Review of Railroad Facility Maintenance Technology using UAV

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Abstract
This paper which is intended to review UAV-based railroad facility maintenance technologies includes the analysis of the tendency on how to utilize growing UAV technologies for railroad facility maintenance. In the United States and European countries, task forces dedicated to railroad facility maintenance using UAV have been established to conduct the facility diagnosis and safety & security process through competent operator, analyzer and developer and UAV has been used more commonly for catenary, supports, station structure and railroad bridge. The factor to be considered before applying UAV to the inspection of railroad facility is drafty conditions and particularly, UAV used in railroad sector is small in size which is vulnerable to environmental factors. To deal with such shortcomings, the study on disturbance resistance algorithm by modeling the attitude control and drafty environment and controller design to enhance hovering accuracy have been actively underway currently. However, in a bid to be able to apply UAV to railroad facility management, it is necessary to solve such problems as sensor error and abnormal GPS signal first.

Keywords: UAV(Unmanned Aerial Vehicle), Maintenance, Railroad, Infrastructure

1. Introduction
Amid deteriorated railroad facilities and lines are increasingly on the rise throughout the world, it’s necessary to enhance the efficiency of railroad facility maintenance which has been mostly manually implemented. Maintenance cost has been soaring because of increasing number of deteriorated facilities along with increasing risk of damage to the people and the properties due to worsened safety level. Manual inspection of railroad facilities may result in subjective judgement which would possibly reduce the reliability. Furthermore, inspection tends to become qualitative without systematic management, making it difficult in implementing systematic maintenance based on data analysis. Hence, in a bid to prevent train accident, the study on railroad maintenance technologies using UAV (Unmanned Aerial Vehicle) has been underway more than ever. In this study, analysis of UAV-based railroad facility maintenance is conducted. Particularly, analysis of technical tendency on UAV control technologies considering UAV operation technology and draft was conducted.

2. Tendency of UAB-based Railroad Maintenance

2.1 UAV operation technology for railroad maintenance
In the United States and European countries which have advanced railroad technologies, many task forces or the subsidiaries dedicated to railroad facility maintenance using UAV have been established and in operation now. French SNCF has the subsidiary, ALTAMETRIS which perform UAV-based railroad facility maintenance. It comprises of competent operator, analyzer and develop with own UAV and robot (2-20 kg) and IT resource for image and point cloud information process. Responsibilities (Fig. 1) include condition diagnosis and safety & security-related missions such as remote inspection of catenary, supports, station structure and railroad bridge[1].
Network Rail (Fig. 2) in the United States performs catenary inspection and automated maintenance using UAV. It is nominated as the final candidate for 2015 UK railroad industry award in service field. It mostly comprises of UAV, dedicated asset management SW and specialized operators and is commonly applied to inspection of station roof, railroad bridge, catenary or transmission tower which are inaccessible for inspection. Because of invisible barrier such as force field on UAV body, photographing is limited. It provides the operator with safety rule and when transmitter signal is interrupted or battery is dead, it guides UAV to safely land on the take-off point. As it has 8 or more motors, it still can fly even in case of loss of one or more motors[2].

**Table 1** Specification of Network Rail’s UAV

<table>
<thead>
<tr>
<th>Payload</th>
<th>7kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel distance</td>
<td>500m</td>
</tr>
<tr>
<td>Altitude</td>
<td>400ft</td>
</tr>
<tr>
<td>Flight time</td>
<td>20 min.</td>
</tr>
<tr>
<td>Operator</td>
<td>2 persons team</td>
</tr>
<tr>
<td>Imaging device</td>
<td>HD, 4K video image and still camera</td>
</tr>
</tbody>
</table>

Inspection of whole structure including catenary top which is inaccessible is achievable. The process (Fig. 3) includes data acquisition using UAV, inspection, generation of report matrix, display and maintenance. It reduces inspection time as well as safety risk of the workers on railway by excluding the work on railway.

BNSF (Fig. 4) in the United States has the task force dedicated to railroad facility inspection using UAV. Since it started UAV operation program in 2013, it started developing UAV and SW for bridge and track inspection in 2015. In collaboration with FAA (Federal Aviation Administration), it obtained approval for a long-distance operation and has used it for a 32,500 mile-long track inspection and bridge maintenance[2].

Plowman Craven (Fig. 5), the survey specialist in UK developed UAV-based system, called Vogel R3D and provides railroad facility inspection services. As railroad inspection using UAV is performed at 25m height, it is possible to inspect the railroad even at the busiest and inaccessible area. After obtaining overlapping image by a million pixel camera and processing it to 3D data, it may be able to survey railroad facilities comprehensively at 5mm or less accuracy level. Vogel R3D system satisfies Band 1 accuracy requirement by British Network Rail and is applicable to track inspection and all GRIP (Guide to Rail Investment Process) stages[3].

**Fig. 3** Catenary maintenance solution using UAV

**Fig. 4** BNSF’s UAV-based railroad facility Maintenance

**Fig. 5** Plowman Craven’s Vogel R3D System

DESTination RAIL project in Europe (Fig. 6) is intended to solve many problems with railroad facilities. It performs operation, maintenance and repair works over 6 implementation plans including problem-finining, analysis,
classification, repair, technology integration & distribution and management. At the first stage, problem-finding, data collection using UAV and analysis are included. It collects the data on track, trackbed, slope and damage to railroad facilities by natural disaster using UAV and analysis in real time and development of DST (Decision Support Tool) is underway for improving maintenance plan[4].

KORAIL (Fig. 7) has been test operating UAV for maintenance purpose and confirmed the reduction in inspection time comparing to manual inspection.

2.2 UAV control technology at drafty condition

Train draft generated at wayside while train passes is the big constraint for UAV operation. Currently, UAV control technologies are under development to be able to withstand such draft. Chi Zhang et al. developed 3D purge PID control method for stable altitude control and tracking in a bid to cope with the vulnerability of small UAV to draft. 3D purge PID control method developed using Simulink and Dryden model (Fig. 8) proved to be superior to existing PID control method in static and dynamic characteristics[5].

Steven L. Waslander et al. mentioned that small SUV is very vulnerable to the draft which is the big threat to UAV when UAV is in operation closely. Ordinary draft condition was modeled to UAV behavior to improve the performance of altitude control and the study on draft measurement algorithm was conducted to apply it to UAV test bed[6].

C. Hancer et al. designed the controller using DOB(Dis-turbance Observer) to improve hovering performance of UAV and tested the performance at various draft conditions (Fig. 10) and consequently, hovering error from the reference point was less than 10 cm[7].

XIONG Hua et al. developed ADRC(Active Disturbance Rejection Control)-based controller to improve the speed and altitude control of UAV (Fig. 11) at draft conditions. When comparing with existing PID controller through simulation, the controller developed at various draft conditions demonstrated the enhanced speed and altitude control performance comparing to existing PID controller[8].
I. Sarras, H conducted the study to compensate the disturbance by wind in a way adopting analytical approach to object route tracking and control of UAV traveling 3D space (Fig. 12). Wind velocity was estimated using kinematic model-based analysis, control design model and I&I (Immersion and Invariance) approach and the theory to supplement UAV route tracking and control interrupted by disturbance was developed which was verified through simulation[9].

Guangying Jiang compared altitude maintenance responsiveness through the test of parallel rotor of standard multi-rotor UAV and non-multi-rotor (Fig. 13) at drafty conditions. Consequently, non-parallel multi-rotor had superior altitude maintenance responsiveness in relation to draft resistance[10].

3. Conclusion

In this study, analysis of the tendency on UAV operation technology and UAV control technology considering the draft among UAV-based railroad facility maintenance technologies was carried out. The possibility to improve the safety, reduce the maintenance cost and damage to the people and properties as well as achieve the systematic maintenance by applying UAV to labor / time-intensive inspection of railroad facilities was demonstrated. But before applying UAV to railroad facilities at the site, the problems including abnormal operation of UAV sensor or instable GPS signal due to steel transmission tower or high voltage shall be solved first. Should such problems be solved together with revision of related law for using UAV, UAV for more systematic and rapid maintenance would possibly be used more than ever.

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References

1. Derived from https://www.altametris.com/
3. Derived from Plowman Craven, VOGEL R3D data sheet.