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Research Article

The Use of Unmanned Aerial Vehicle Equipped with Auto-Pilot System in Railway Security

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Abstract
In this project, an unmanned aerial vehicle (UAV) was developed with the purpose of enabling that the control of railroad security, which is routinely made by a line control team, could be performed at less cost, in a shorter time and more securely. As such experimental studies were made using the developed UAV for railway control.

Keywords: Unmanned Aerial Vehicle (UAV), Railway Safety, Rail Transport, Road Control Officer

Demiryolu Güvenliğinde Otomatik Pilot Sistemine Sahip İnsansız Hava Aracı Kullanımı

Öz
Bu çalışmada, demiryolu hat kontrol ekibi tarafından rutin olarak yapılan demiryolu güvenliği kontrolünü daha kısa sürede, daha az maliyetle ve daha güvenli bir şekilde yapılmasını sağlamak amacı ile bir İnsansız Hava Aracı (İHA) geliştirilmiş ve geliştirilen bu İHA ile rutin olarak yapılan demiryolu güvenliği kontrolü yapılarak elde edilen test uçuşu verilerinde İHA' nın demiryolu güvenliğinde uygulanabilirliği sonucuna varılmıştır.

Anahtar Kelimeler: İnsansız Hava Araçları, Demiryolu Güvenliği, Demiryolu ulaşımı, Yol Kontrol Memuru

1. Introduction

One of the most important parts of everyday life, transportation demand, the population density in Turkey increases parallel to the development of industrialization and trade. Transportation mobility has increased in parallel with the innovations in our lives, and transportation types have been diversified to meet the needs arising from social and economic developments in freight and passenger transport.

In addition to railway transport fast and economical, it is also expected to be the most secure transport. Events such as frequently experienced deteriorations of rail track in railway transport and possible sabotage incidents threatening security must be controlled within a program. Although signalization and electrification applications have been developed to warn of any interruptions that may occur on the train tracks, they are not efficient in the detection of faults which could be

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determined on the railroad by controls carried out using observational methods. Therefore, this has been done continuously and observationally within a determined program by persons known as railroad control officers (Demirdağ, 2007).

Comparisons of public transport systems with respect to each other are made taking into account the economic, technological and environmental characteristics. When considering the economic characteristics of public transport systems, vehicles that save more in terms of energy, time and costs are preferred. Compared with other systems in passenger and freight transport, railway transportation seems to be more economically advantageous.

When the literature is examined, the UAV has been applied successfully in military applications, forest fire, atmospheric survey, ocean observations, geological surveys, weather forecasting and many civil applications.

Unmanned aerial vehicles have been used in railway security applications. Some of them are;

- Sushant et al. (2017) used a UAV for detecting cracks in a railway track. Their paper mainly deals with the localization of a UAV and how it can be applied for detecting cracks in a railway track using the concepts of image processing.

- Bettemir (2015) used a UAV for detecting of railway tracks. In this study, a robust and economical method, which automates the investigation of railway tracks, is proposed. The proposed method scans the railway track by a high-resolution optic camera mounted on an UAV.

- Can (2016)'s paper introduces the composition of UAV aerial photograph system, the structure, advantages and disadvantages of accident scene image transmission system based on UAVs.

In the second part of the article, we have been informed about UAV, advantages of UAV, classification of UAV and applications of UAV made in Turkey. In the third part of the article, information was provided on railway transport, railway safety inspections, road control officers, and controls they carried out. In the fourth part of the article, information was given about the airborne platform and ground control station used in the study. In the fifth chapter of the article, the feasibility of using UAV in railway safety checks is given in comparison with traditional methods.

2. Unmanned Aerial Vehicle (UAV)

Unmanned aerial vehicle (UAV) is an unmanned vehicle which can be used either by a person from the ground through remote control or it can fly automatically with a flight plan which is planned beforehand.

UAV was first used in the 1900th century. UAV gain its popularity in the last decade and many scientists focused on UAV. Generally, UAV is used military purposed but in previous years we are witnessing the use of UAV for academic research and some time for civil purposes. In the beginning, a few countries could use UAV, but now many countries have access to the use of UAV (Altunok, 2010).

2.1 The Advantages of Using UAV in Railway Security

Unmanned aerial vehicles (UAV) have been used for civilian purposes and they have been tested in the control works of railway security. UAVs will be able to undertake this role, especially in places which are difficult to be reached by humans. We created a new UAV for use in the control of currently ongoing railway security in Turkey.

The following is an overview of the railway safety studies conducted by using the UAV, as compared to the conventional safety checks:

- It is possible to record images taken with the video transmitter and external memory on the UAV used in this study and to monitor them online from the ground control station. In this way, it is possible to capture the details that can be avoided from the eye at the controls made by the normal method.
- UAVs will be able to assume this role, especially in places where it is difficult for them to reach by people.
- In the case of classical methods, the road control officer who controls the road safety can control an area of only 10 km, and image transmission to high distances will be achieved according to the characteristics of the image transmitter placed on the UAV to perform this operation.
- The difficulties encountered by personnel who will be involved in road controls to be carried out in rugged, degraded and mountainous areas will be removed from the controls made by the UAV.
- Considering the sabotage situations that put railway safety in danger, it is possible to make a quick assessment in case of any notice related to this issue.
- In case of need of logistic material to the region where the road maintenance is performed, material transportation can be carried out in the direction of the weight that the UAV can carry to the desired point.
- The road closures caused by the instant nature events that may occur on the train tracks cause delays in the train services. Preventive measures are taken in case of any

problems with frequent control of the risky areas by the UAV.

- The cost of the UAV platform will be much less than the cost of the employed road watchers, which will provide a significant cost advantage (Akgül, 2010), (Ferit, 2004).

3. RAILWAY SECURITY

3.1 Railway Transportation

The need for transport, which is one of the most significant parts of our daily lives, has been increasing in the world in parallel with population density, industrial and commercial development. While transportation activities have been rising parallel with the developments in our lives, types of transportation have also become varied so that they can meet the needs which have arisen because of social and economic developments in load and passenger transport (Demirdağ, 2007).

The movement of people or loads on a metallic way by vehicles is known as railway transport. Railways are used in city and intercity transportation as well as being commonly used for the purpose of transnational passenger and load transport (Koçtürk, 2013).

3.2 Knowledge of Superstructure

The way section built under determined criteria with the purpose of providing railway vehicles` movement for the purpose of passenger safety and comfort, on which railway vehicles move is known as superstructure (Koçtürk, 2013).

The factors that constitute a superstructure are as follows:

- Railways
- Crosstie
- Ballast
- Switch

3.3. Protective Maintenance

The preventive maintenance, known as systematic maintenance, is carried out within a program. Periodical maintenance is called Periodic Maintenance in order to perform maintenance within a program. Depending on the work to be done, maintenance can be carried out in the following periods (Demirdağ, 2007);

- Weekly checks
- Checks made every 15 days
- Monthly inspections
- Quarterly inspections
- 6 Monthly checks
- Annual controls

3.3.1. Control of the line by the Road Control Officer

The road control officer is responsible for the control of the railway which is 8-10 km long which is his responsibility.

The following visual checks should be observed at these controls

- Visual control of railways
- Visual control of traverse
- Visual control of weld
- Visual control of rail fasteners

- Visual control of track geometry
- Visual control of points

4. Material and Method

4.1 Method

In this article, researching the efficiency of using UAV for railway security was realized by a modified quad rotor helicopter model as a platform. The UAV system used in the railway security project consists of an air platform and ground control station (GCS). The model has an adequate lift for electric and electronic (avionic) systems, and the parts provide ease of operation thanks to having sufficient thrust produced by its engines.

The developed UAV performed a test flight for railway security work in the determined area and then the same area was controlled in the presence of experts who made observations by traditional methods. When the obtained findings were compared, those derived from the images provided by the UAV checks highlighted the results sought in the same checks made by traditional methods almost completely. As a UAV can instantly inform via video images about damage to a railway track, possible sabotage, the condition of bridges, tunnels and retaining walls, the recording of these video images to an external memory located on the UAV enables watching online or later.

The first test flight of the model aircraft, assembled in Laboratory of College of Aviation of Erzincan University, was performed between 0 and 15th kilometers of the Erzincan – Erzurum railway after obtaining permits from Turkish State Railways 4th Regional Directorate on 21st of May, 2011 and the test flights of this model aircraft continued regularly until 8th of June, 2013 when the last test flights were performed at different flight levels in Istanbul Haydarpaşa Station and positive results were obtained.

4.2 UAV Air Platform

A mini helicopter with rotary wing and quad rotor was used as the air platform. The model used had appropriate place/space for the installation of electric and electronic (avionic) systems and camcorder systems, such as camcorder, video transmitter and standard radio transmitter. Figure 4.1 shows the UAV used as the air platform.

Figure 4.1 Air platform

4.3 The Features of the Used Model

The used model had features that facilitated the use of technical specifications, as shown in Table 4.1, including position and altitude stabilization, intelligent direction control, safety, automatic return and landing, low voltage protection, LED warning system and camcorder frame.

Table 4.1. DJ PHANTOM model of specifications

Parameter	Span
Operating frequency	2.4 GHz
Operating Temperature	50 ° C / -10 ° C
Power Consumption	3:12 W
Operating Voltage / Current	6V / 52 mA
Flight Sensitivity (GPS mode)	Vertical ± 0.8 m. Horizontal ± 2.5 m
Mak. Yaw angular velocity	200 ° / s
Mak. Tilt angle	45 °
Mak. Ascent / descent (vertical) speed	± 6 m / s
Maximum Flight Speed	10 m / s
Weight	670 g
Weight (with battery)	800 g

4.4 Ground Control Station (GCS)

As well as visual operation of the UAV, it was also controlled by transferring video images, taken by the camcorder located on UAV and received by a video receiver in the GCS, to monitor during use of the UAV over long distances. As already mentioned, by using this system, guiding the aircraft and railway control can be performed by receiving voice and video data, thanks to the images on the monitor screen. GCS consists of a six channels standard radio transmitter, one monitoring unit and one video receiver.

4.5 Receiving Synchronous (online) Video Images and Transfer

Railway security entails control of railway track damage which may occur, possible sabotage actions, places where the probability of interruption caused by natural events like a landslide is high or control of railways under risk during harsh winter conditions. A camera system providing simultaneous/synchronous video image transfer was developed and installed perfectly on the UAV without damaging its avionic structure in order to detect any interruptions in the determined area.

The received video images were synchronously recorded and watched on the GCS thanks to a video transmitter located on the UAV used in this project and an external memory. With this method, it is possible to capture details that could be overlooked with controls performed using normal methods.

4.6 Autopilot System

This is the main control problem of holding a UAV over a specified time period for a desired flight on a predetermined route. During this process, the dynamic status of the UAV could be affected by disruptive impacts created by its own system or caused by the external environment (Kahvecioğlu, 2006). In the cases of deviation from equilibrium, the desired stability and performance will not be realized during manual control of the UAV from the ground.

Holding an aircraft continuously horizontal and fixed on predetermined coordinates and serial control mechanisms designed to generate the commands returning it to its former position in the case of necessary status changes is known as “Automatic Pilot” or “Auto Pilot” (Dönmez, 2005).

Directing the model to the operation area where manual operation is inadequate, taking images, making exploration and providing more a stabilized flight and facilitating the return of an aircraft which is out of range of the GPS coordinates noted at the beginning can all be carried out by the auto pilot system thanks to the software installed into auto pilot system.

4.7 Test Flight

The first test flight of the model aircraft assembled in Laboratory of College of Aviation of Erzincan University was performed between 0 and 15th kilometers of Erzincan – Erzurum railway after obtaining permits from Turkish State Railways 4th Regional Directorate on the 21st of May, 2011 and the test flights of this model aircraft continued regularly until 8th of June, 2013 when the last test flights were performed at different flight levels in Istanbul Haydarpaşa Station and positive results were obtained.

Test flights showed that the chosen model had a stable structure that could be used in railway security work. Being a durable model, flying stable, producing enough lift power, easily being flown and having adequate internal volume for all systems, allowed the UAV to proceed to the next step wherein the aircraft would be used as an air platform. Test flights were performed at 1m, 5m, 10m, and 15m altitudes between 3pm and 7pm. Table 4.2 shows the weather conditions on the days and times that test flights were made.

Table 4.2. The weather conditions at the test flight of the day

	Temperature	Wind Speed	Wind Direction
Weather	21.3 ^{0}C	8.2 m/s (10 meters high)	Northerly

4.8 Results of Test Flights

The test flights for railway security application with a UAV were performed at different flight levels and different flight speeds, as shown in Table 4.3, on 8th of June 2013 in Istanbul Haydarpaşa Station.

Table 4.3. The test flight data

Checklist	**Control Type**				
	Controls that the railway line supervisor has visually done	**Controls that the railway line supervisor can perform from the camera images of the UAV**			
		Test Flight 1 (1 m)	**Test Flight 2 (5 m)**	**Test Flight 3 (10 m)**	**Test Flight 4 (15 m)**
Fractures that may occur in rails	✓	✓	✓	✓	✓
Control of rail connecting materials	✓	✓	✓	✓	✓
Crust on the rail surface	✓	✓	✓	✓	X
Scratches due to rolling	✓	✓	✓	X	X
Control of rail welding	✓	✓	✓	✓	✓
Rigidity of rail fasteners	✓	X	X	X	X
The status of Traverse	✓	✓	✓	✓	✓
Control of switches	✓	✓	✓	✓	✓
Physical changes due to temperature on rail	✓	✓	✓	✓	✓
Control of barriers	✓	✓	✓	✓	✓
Disruptions caused by natural phenomena (snow, flood, landslide, etc.)	✓	✓	✓	✓	✓
Control of persons not authorized to travel on the railway in terms of protection of railway	✓	✓	✓	✓	✓

Two researchers took part in the test flights. One's task was to fly the UAV while the second was responsible for taking notes about the UAV's speed and altitude and taking any necessary photos and recording necessary video images. The train tracks were clearly observed at each test flight as shown in Table 4.4.

Table 4.4. Determining control performed

Test Flight	Height (m)	Ground Speed (km / h)	Determining control performed (Number)
1	1	10	12
2	5	10	12
3	10	10	11
4	15	10	10
5	1	15	11
6	5	15	11
7	10	15	10
8	15	15	9

Figure 4.2. Cracks may occur on the switch

Figure 4.3. Control of rail fasteners

Figure 4.4. The surface crust formed in the rail

Figure 4.5. Control of weldings of rail

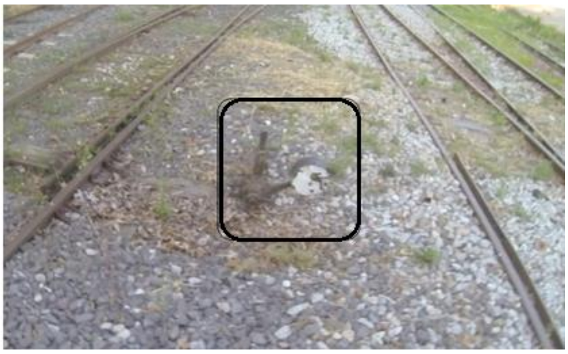

Figure 4.6. The status of Traverse

Figure 4.7. Control of switches

Figure 4.8. Control of foreign object on rail

Figure 4.9. Robustness of the art building

5. Results and Recommendations

The project will bring the unmanned aerial vehicle to a state where it can be used for discovery, surveillance and operational purposes and it will be possible to make continuous control by using the camera which is a daytime and night vision system. In the study of the railway safety control with the developed UAV, test flights were carried out in the determined regions and necessary data were obtained.

The test flights for railway security application with a UAV were performed at different flight levels and different flight speeds, the necessary data were obtained by performing test flights using the developed UAV on the predetermined area for the railway security project. The points which could cause problems identified through essential routine controls by experts using conventional methods in the area where the test flights were performed and these were then compared with the test flight data and it was concluded that could be performed the cost of the UAV platform will be much less than the cost of the employed road watchers, which will provide a significant cost advantage, in a shorter time and more securely.

It was only possible to carry out research activities in a limited area and time period due to the fact that using a mini UAV in this study required taking into account the volume of load that could be transported, battery use and the monitoring systems.

A larger area could be controlled by providing a more developed sensor and greater transport of payload if a UAV with additional physical improvements and transport capacity is used.

The UAV used in this study was managed with a radio-controlled system and was applied autonomously in case of any problem during flight. It has been thought that the UAV will be autonomous and programmable in its entire take-off, flight and landing stages, but it cannot be resumed during the thesis study and it is planned to be applied in future studies. The design of the UAV to provide such a flight will significantly reduce the pilot's burden in the ground control station.

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