On the Optimisation of Intelligent Robots for Error Detection of Shadow Regions

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Abstract. With the continuous development of robotics, the improvement of visual obstacle avoidance has become an important direction to achieve autonomous navigation. However, the presence of shadows seriously affects the robot's visual recognition system, resulting in poor obstacle avoidance. Therefore, this paper considers it necessary to give appropriate optimization for some recognition problems of shadow removal. In such a background, this paper designs a new shadow removal method based on the properties of image colour, pixel luminance value, and chromaticity of the shadow part. The method combines morphological processing and median filtering algorithm for noise removal, and simulation experiments are carried out in a Matlab environment to achieve more satisfactory results. The experiments show that the proposed method has higher accuracy and wider applicability in removing marker shadows, and can effectively improve the visual obstacle avoidance ability of the robot. However, the method is not effective for dynamic image processing, and it is expected to solve this problem by training artificial intelligence models in the future.

Keywords: Shadow, Shadow detection, Visual obstacle avoidance.

1. Introduction

In recent years, intelligent machines have gradually become popular, and intelligent robots play an irreplaceable role in people's lives. In the process of achieving the universalization of intelligent robots, robot visual obstacle avoidance is an essential part. Robot visual obstacle avoidance is to detect obstacles from the scene and avoid them. However, in the actual process of intelligent robot obstacle avoidance, obstacles in the scene often carry more or less shadows due to the presence of various lights. These shadows have the same or similar characteristics as the obstacles that produce them, which makes it easy for intelligent robots to treat the shadows as obstacles during the image processing detection process and hinder their work [1].

Foreign research has made important advances in the field of visual obstacle avoidance, for example, algorithms based on colour extraction and edge detection have been used for road recognition. Since, boundary wear makes colours unsuitable for boundary extraction, their system introduces a Bezier spline edge detection algorithm with control point optimisation to extract the edges that best fit the road boundary [2]. Detection based on this approach achieved significantly better results than using only colour extraction, but there were limitations of shadows and light intensity.

Domestic studies have pointed out that the first step in robot visual obstacle avoidance is to detect obstacles from a designated monitoring scene and avoid them. However, in the actual indoor intelligent robot obstacle avoidance process, due to the presence of various light, the obstacles in the scene often more or less carry shadows, and the shadows and the obstacles that produce shadows have the same or similar characteristics, which makes the intelligent robot easy to take the shadows as obstacles in the image processing and detection, which disguises the enlargement of the obstacle area, while reducing the feasible area, thus affecting the robot's walking. This makes it easy for the intelligent robot to treat shadows as obstacles during image processing and detection, which in effect enlarges the obstacle region and reduces the feasible region, thus affecting the robot's walking.

If the robot is to be widely promoted for use in the market, it is also necessary to optimize the design of the robot's visual obstacle avoidance function. This paper aims to further improve the robot's ability in detecting obstacles, therefore, in this paper, after analyzing several characteristics of shadows, the image will be denoised using morphological algorithms and median filtering algorithms, and then a simulation experiment is designed to simulate the process of shadow removal, which provides a new design for the robot's visual obstacle avoidance planning method in the process of travelling.

2. Methods

2.1. Shading characteristics

Shadows are dark areas formed when light is blocked by non-transparent objects and can be divided into intrinsic shadows and projections. Principal shadows are part of the obstacle itself and help to enhance the three-dimensional sense of the object and need to be preserved, and their impact on the visual obstacle avoidance of intelligent robots is not significant. However, the presence of projections often results in the extracted obstacle area being larger than the actual area, causing problems such as larger shape changes. Therefore, it is the projection of the object that needs to be considered and removed in the target extraction process when processing the image.

In general, the luminance value of each pixel in the shaded region is lower than the luminance value of each pixel in the non-shaded region compared to other regions, in addition, the colour of each pixel in the shaded region is different from that of each pixel in the non-shaded region, and shadows can not change the texture features of the background region. For shadow removal, it can be divided into three methods: physical model-based methods, shadow feature-based methods and Matting image extraction [3]. Physical model-based methods mainly analyse the physical process of shadow formation and use some algorithms to derive a shadow model, based on which specific regions of the acquired image or video are matched, detected, and removed [4]. Shadow feature-based methods usually detect and remove shadows by visually finding the difference between shadowed and non-shadowed regions, and image extraction (masking) methods usually achieve shadow removal by separating the foreground from the background of an image. In this paper, based on the analysis of shadow characteristics, we propose a method to remove shadows by using the difference between foreground and background as well as morphological means.

2.2. Feature identification and extraction

Feature extraction is a very important step in the image processing process where various techniques like texture and edges can be used to identify the target area. Colour is one of the commonly used methods of recognition and it has important information in all cases of target recognition in images. In the case of making the road surface condition of the road region remain approximately the same during the recognition process, the road region will be brighter than the other shaded regions, which is commonly used as a colour based extraction method for the classification of the road region [5]. In this paper, the colour similarity based basis is used for road region recognition and optimized to improve the situation where incorrect judgments may be made for shaded regions.

2.2.1. Morphological processing

The erosion operation shrinks the edges of an image by selecting the minimum value of a pixel through the template, thus reducing noise or the prominence of small objects. The expansion operation, on the contrary, expands the edges by selecting the maximum value within the template, connecting separated image regions. The combination of the two forms an open operation (erosion followed by expansion) and a closed operation (expansion followed by erosion), which enables noise removal and boundary smoothing. Fig. 1 and Fig. 2 show the effect of erosion and expansion on binary images, respectively.

Erosion is the process of using a rectangle of width m and height n as a template, and doing the following for each pixel x in the image: pixel x to the centre of the template, and depending on the size of the template, iterating over all the other pixels covered by the template, modifying the value of pixel x to be the smallest value among all the pixels. The result of this operation is that the salient points at the periphery of the image will be eroded. The principle of corrosion is simply that, in the background is black (0), the foreground is white (1) in the image, the core (1) and its coverage of the image part of the 'with' operation, if all the 1, the pixel is 1, otherwise 0; that is, the 1 is not easy to get, the white part of the less white part of the white part of the image is corroded (Fig. 1).

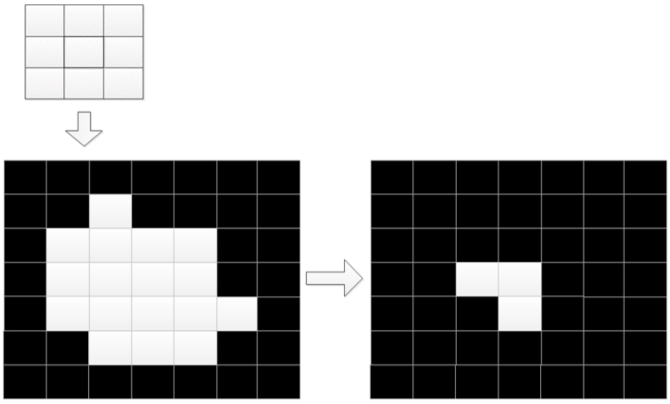

Figure 1. Erosion

Expansion also takes a rectangle of width m and height n as a template and does a traversal of each pixel of the image [6]. The difference is that the value of the modified pixel is not the smallest value of all pixels, but the largest, and the result of such an operation connects and extends the salient points on the periphery of the image outwards, expanding the boundary of the pixel-connected components of the binary image each of which is 1 by one layer (Fig. 2).

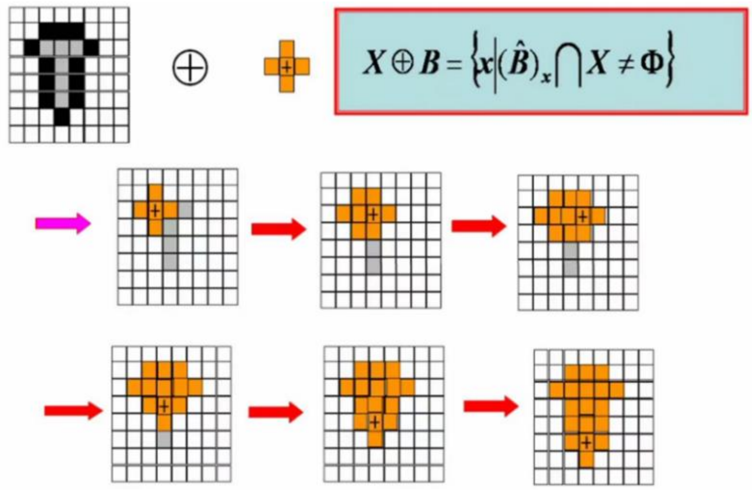

Figure 2. Expansion

Eroding first and then expanding is used to eliminate small objects, to separate objects at slender points, to smooth the boundaries of larger objects without significantly altering their area, and to eliminate protrusions on the surface of an object to achieve the morphological open operation.

Expanding and then eroding an image is a closed operation. The result is generally that many close blocks can be connected as a connected domain without protrusions. The original image is first expanded to combine two separate blocks, then eroded to flatten the edges and protrusions of the connected domain, and finally, a connected domain without protrusions is obtained [7].

2.2.2. Filtering algorithm denoising

In the current filtering algorithm pathway used for image denoising, in this paper, the value mean value filtering algorithm or filtering algorithm is considered for calculation.

The mean value filtering algorithm first determines the neighbourhood range for each pixel in the image. The size of the neighbourhood can be set according to the demand, such as 3×3, 5×5 neighbourhood, etc. Then calculate the average of the grey values of all the pixels in the neighbourhood, and take this average as the new grey value of the central pixel. For the current pixel point (x, y) to be processed, select a template which consists of a number of pixels in its immediate neighbourhood, find the mean value of all the pixels in the template, and then assign this mean value to the current pixel point (x, y) as the grey level of the processed image at the point g(x, y), i.e., $g(x, y) = \sum f(x, y)/m$, where m is the total number of pixels in the template including the current pixel.Because this is done for each pixel, this smoothes out regions that may be due to drastic changes in grey values due to noise, achieving the effect of smoothing the image. The disadvantage is that since the average of the pixel values in the neighbourhood of each pixel is used as the new value for that pixel, although it makes the noise suppressed to a certain extent, the mean filtering algorithm may make the image blurrier due to its weak ability to differentiate between the edges and the details, and in particular the texture details and the fine features of the object are easily lost [8].

The median filtering algorithm is for each pixel in the image, a neighbourhood of fixed size is selected, all the pixel values within the neighbourhood are sorted, and then the original value of the central pixel is replaced with the sorted middle value. Since noise usually manifests itself as isolated extreme points, median filtering can effectively remove these noise points, while at the same time better preserving detailed information such as the edges of the image, so as to achieve the smoothing effect of the image. Unlike the mean filtering algorithm, the median filtering algorithm does not smooth the image by calculating the average value, but by selecting the middle value to replace the pixel value, which makes it perform better in removing part of the impulse noise, and to a certain extent, it can reduce the degree of blurring of the image. Therefore to avoid some isolated noise points that may arise during the process, a median filtering algorithm is used in this paper for denoising the image.

2.3. Shadow Removal Procedure Flow

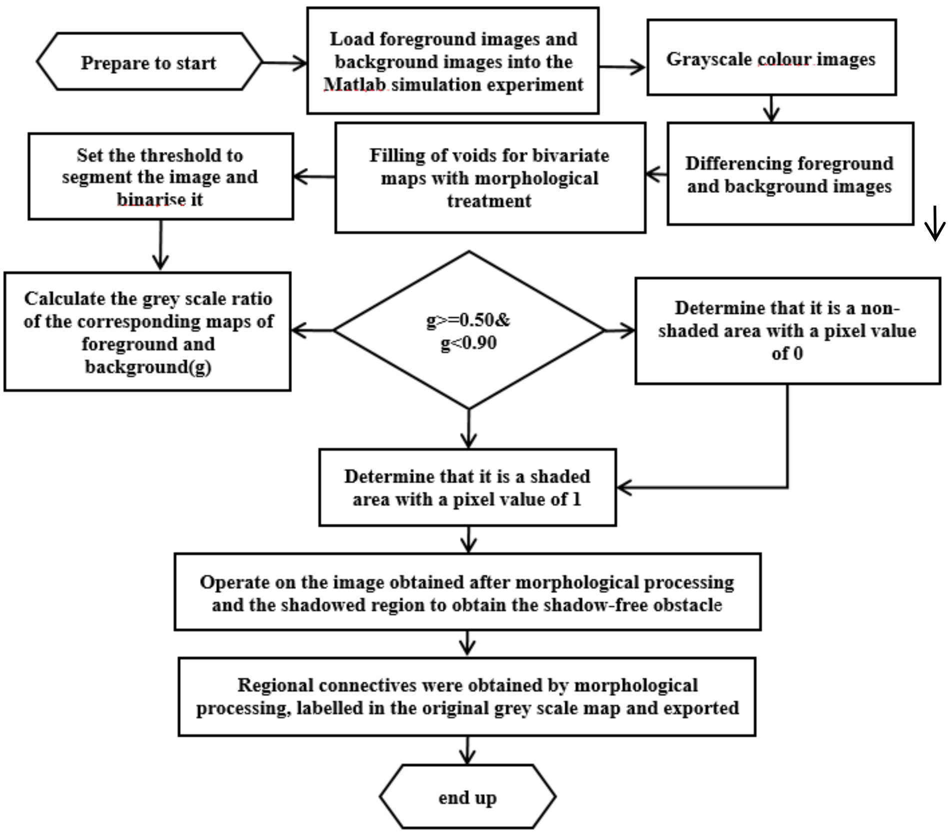

Figure 3. Flowchart of the simulation experiment

Matlab flowchart as shown in the Fig.3, for a group of placed obstacle groups, the foreground and background images taken are first stored in the memory, then the colour images in the memory are greyscaled, followed by differential method, morphology and other processing, after judging whether it is a shadow region through the grey scale ratio, and then after morphological processing to get the region connectors [9]. After many experiments, it can be seen that the greyscaling value g of the shadow part of the image is set between 0.50 and 0.90, when the shadow detection is more effective [10].

3. Discussion

The optimisation method proposed in this paper obtains clearer images through denoising means such as median filtering algorithms, making the recognition results more accurate, and at the same time identifying shadowed areas that are difficult to detect effectively using other methods. However, this method may be affected by the reflection of the object or the accumulation of grey in practical applications, and the use of artificial intelligence models to assist the recognition may be able to improve the accuracy of the results and to solve the difficulties of processing dynamic images. In this paper, we hope that this optimised shadow detection method can improve the accuracy of robot recognition in obstacle avoidance, and that the algorithm has better performance in dealing with complex shadow scenes. In order to verify the applicability of the optimised shadow detection algorithm in complex scenes, this paper combines a priori knowledge and a qualitative spatial representation for experimental validation.

This paper shows how a qualitative spatial representation and a priori knowledge of shadow regions can be combined to enhance a simple threshold-based shadow detection algorithm. However, this approach currently does not work ideally for dynamic images, so future research will be directed towards recognition techniques for shadow detection in dynamic images, while future work will consider the introduction of more complex shadow detection algorithms that incorporate shadow inference into the perception-planning-action cycle. When using filtering algorithms for denoising, it is possible to perform multiple alternating filters between the null and frequency domains, or to try different filtering sequences, evaluate the denoising effect after each iteration and adjust the parameters accordingly, and fuse these results. In the course of completing this research, this paper also raises questions and reflections that could be subject to further optimisation, such as how does shading improve object localisation when compared to object-based methods? Under what conditions can shadows be used more effectively? How can future research combine shadow-based predictive localisation with object pose-based predictive localisation? To address the possible problems, some solutions that can be envisioned in this paper are e.g., using an artificial intelligence model to go through the object features, i.e., its own shape and texture features, to compare and differentiate from the shadow features to more accurately determine the location of the object; and at the same time, using this model to speculate on the possible poses of the object based on the features of the shadows during the recognition process, and then predicting possible shadows based on the object's poses, e.g., if a person is passing in front of him, the system can quickly simulate what kind of shadow area will be created by his next walk, and use this prediction as part of the input for correction and optimisation. In addition, for spatial variations in dynamic lighting, the use of imaging devices that capture a wider spectral range or have a higher dynamic range may allow objects to be more clearly defined, thus improving positioning accuracy.

4. Conclusion

In this paper, in order to solve the problem of optimising intelligent robots for false detection of shadows, a more effective and accurate detection method is proposed on the basis of traditional detection methods. The denoising result of the image is enhanced by morphological processing and median filtering algorithm, and then the judgment of the shadow area is carried out, and finally the passable area is derived. The final experimental results show that this series of flowsheet design has achieved considerable success in accurately delineating shaded and non-shaded regions. However, the method proposed in this paper is not effective enough for shadow detection in dynamic pictures, so future optimisation based on this method can improve the accuracy and adaptability of detection by using intelligent algorithm models and then deep optimisation of the learning model to automatically learn the features and patterns of shadows. At the same time, a lighting model is established to more accurately simulate and consider the light changes in the actual scene, and to judge the occlusion relationship between objects and the generation of shadows, to detect the shadows due to light changes.

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