CONDITION MONITORING OF RAILWAY TRACK BASED ON INSAR ANALYSIS AND USING PORTABLE DEVICE FOR YANGON CIRCULAR RAILWAY

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ABSTRACT: This study examines two approaches which are satellite image analysis and onboard sensor measurement for monitoring of track condition of railway in Myanmar. The number of population of Yangon City is 5.1 million and will be reached 9.5 million by 2035. Most residents use own cars and buses as means of transportation, and a modal share of railway is approximately one percent. Therefore, road congestion is becoming more severe, and a modal shift from cars to public transportations is needed. Yangon Circular Line has 38 stations and double-track, and its total length is approximately 46 km. This line has some problems such as slow speeds, delays and derailments caused by deterioration of facilities and equipment. Myanma Railways which operates this line plans update of track for safety and comfort. This study aims to detect damage at an early stage to make maintenance works more efficiently and economically and to make passenger safety and comfort high level. To monitor a track condition and detect fault parts, secondly, car body vertical and lateral acceleration are measured by accelerometer in a smartphone. Cabin vibration on section of track irregularity will be larger than ones on normal section. These results will show that a rail condition can be estimated effectively. Firstly, PALSAR and PALSAR-2 images will be analyzed with interferometric technique. Railway subsidence will be detected by analyzing SAR images which are acquired periodically.

1. INTRODUCTION

1.1 Background

Yangon is the largest city and main economic hub in Myanmar. According to the census report which was conducted in 2014 and published by department of population, ministry of immigration and population, the number of population is 7.4 million in Yangon City (Department of Population, 2015). The population has been grown drastically in the last 30 years though its number was 2.5 million in 1983.

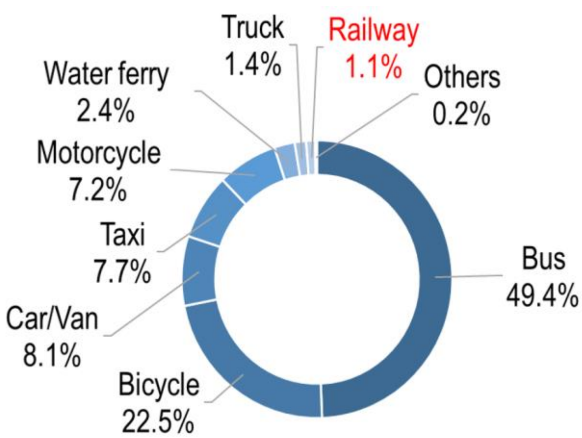


Figure 1. Modal split excluding walk trips in Yangon City investigated at the Project for Comprehensive Urban Transport Plan of the Greater Yangon (JICA, 2013). The share of railway is a mere 1.1 percent. In some district of Yangon City Development Committee (YCDC), use of motorcycle is banned currently.

Recently, the number of vehicles has been increasing with population growth. Road capacity is saturated during rush hour so road traffic congestion becomes social issue currently in Yangon City. Thus, modal shift from private car to railway could be a solution.

Figure 1 shows the modal split of transportation in Yangon City. Most residents in Yangon use road traffic (e.g. private car, public bus and taxi). However, a modal share of railway is a mere one percent. The reason of this issue can be considered that railways in Myanmar suffer from deterioration of facilities and equipment. JICA (Japan International Cooperation Agency) expert team has been supporting Myanma Railways which operates all railway lines in Myanmar since 2013, and they have been updating their civil engineering facilities (Myanma Railways, 2016). After upgrade plan is finished, operation interval can be reduced, and the carrying capacity will be increased. Management of the railway operation and maintenance of their facilities properly in order to improve the comfortable and keep the safety after speed-up.

In remote sensing technology method, Synthetic Aperture Radar (SAR) does not suffer from the limitation of sunlight and weather condition compared with optical sensors. Phased Array Type L-band Synthetic Aperture Radar (PALSAR) onboard ALOS satellite was L-band radar observing the earth surface which launched in 2006 (Shimada, 2010). Then PALSAR-2 was launched and has been operated since 2014 as successor model. Arimoto *et al*. (2013) studied to measure the land subsidence in Semarang, Indonesia using a small baseline interferometric SAR time-series analysis using the 34 PALSAR images, and their study shows the feasibility of L-band SAR data in order to monitor land subsidence over time. Hashimoto (2014) analyzed PALSAR images in order to measure ground deformation in the Kyoto basin and the Osaka plain, Japan with a 2.5 dimension analysis, and detected upward of approximately 10 mm/yr in southern area of the Kyoto basin.

There have been several studies using satellite SAR interferometry for detection surface changes along railway. Fulong *et al*. (2012) tried to observe distinct surface motions along the embankment of the Qinghai-Tibet Railway which is the longest plateau linear structure. Matthew *et al*. (2017) studied the use of Persistent Scatters Interferometry for monitoring the response of railways to ground movements across six sites in England.

1.2 Objective

The objective of this study is to develop integration monitoring system of track condition and to improve comfort and speed, and optimize operation management. A low-cost, efficient and handy monitoring system for railway track contributes railway operation.

2. METHODOLOGY

2.1 Flowchart and data

Figure 2 shows the flowchart of this study. Train car-body acceleration data and PALSAR-2 data are used. Triaxle car-body acceleration data and angular velocity data all along the Yangon Circular Railway Line were measured by portable device during 9-10 February 2017 and 22-23 August 2017 at field survey which we conducted. These data are used for detection of sections which track irregularity occurred.

The SAR data are PALSAR and PALSAR-2 covering Yangon Circular Railway Line, and will be applied for detection for railway subsidence at an early date.

2.2 Measurement method and device

In the field survey which we conducted, smartphone-based accelerometer, GPS logger and wearable camera were used as measurement device as shown in **Figure 3** and **Table 1**. iDRIMS measurement is an iOS app and can records triaxle acceleration and angular velocities (Zhao *et al*., 2017). After measurement through iDRIMS measurement app, data is resampled exactly at 100 Hz by iDRIMS Resampler. This app was developed for road roughness estimation mainly. However, these app and software can be applied to estimate car-body acceleration.

GPS track data is used to grasp the position and time of train. When an unusual condition is detected by acceleration response, it specifies the position. Wearable camera takes a movie covering the track condition, and it compensates the analysis result through acceleration response.

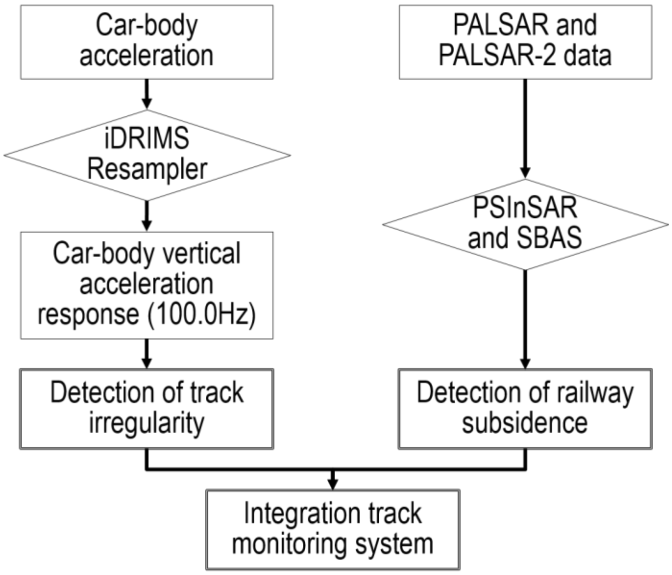


Figure 2. The flowchart of this study. Car-body acceleration and angular velocity were measured in February and September 2017 and are used for detection of track irregularity. PALSAR and PALSAR-2 data will be used for detection of subsidence along railway.

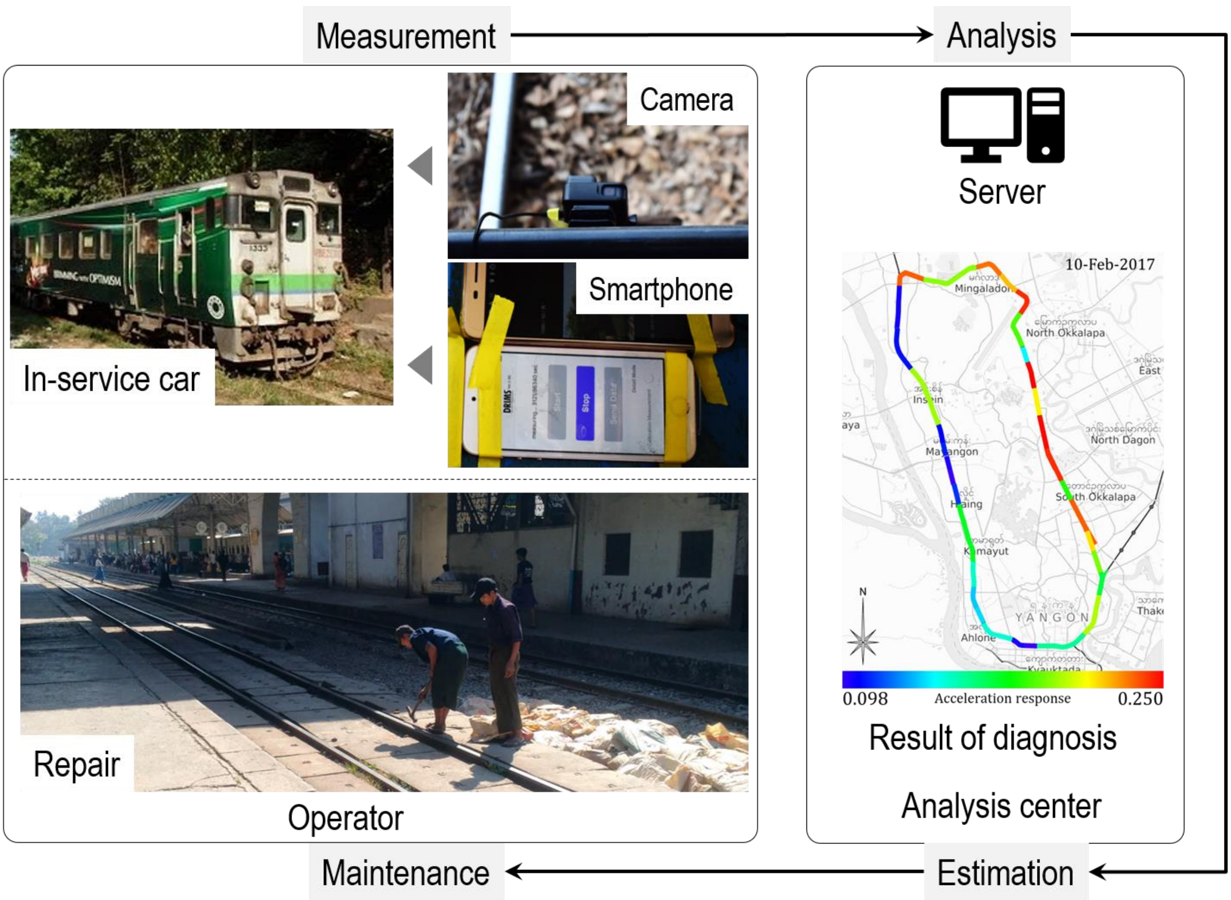


Figure 3. The overview of the portable monitoring system and flow of maintenance. Smartphone based accelerometer measures car-body acceleration, and the data is analyzed and diagnosed. If track irregularity is estimated, operator repairs a damaged track based on a result of diagnosis.

Table 1. Device used in our field survey. Video taken by wearable camera for track compensates a diagnosis and a condition on track can be realized from movie.

Collected data	Device
Car body triaxle acceleration response and angular velocities	iPhoneSE (iDRIMS Measurement)
GPS log	GPS receiver (IGotU)
Video	Wearable camera （GoPro HERO5）

3. RESULTS AND DISCUSSIONS

3.1 Results

Figure 4 shows absolute average value of car-body vertical acceleration data calculated between each station separated by all 38 stations on the clockwise direction line of Yangon Circular Railway Line. The data obtained on 10 February 2017 is measured in whole section, whereas the data obtained on 22 August 2017 is not measured between Yangon Central Railway Station and Phayalan Station and Between Pezundaung Station. In the section which operation frequency is higher between Yangon Central Railway Station and Danyngone Station, lower absolute average value is shown. The value between Hledan Station and Kyamaryut Station is remarkably high in right part.

Figure 5 shows the color mapping based on the value shown in the graph in **Figure 4**. Low acceleration value is assigned as blue color. In this case, minimum value is set as 0.098 m/s^2. 0.250 m/s^2 or over is assigned as red color.

3.2 Discussion

As shown in the graph in **Figure 4** and the map of **Figure 5**, lower values are seen in the western section between Yangon Central Railway Station and Danyingone Station. On the other hand, higher values are shown in the eastern section between Danyingon Station and Yangon Central Railway Station. In the western section between Yangon

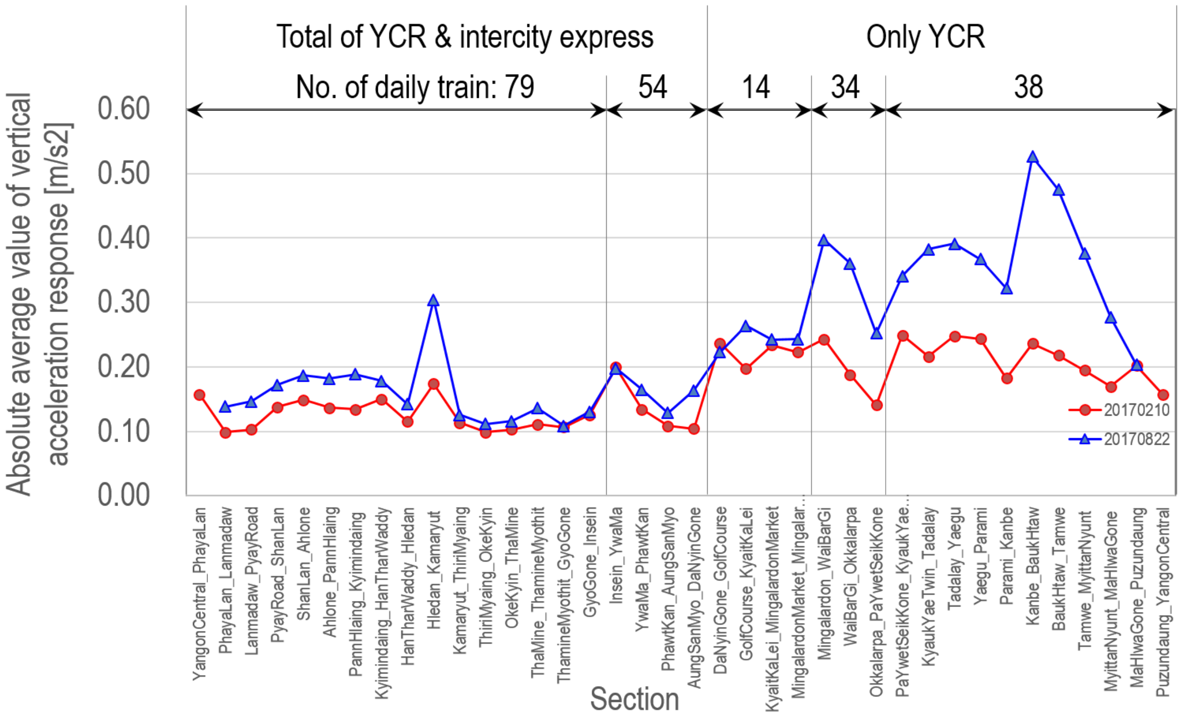
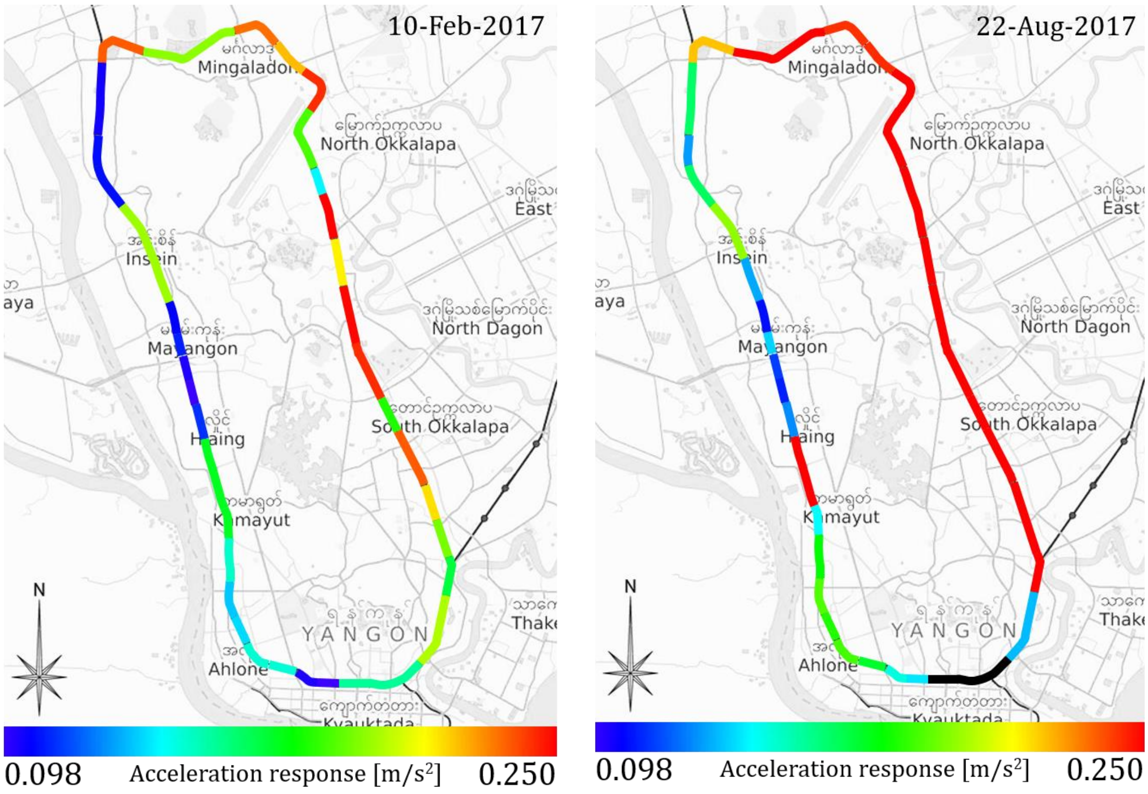


Figure 4. Car-body vertical acceleration response for each section separated by stations based on measurement data obtained on 10 February 2017 (red line) and on 22 August 2017 (blue line). The section of left from Danyingone Station is run by circular train, intercity express, suburb train and local section train. The section of right from Danyingone Station is the section run by only circular train.



(a) **(b)**

Figure 5. Condition mapping based on analysis of car-body vertical acceleration response for each section separated by 38 stations; (a) Result from measurement data on 10 February 2017, (b) Result from measurement data on 22 August 2017.

Central Railway Station and Danyingone Station, not only circular train which runs for a round but also intercity express, suburb train and local section train run on the same track. The number of daily train in western section are higher than eastern section as shown in the same figure. Thus, we can assume that priority of maintenance of track is different among those sections.

The values between Hledan Station and Kyamaryut Station on both 10 February 2017 and 22 August 2017 are remarkably high in the western section. We can assume that this section has a potential of severe damage of track condition.

As shown in **Figure 4,** blue graph is above red one in most sections. In the field survey, we boarded the same type but different train car to measure acceleration response. The large difference values between blue graph and red one in was shown in some sections since different car-body characteristic such as suspension has an effect.

4. CONCLUDING REMARKS

In this study, the vertical car-body acceleration data was used for detection track irregularity for Yangon Circular Railway Line.

Thorough the analysis of car-body vertical acceleration between each section, different trend of track condition between western section and eastern section was shown.

As our next step, we will try DInSAR analysis using PALSAR and PALSAR-2 data covering Yangon Circular Railway Line and detect railway subsidence along the track. SAR data which covers a whole track of Yangon Circular Railway Train is obtained periodically and instantaneously. By analyzing changes of track bed chronologically, damaged section can be grasped along the railway track. Integration monitoring system which is composed by the on-board portable sensing method and DInSAR one improves maintenance and operation works.

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