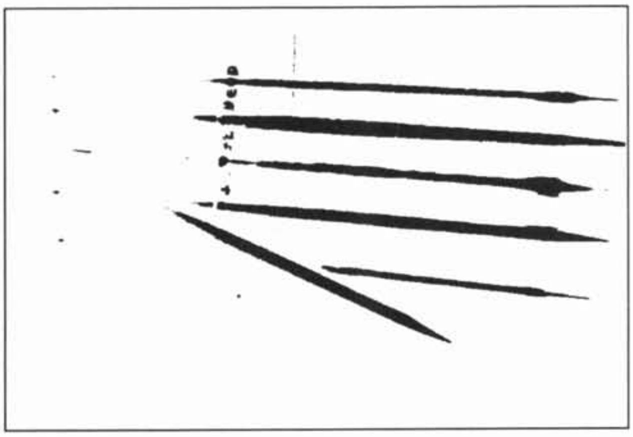

Figure 6 : Ratio image after a basic thresholding.

Then, the symmetry axis of each zone (in fact, we consider that little highlight zones do not correspond to pipes) is estimated which gives the direction of the pipe axis. Indeed, we can be prove than the highlights axes coincide with the pipes axes. The highlights axes are drawn on the image which maximizes highlights (Fig. 6).

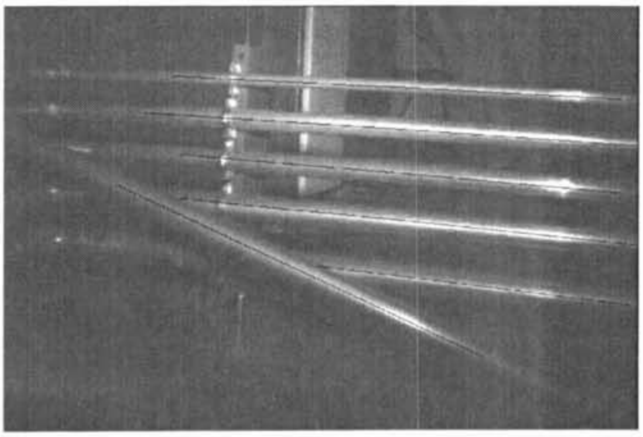

Figure 7 : Image with the axes of highlights.

4. Advantages and Limits

- Our method of pipes axes detection is faster than classical methods which consist in estimating theoretical parameters of the specular part of light intensity model. So, it suits well to real time processing.
- On the other hand, the more the lighting incidence direction is normal to the pipe, the stronger the highlights. And, on the opposite, the more the incident ray is shifted in relation to the normal direction, the weaker the highlights. In this case, information to extract pipes axes is not always sufficient (Fig. 7).

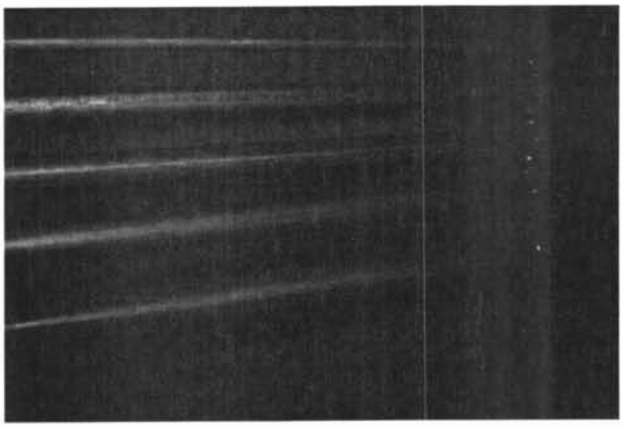

Figure 8 : Im_{max} with few highlight information because the incidence direction of the light is not normal to the pipes.

- Furthermore, in complex scenes, phenomena of interreflection may generate a depolarization of the reflected rays, so the specular part is not wholly suppressed when the polarizers are crossed (Fig. 8).

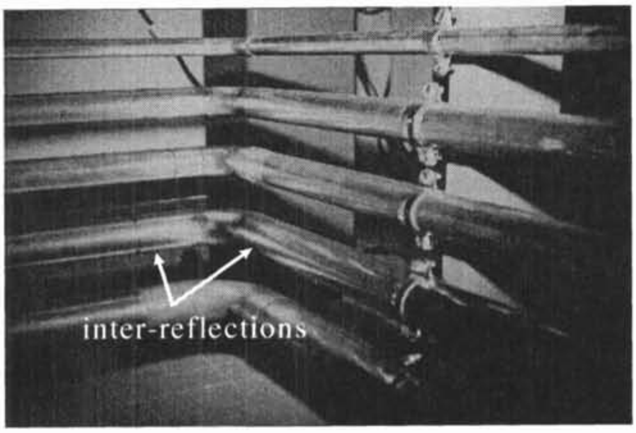

Figure 9 : Phenomena of inter-reflection caused by an elbow.

5. Future works

The system described above is able to extract axes of the pipes in the image. We can keep axes as image measures, and for example then track the pipes from these data (using the Kalman filter). We can also consider it possible to extract the edges of the pipes thanks to theirs axes. In this aim of view, the axis can give the direction of a directional filter ; this filter will be applied locally around the pipe to find the pipe edges (Fig. 10). The zone in which it will be applied is determined thanks to the database.

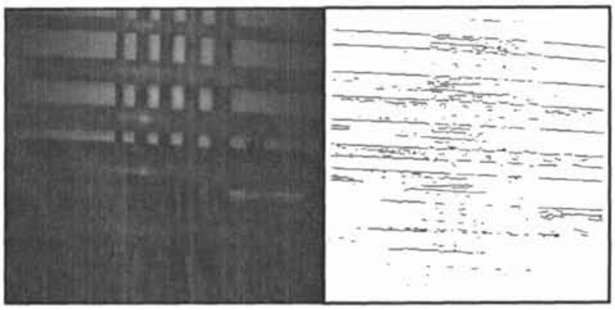

Figure 10 : Directional filter applied on a part of a grid of pipes.

The axis can also be used as initialization of an active model, which will be attracted by the pipe edges. We are going to undertake the evaluation of these different possibilities.

We have proposed a polarization of light based system, which suppresses highlights caused by the robot light source. It also uses these highlights to extract pipes axes in images. The method is easily implemented and suits well to real time applications. Furthermore, images without highlights, are easier to process. For example, an edge detection method will be more reliable on such an image.

Our future works tend to deal with images which do not contain enough information to estimate pipes axes an then exploit the axes of the pipes to localize the robot in the environment.

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