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A SIMPLE NEAR-REALTIME CRANE WORKSPACE MAPPING USING MACHINE VISION

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ABSTRACT

Overhead cranes are widely used in industries all over the world. It's not easy to control the crane without hitting things or causing accidents. Even the experienced crane operators make mistakes that cause a big loss of money and time. The reasons of this kind of incidents are the operators limitations in field of view, depth perception,dynamic environment of the workspace, lack of knowledge of the whole workspace etc. One possible solution could be aiding the operator with a dynamic map of the workspace which shows the current position of the obstacles as well as the probable high risk areas where it's more likely to find an obstacle. Once the map is created and the positions of the obstacles are known, it is possible to create virtual boundaries around known obstacle locations and reduce the crane speed in high risk areas for safe operations. The research described here is a simple yet effective method of mapping the workspace using machine vision. A camera mounted on top of the crane is used for the mapping.

INTRODUCTION

Accidents in overhead crane operation remains a problem, causing damage and injuries. According to Crane Inspection and Certification Bureau, 90% of all crane accidents occur due to human error. 54% of these incidents are the result of swinging the boom or making a list without the outriggers full extended. 40% of the victims were struck by an object. 50% of U.S. crane accidents that had injuries in 2009 resulted in fatalities.

FIGURE 1. CRANE OPERATOR POSITIONING PAYLOAD

Recent development in crane vibration reduction research has greatly reduced the vibration of the crane, which in turn greatly increased the efficiency and reduced the time of operation. One of these techniques is input shaping [1], [2]. It preshapes the command input by convolving a sequence of impulses with desired system command. The convolved signal is then used as the reference command. This technique has been proved very useful for vibration reduction of cranes [3], [4].

The vibration reduction techniques greatly reduced the

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cranes probability of running into things. But still because of lack of knowledge of the workspace and the common flaw of human perception in sensing distance and depth and limitations in field of view makes it difficult to safely moving cranes through the workspace. One good solution of these kind of problems is aiding the operator with a 3D map of the workspace that depicts the current position of the obstacles and also the areas where there is a high probability of collision.

Researches have been carried out to model the workspace in order to avoid crushing obstacles during operations of heavy equipment [5]

The idea of using vision system was implemented in tower cranes [6], But the sole purpose was to help the operator see the workspace clearly. There was no use of mapping of the workspace or obstacle avoidance. (here I add more literature review)

In the following sections, the object detection and mapping techniques are explained. In section two, the steps of image processing, background detection, obstacle detection, elimination of payload from map and stitching technique are discussed. In section three, few possible setup of the map are discussed. In section four, the experimental results of how different kind of setup of the map may affect the distance traveled and time required for the payload to reach it's goal are compared.

Overview of Mapping

For the mapping technique used in this research,a smart camera is mounted on the crane trolley, which automatically takes pictures each time it reaches some predefined points. These images then go through a series of processing. The background is detected and the hook is masked. Then obstacles are identified and a graphical representation of the workspace is generated. The position and time information of each image is taken into account to show high-risk zones where the possibilities of finding obstacles are greater.

Individual Image Processing

For the mapping , OpenCV has been used with C++ as the programming language.OpenCV is a free online computer vision library .The map shows the current positions of the obstacles in red and high risk areas where there are probabilities of finding an obstacle in yellow. The brightness of the yellow regions depends on how long ago there was an obstacle in that spot. The steps to obtain the map is described in the following subsections.

For eliminating noise smoothing image is a good technique. In this work, the GaussianBlur and medianBlur functions are used. GaussianBlur is commonly used for smoothing, medianBlur keeps the edges while smoothing.The kernel size chosen dictates the degree of smoothness,but bigger kernel size take greater computation power.

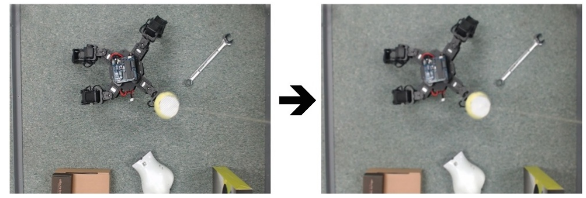

FIGURE 2. IMAGE BLURRED

To separate the obstacles from the background it's necessary to detect the background first. Ideally all pixels in the background should have same value in all three channels. But in actual case, the background pixel values are not all the same. Depending on the noise level and lighting, it may vary significantly. Moreover, the reflections of the lighting source and the shadow of the objects make it more difficult to distinguish the obstacles from the background. The method used in this research to detect the background is statistical. Each three channel of the image is divided into ranges of equal length. Then the pixels are scanned and how many pixels fall into each range is counted. The range where most of the pixels fall into is most likely to be the background value range of that image in that channel.

But scanning each pixel does not give the right background, because the background is not even in most cases and some of the objects which are bright or dark enough have much more concentrated pixel values. It means if any object is smoother than the background, scanning every pixel gives wrong background value.

(here i can make a graph to show this phenomenon) Moreover, scanning every pixel takes a big portion of computing power. One good solution is skipping pixels. It eliminates the possibility of highly concentrated small areas to be considered as background. But how many pixel value should be skipped remains a problem, because it is highly dependent on the noise level and lighting condition of the workspace. Good results came in experiment when every 700-1000 pixels are skipped.

There will always be the crane hook/payload in the image blocking a portion of field of view of the camera, because the camera is mounted directly over the the hook. A simple approach is to cover that part of image with the average background color calculated before. It's commonly assumed that the hook is in the center of the image, so a portion around the center is masked. The information blocked by the hook can be recovered from the side images after stitching. How much information from the blind spot is recovered depends on the amount of overlap among the images. A larger overlap means greater portion of information recovered.

Though it's assumed that input shaping is applied in the crane control system and the payload is always at the center of the image, a small sway of the payload makes it difficult to mask it. It's necessary to know the precise position of the payload to

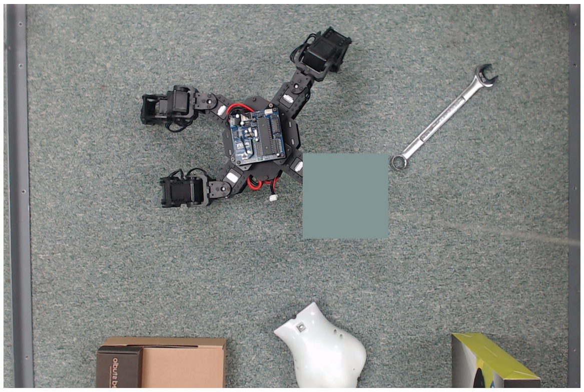

FIGURE 3. CRANE HOOK MASKED

completely mask it.

OpenCv stitcher class is used to stitch the images together. It consumes a significant amount of memory. Using the graphical processing unit for stitching significantly reduces the stitching time. The images have to have significant amount of overlap for the stitching to work correctly and in a short time. This is so because in order to stitch the OpenCv stitcher class detects key points in both images and tries to match them. Plane Warper should be selected to warp the images.

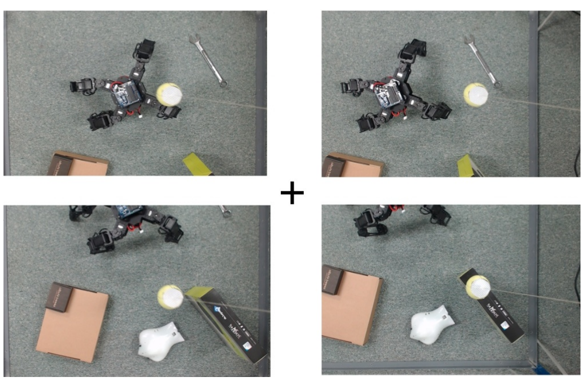

FIGURE 4. INDIVIDUAL IMAGES

Once the background is detected, the image is thresholded through two scalers close to the background. The range of these two scalar depends on the degree of noise in the background. A small threshold is sufficient for a smooth background, and gives very clean result after thresholding. The resultant image is a binary, the background being 1 and all other objects 0.

To refine the image we have, we use erode and dilate functions.These two functions removes the unwanted small blobs from the thresholded image.

FIGURE 5. STITCHED IMAGE

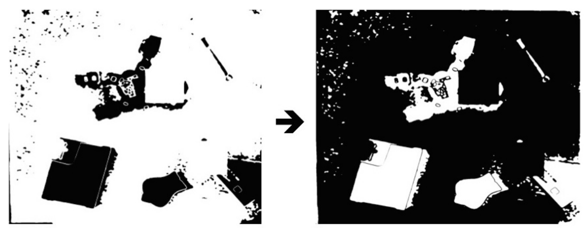

FIGURE 6. THRESHOLDED AND ALTERED IMAGE

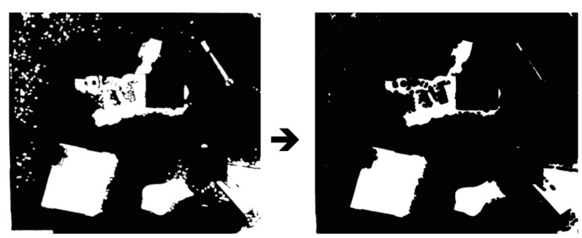

FIGURE 7. DILATED AND ERODED IMAGE

After erosion and dilation, the contours of the obstacles are extracted using findContours function. Then, a polygonal curve is estimated by approxPolyDP function. Finally, The contours are drawn using the drawContours function. The color used to draw the contours is a function of time when the images are taken, to make it apparent how long ago there was an obstacle in that place and if there is any right now.

FIGURE 8. IMAGE AFTER CONTOUR IS DRAWN

Mapping

The mapping process described above takes the latest positions of the obstacles into account. But the older positions could be helpful to know the high-risk zones. If in a particular position an obstacle appears frequently, it can be assumed that position is a high risk area. If an obstacle appears just once in a position, then it might be just a moving object or human being. The high risk zones are shown in bright yellow, and the low risk zones are shown in light yellow. The color intensity represents how frequently the obstacles appear in a particular position, hence the probability of running into an obstacle. The latest positions are always shown in red to indicate the certainty of finding an obstacle. The crane can be programmed to never enter the red areas, and slowing down at the yellow areas.

In this research, the time when a particular image was taken determines its weight. The older the the image is, the less weight it gets, if it's older than a particular time, it's forgotten. The time when it's forgotten is called forgetting factor.

For overlapping the older image, a linear or exponential decay can be used. This is a way of remembering where an obstacle was before. The latest position of the obstacle gets 100% intensity of yellow. Then the intensity of the older potation are calculated using time as variable. The slope/decay constant is assumed. The more it is, the less weight the older images get. The half-life is also calculated. If the image taken is older than the half life, it is discarded. Finally, the images are convolved to create the final map.

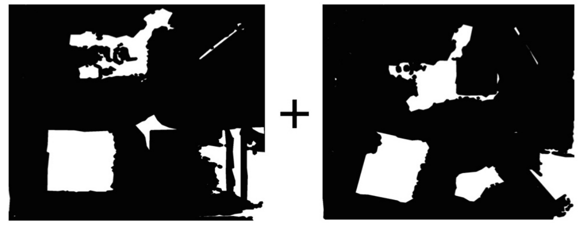

FIGURE 9. IMAGES AT TWO DIFFERENT TIMES

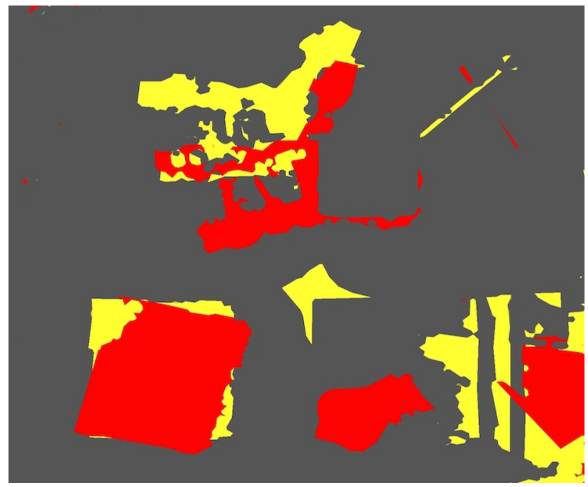

FIGURE 10. IMAGE AFTER OVERLAPPING

1 Conclusion

Although this mapping technique is very promising, there are some problems yet to be taken care of. The background detection method described is very sensitive to noise and lighting, and the parameters have to be adjusted depending on that. There is always some distortion when the images are stitched together. Every time a new image is taken, the whole process is repeated, which is a waste of time and computation power. It would be much more efficient if just the portion of the map where the new image was taken could be changed. The thresholding is also very sensitive. If there is an object which has the same color as the background, it will go undetected. If the background pixel has a wide range of values, the thresholding range has to be big, which means there will be a greater chance of missing obstacles. If the background is noisy and the threshold range is small, there is good chance that some portion of the background will be detected as obstacles. It's difficult to find the optimum value of the threshold range for a particular workspace. Depending on the time of the day, the lighting condition changes in the workspace, which makes adjustment necessary for the mapping to work properly. If the background has shiny surface, the reflection of the light could be detected as obstacles. If there are more obstacles than floor area, there is a good chance that the obstacles are detected as background and the background is detected as obstacles, making the obstacle avoidance control system stop working.

The blind spot created by the payload may be dangerous if there is a obstacle right under it, which goes undetected.

The mapping process can be improved to a 3D map, which takes the height of the obstacles into account. Disparity map using stereo vision might be a good way to do that. It will also solve some of the problems occurred in 2D mapping. Anything higher than the ground level can be assumed as an obstacle. The height-based object detection method can eliminate the drawbacks of color-based object detection. Combining these two techniques can be more robust than applying them individually.

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