A Design on robot system for artillery barrel inspection

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Abstract

Background/Objectives: In this paper, a design on robot system for barrel inspection for 155m artillery weapon is proposed.

Methods/Statistical analysis: To remove the distortion of captured image due to internal curve of barrel and camera, camera and distortion matrices are adopted for captured image. With undistorted image, pairwise stitching is done using the RANSAC. For controlling camera system and robot system, the method of socket communication is used between robot program and camera program.

Findings: The method of TCP socket program can be used for different program without delay. Therefore, with the designed platform, automatic generation of barrel image can be produced in a short time.

Improvements/Applications: Using the developed platform, the defects of artillery barrel and pipes can be inspected effectively.

Key Words: artillery barrel, inspection, stitching, panorama image
1 Introduction

Artillery has remarkable ability of destructive power. It plays important role as a major weapon enough to affect the outcome of the war. Shell mounted on tank has a smaller size than the missile, and loaded with large quantities, it can be fired during a short time to targets through gun barrel. Gun is mounted to the external are exposed to multiple environmental factors. And pressure and heat generated during firing, contaminants after firing occurs deformation. The cracks or abrasion of gun barrel occur poor accuracy. In the worst case, there is also an explosion inside the gun. For accident prevention, it should be removed the contaminant by using the "gun barrel care stick" after firing and lubricated to prevent corrosion. In addition, if it exceeds the number of times that have limited the launch, they are exchanging gun. Therefore, many researchers studied for the internal state of gun barrel. This paper provides a robot to inspect the gun internal states. The robot has wheel gear, unaffected gun rifling during traveling. Robot has a camera mounted on top of, can be close-up photography, since the rotation that can be able to record image the whole internal gun.

For general method for stitching used for panorama image of digital camera is using the Invariant feature. The features generally adopted are SIFT, SURF, ORB for stitching. The SIFT method is accurate but time complexity is high, SURF has high speed but has a demerit for accuracy. Using the feature, RANSAC (RAndom SAmply Consesus) method is used for generation of panorama image.

But, in artillery case, as the pattern is very similar in the barrel, the feature is very similar. Overall stitching all at once is not appropriate than pairwise stitching and the position of captured image can be determined using the captured sequence.

2 Proposed Work

Figure 1 shows the proposed artillery barrel inspection system, which composed of robot equipped with camera and software controlling the robot and camera system.
2.1 Robot system

Figure 2 shows the cannon robot software GUI. With the program, the control of robot system can be done using the parameter in the GUI. For the correct operation of robot, camera rotation angle and moving distance of robot have to be inputted for robot control software in the GUI.

The inspection robot, which can move in the 155mm artillery weapon, is shown in figure 3. In the robot system Driving motor is used for forward movement and backward movement of robot. Servo drive is used for camera rotation.
Table 1 shows the Robot system specification. Driving part speed is 200 mm/s and sensor rotation part can rotate with the speed of 180 deg/s. To meet the military spec, operating temperature of Robot system is $-40^\circ C \sim +85^\circ C$.

<table>
<thead>
<tr>
<th>Part</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Driving Part</td>
<td></td>
</tr>
<tr>
<td>Speed (mm/s)</td>
<td>200</td>
</tr>
<tr>
<td>Size (mm)</td>
<td>1200 x 190 (L)</td>
</tr>
<tr>
<td>Sensor (camera) Rotation</td>
<td></td>
</tr>
<tr>
<td>Speed (deg/s)</td>
<td>180</td>
</tr>
<tr>
<td>Size (mm)</td>
<td>1000 x 190 (L)</td>
</tr>
<tr>
<td>Operating Condition</td>
<td>$-40^\circ C \sim +85^\circ C$</td>
</tr>
</tbody>
</table>

2.2 Obtaining of undistorted image of barrel

To remove the distortion of captured image due to internal curve of barrel and camera, camera 3x3 matrix $^9$ and distortion $1 \times 5$ matrix$^{10}$ are generated with the 30 chess board images captured in 155mm artillery weapon. The captured image is converted into undistorted image using the generated matrices. Figure 4 shows the captured image and undistorted image using the camera and distortion matrix (1).
Fig. 4. Original image and undistorted image of Gun barrel using chess board.

\[ M = \begin{bmatrix} 5555.80 & 0 & 342.696 \\ 0 & 3873.15 & 257.883 \\ 0 & 0 & 1 \end{bmatrix} D = \begin{bmatrix} 22.9019 & 585.969 & 0.0963096 & 0 & 3873.15 \end{bmatrix} (1) \]

2.3 Communication method and control flow of system

Table 2 summarizes the communication method in the barrel inspection system. As the robot software and image processing software are developed independently, the communication between robot software and image software (capturing/processing) is needed. So TCP socket method is applied for the communication between robot software and image software. For the communication between robot and robot software, the CAN communication method is applied.

Table 2. Communication method in barrel inspection system

<table>
<thead>
<tr>
<th>Communication</th>
<th>Communication method</th>
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<tbody>
<tr>
<td>Robot Operating S/W &lt;-&gt; Camera S/W and stitching software</td>
<td>Socket</td>
</tr>
<tr>
<td>Robot (Control board) &lt;-&gt; Robot operating S/W</td>
<td>CAN</td>
</tr>
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Figure 5 shows the flow chart of robot and image processing program, which can operate the two software program.
For the generation of result image, camera rotation angle and moving distance of robot have to be inputted for robot control software GUI as shown in figure 2 and camera barrel distortion parameter have to be inputted for image processing software.

As the software operation sequence is dependent on hardware operation, 4 communication command between robot software and image processing software is needed.

1. Inspection start is a command to the robot program to set the angle position and position setting in the barrel.

2. Capture command is a command to image processing program to capture image.

3. Capture one picture is a command to robot software to permit the moving of robot and camera.

4. Inspection done is a command to enable the start of stitching

With the TCP socket, 4 communication command is transmitted to robot software and image processing software. By the experiment, little delay occur in operation of the control flow.

Fig. 5. Flow chart of robot and image processing program.
3 Results and Discussion

Figure 6 shows the inspection system implemented for 155mm gun barrel. Left side shows the robot control box and controlling PC, and right side shows the robot equipped with camera.

![Fig. 6. The inspection system for gun barrel.](image)

Figure 7 shows the 36 images captured on every 45° angle. In vertical direction, 4 rows image is captured, and $360/45 = 8$ cut is needed but last one is captured for the verification of same image. In the figure 6(a), 0th image is same with 8th image. The image $0^{th} \sim 7^{th}$ image in the figure 7(a) are stitched into bottom row image of figure 7(b). After horizontal direction stitching, vertical direction stitching is performed. Figure 7(c) shows the stitched image of overall image.

![Fig. 7. Inspection results for gun barrel](image)

4 Conclusion

This paper proposed and implemented the camera inspection system for 155mm artillery weapon. The robot equipped with camera system is controlled by program on the PC, which controls capture time and position of robot. To eliminate the distortion due to the camera and curve of barrel of artillery, the calibration is performed.
on the captured images. So the undistorted images are obtained and overall internal image of artillery is obtained by stitching the undistorted image.

References


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