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SWOT Analysis of Unmanned Surface Vehicle for Environmental Monitoring Tasks in Maritime Ports

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Özet: Ticari denizcilik sayesinde yüksek miktarda taşınan yükler ile limanlar ticaret merkezleri haline gelmektedir. Bu büyük yapılar, tek noktadan denizlere açılan gemilerin neredeyse tüm ihtiyaçlarını karşılayabilen bölge için büyük öneme sahiptir. Deniz taşımacılığında, limanlar ticari gemiler için özel ihtiyaçlara hizmet etmektedir. Öte yandan Akıllı Ulaşım Sistemleri lojistik sektörü için ana başlıklardan birisi haline gelmiştir. AUS öncelikle güvenli, akıllı ve temiz mobiliteyi ve aynı zamanda enerji, zaman ve para tasarruflarını hedeflemektedir. Yüksek miktarda kargo ihtiyacı yüzünden limanlarda aşırı yoğun deniz trafiği meydana gelmektedir. Deniz çevresinin korunabilmesi için bu yüksek miktardaki trafiğin kontrol edilmesi gerekmektedir. Sürekli izlemenin en ucuz ve kolay yolu insansız ya da otonom su üstü araçlardır. Bu çalışmada, limanlarda kullanılabilen deniz çevresi izleme görevinde kullanılan insansız su üstü araçlarda kullanılan algılayıcıların SWOT analizi yapılmıştır. RF, LTE, Bluetooth ve WLAN teknolojileri algılayıcıların değişik özellikleri çerçevesinde karşılaştırılmıştır.

Anahtar Kelimeler: Deniz Ulaşımı, SWOT Analizi, İnsansız Su üstü Araçlar

Abstract: Ports are becoming commercial centre due to large amounts of cargo transported via commercial shipment. These large structures, which can provide almost all the needs of the ships traveling on the high seas from a single point, have high importance for the region. In maritime transportation, ports serve special purposes for merchant vessels. On the other hand, Intelligent Transport Systems became the main target of logistic market. ITS' primary aim includes safe, smart and clean mobility and as well as saving on money, time and energy. Demand of high amounts of cargo operation causes high vessel traffic in maritime ports. For environmental protection all these merchant vessel traffic should be monitored. The easiest and cheapest way of continuously monitoring is unmanned or autonomous surface vehicles. In this study, SWOT analysis of unmanned surface vehicles is used for determining which communication sensor is suitable in ports. RF, LTE, Bluetooth and WLAN technologies are compared in the scope of different properties of sensors.

Key words: Maritime Transportation, SWOT Analysis, Unmanned Surface Vehicles

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1. Introduction

By the invention of wheel, transportation became the most important part of human life. Even on daily basis, people have to use any means of transportation in order to reach from one point to another. From foods to medicines, almost everything is carried by one or more transportation systems. On the other hand, by using new types of transportation systems, mankind has discovered lots of different places. Moreover, discovering new areas require more advanced transport systems in order to reach effectively. But like all new technology, advanced systems require more technical effort to run trouble-free. Due to limited manpower, computer based aids are essential for transportation systems. By implementing computer systems into transportation systems, Intelligent Transport System idea was born in the 1980's. Because of that, Intelligent Transport Systems (hereinafter ITS) became the main target of logistic market. ITS' primary aim includes safe, smart and clean mobility as well as saving on money, time and energy. ITS involves car information, collision avoidance, terrestrial broadcast, advance route planning, fleet management, travel assistance, toll collection, intermodal communications, etc. Besides that, ITS is not only for road transportation but also for rail, air and sea transport systems including lots of different assistances such as autonomous navigation. In terms of autonomous navigation at sea, for instance, Autonomous Surface Vehicles (hereinafter ASV) at sea is broadly used in tourism activities such as whale monitoring, in scientific researches such as surveying and environmental monitoring or data collection. Main purpose of using ASVs is to save money and precious time for all regarding operations mentioned before. Similarly, other than the purpose of saving money or time, in military industry there are a lot of surface vehicles equipped with different weapon systems currently in use. Thereby, it is predicted that ASVs are going to be the main type of maritime vessels in regards to cheap and safe navigation.

Unmanned Surface Vehicle (hereinafter USV) is cheaper option for port management, government, pleasure activities etc. Different than ASV, USV require human control in almost every tasks. Autonomous technology allows vehicle to run almost every condition without any interruption. But in unmanned technology, there should be predefined task order or a human remote control.

In this study, it is aimed to compare different communication technologies for remote operated surface vehicles by analysing their technological advantages in environmental monitor tasks at port area.

2. Background and motivation

Although there are a lot of ASV samples, EU Project MUNIN (Maritime Unmanned Navigation through Intelligence in Networks) is the one that actually regarding merchant shipping industry. In order to study within e-Nav project's scope, for a small ASV, there should be any navigational information that user could reach easily via any means of communication options. That includes GPS position data, heading course, live camera images, engine status, etc. End user of a vehicle could reach this information either via mobile station or via shore based control station.

In different scale of surface vehicles, unmanned vehicles are used for port operation tasks. Due to limited manpower and cost of labor at port, unmanned vehicles are good solutions for pre-defined routes. Different than ASV, in unmanned vehicles there could be crew or other responsible personnel to complete special missions such as, pilotage, vessel monitoring, port services, rescue missions, environmental monitoring etc.

There are already several academic studies done on the usage of unmanned vehicles at maritime ports, as following:

Howard et al. (2017), in their paper, studied on a small unmanned surface vehicle designed to support maritime domain awareness in port and harbor environments. The authors discussed advanced technologies in autonomous platform such as sensors, control and command strategies.
Johansen, et al. (2014) focused on communication of underwater vehicles different than surface vehicle communication system. One aerial unmanned vehicle was chosen as a wireless communication relay in underwater research operations. The authors conducted tests worse than ideal conditions and figured out distance and altitude between two vehicles were not the bottlenecks.
Liu & Bucknall (2015) studied about autonomous surface vehicle fleet operation. They clearly stated weakness of unmanned surface vehicle operation such as low payload capacity, short endurance, and small size. Their research paper covered unmanned surface vehicle path planning problem in a complex navigation environment.
Leirens & Pierquin (2004) presented unmanned surface vehicle's autopilot equipment. The authors tried to deal with the development of an unmanned vehicle for environmental monitoring. They preferred unmanned technology in order to reduce the cost of surveys.
On the other hand, within study area of this paper, there are four main cheap options for data connection. One solution is connection via Wireless LAN technology. Another solution is connection 3G technology of mobile broadband. That requires different data connection between terminals different than Wireless Network. Besides the limited coverage of Wireless LAN, 3G data communication is available at mobile phone coverage map. Radio Frequency and Bluetooth communications are another solutions for close range operation. These two options are cheaper than WLAN and 3G communication systems.
In previous studies there are a lot examples regarding communication of vehicles. Mainly, studies focus on four different technologies, such as Bluetooth, LTE, WLAN and Radio Frequency.
Tsugawa (2005) studied about vehicle to vehicle communications for increased road safety. Named "Advanced Traffic Management Systems / Advanced Traveler Information Systems" are the one explained communication systems which uses 220 MHz radio frequency. On the other hand, the author mentioned about "Advanced Vehicle Control and Safety Systems". AVCSS system uses WLAN technologies in order to transmit and receive information of transporting vehicles.
Ferreira, et al. (2009) made a risk assessment for Robotic Surface Vehicle. The aim of using Robotic Surface Vehicle is conduct an ocean hydrographic surveys near very shallow waters where big vessels cannot sail. They used IEEE 802.11 a/b/g Ethernet modem with external antenna and they achieved higher range and bandwidth in comparison with 2.4 Ghz Wi-Fi.
Horner & Healey (2004) focused on Automated Underwater Vehicle communication options. The authors introduced the idea of fleet communication which is very unique for the AUV fleet. The limited distance due to higher frequency of WLAN communication eliminated with using aerial vehicles as a communication bridge. On the other hand, higher frequency allowed to improve AUV operations.
Zhao, et al. (2018) introduced several long-distance communication methods. They compared existing maritime communication methods with LTE technology. The paper includes communication rate and distance of fiber/satellite communication. Moreover, the advantages of LTE communication mode which is coverage area and speed analyzed with other long-distance communication methods.
Stelzer & Jafarmadar (2012) designed Autonomous Surface Vehicle that feautures three-stage communication system which combined WLAN, 3G and iridium satellite. The ASV named "ASV Roboat" sailed 71

nm fully autonomously in severe weather conditions.

3. Technologies in Maritime Sector (ASV-USV)

ITS can provide technology that improved safety, productivity and environmental performance for transportation systems. That includes some important applications that have been using in recent years such as information and warning systems for cars. They are vital for safety of road transportation. ITS is not limited to road applications. Railway, aeronautical and maritime systems applications are already in use by all means. Railways signal systems, aeronautical traffic control systems are some examples. They are vastly use in maritime sector as well, especially in navigation systems such as chart or vessel information systems. ASV, is a vehicle that can operate water navigation without crew. There are three different navigation mode for ASV. First one is "Manuel assisted" mode. It requires remote control by means of joystick or command center. By using command center, user can adjust heading or thrust. Second mode is "Automatic" mode. In this mode, vehicle can perform planned navigation routes without any assistance. But at all times, vehicle navigation data is observed from master command station. Third mode is "Autonomous" mode. Vehicle can perform all navigation tasks without any assistance. It includes obstacle avoidance and target identifications, etc.

In communication domain, "Wireless Technology" is basically transfer of data or power between two point without any cables. Electromagnetic waves help to connect these two points in order to link each other. There are a lot of examples of wireless connections but radio is the most common one. Radio waves can travel up to millions of kilometers without any cable connection. Wireless data connection is a technology that linked mankind from its establishment date. Without wireless technology, it is impossible to handle data connection on the world.

Wireless local area network technologies are essential for everyday life in order to create home network, using mobile phones or sensors, etc. Besides than creating home network, most of collages or other types of places requires data network flow could use WLAN that provides low-cost wiring options. There are some standards for WLAN technology, but mostly used ones are IEEE 802.11 a/b/g/n.

Long Term Evolution (Herein after LTE) is a mobile communication standard, which is an evolution of previous 3G Universal Mobile Telecommunications System (UMTS). It is widely adopted over the previous systems and it can provide high speed data transfer rate. LTE does not mean 3G, actually it can be up to the ten times faster than 3G. 4G technology is based on improvement in 3G network. On the other hand, LTE technology is sometimes called 4G LTE or true 4G by different authorities. However latest cellular network technology called as LTE in order to prevent misunderstandings. The 3rd Generation Partnership Project (3GPP) provided standards for LTE that defines a peak cell data rate of 300 Mbps and 75 Mbps in the downlink and uplink directions.

Radio frequency (hereinafter RF) is widely used almost every single electronic device that requires simple or advanced communication systems. Although it becomes synonymous with wireless and high-frequency signals, it could be described anything from AM (Amplitude Modulation) radio between 535 kHz and 1605 kHz to computer local area networks (LAN) at 2.4 GHz. To be brief, there are lots of frequency options that are suitable for any applications. Although the wide range of frequencies available, Raspberry Pi's RF module is working on 433 MHz frequency. In other words, there is only an option for RF communication frequency.

Bluetooth is an another technology that allows us to connect everything, where special device, such as computer chip, installed. Bluetooth device uses radio waves rather than cables. The most well-

known example for Bluetooth devices are mobile cell phones. By using Bluetooth network lots of different equipment can be controlled.

4. Comparison of Technologies SWOT Analyses

First of all, navigation area for ASV should be clearly designated. Because of the nature of data signals, they could be affected by any different type of source. In order to prevent this problem, there are some elements that have to be determined.

Firstly, we have to specify range of ASV operation. For longer ranges, LTE technology is the best solution due to coverage area. Simple Hardware On Top (HAT) for Raspberry Pi is great solution for communication. With LTE coverage area on the world, ASV could be controlled from anywhere that user has access to LTE system. Bluetooth is capable of data transmitting at only 100 meters. Hence, it is not suitable for longer applications. Just as Bluetooth, Wi-Fi has almost nearly same range as Bluetooth by 92 meters. For RF Module, 31 meters is the optimum range for users according to field tests.

Secondly, communication data speed is important task for navigation. There should be zero delay in order to achieve safe navigation. RF has relatively lower data transmit speed than others. It can reach only 1 Kbps to 10 Kbps. Currently, fastest data speed technology is Wi-Fi. Wi-Fi network has 150 to 600 Mbps data speed in LAN area. Different from that, LTE technology can reach to 5 to 12 Mbps download speeds. Similarly, its peak download rate is 50 Mbps. On the other hand, Bluetooth 4.0 technology allows user to make connection at 25 Mbps.

The third one is reliability. Wrong data transmit command leads to inevitable results. User needs to be sure about which command is sent. Any miscommunication problem leads to wrong navigation path. Due to frequency band which could be used by another user, it is hard to install RF transmitter properly. On the other hand, while using Wi-Fi LANs, addresses can be jammed. Although it is a rare scenario, that is not recommended for autonomous operation. In contrast, Bluetooth has special algorithm to assign two different devices. This can be called as secure connection. Similarly, LTE connection has special data connection via satellites. This makes two communication system reliable.

The other important one is the energy consumption problem. Due to limited battery power, this task should be taken into consideration. RF and Bluetooth have lowest energy consumption. RF modules requires power when only in transmitting mode. Not different from RF, Bluetooth devices such as small products are able to operate more than a year on a button cell battery without recharging. Wi-Fi and LTE have different characteristics on power consumption case. Many things have to be considered in order to make calculations, yet both of them consume more energy than RF and Bluetooth.

Last and the most important one is security of communication system. Bluetooth 4.0 is using AES 128-bit encryption, similarly Wi-Fi Direct is using AES 256-bit encryption. Both offer enough security for the average consumer.

4.1. SWOT Analysis

In order to clarify every aspect of data communication methods, SWOT analysis is used. Rather than single point of approach, every properties of communication system are compared with each other in same matrix. For the more information about SWOT analysis Ireland, et al. (2003) published academic paper about not only ore functions of method but also implications as well.

SWOT matrix of communication methods as follows:

Table 1. SWOT Analysis Table

SWOT	Helpful	Harmful
Internal Origin	WLAN: Mobility, Speed, Range RF: Mobility, Low operation costs, Low energy consumption LTE: Mobility, Range BT: Mobility, Range, Low energy consumption	WLAN: High energy consumption, Operation costs, Security problems RF: External antenna requirements, Limited range LTE: Expensive sensors, Complex system structure BT: Expensive sensors, Complex system structure
External Origin	WLAN: Multiple network solution, High bandwidth, Redundant network architecture RF: Low sensor costs and easy to replace & maintenance LTE: Access from longer ranges BT: Higher security standards	WLAN: Data or signal loss RF: Prone to cyber-attacks, Data or signal loss LTE: Prone to cyber-attacks, Data or signal loss BT: Data or signal loss

5. Results

According to comparison table, there are multiple options that user could choose. For example, if port authority needs low energy consumption, it has to sacrifice range properties. Yet, it is obvious that LTE is the best option for normal navigation tasks with added battery cells. In case of high security needs, mobility could be reduced to range limits because of WLAN & Bluetooth's limited range properties. On the other hand, only RF is not reliable enough to make precise maneuvers in case of action to avoid collision. Besides that, RF is favorable option for current IoT market. One other option of RF is Bluetooth modules. Not only they can provide same flexibility as RF, but also can provide more security choice.

6. Conclusion

In this study, it is aimed to compare different communication technologies for ASV by analyzing their technological advantages. Based on literature reviews and user experiences RF and Bluetooth modules offer enough properties for environmental monitoring tasks. If user decides to use ASV on longer range, he/she has to move more advanced technologies, such as LTE. Besides than small autonomous surface vehicles, autonomous surface vessels are using satellite based communication which

is advanced and more complex. For small autonomous surface vehicles, there is no point to install such a very expensive and complex system to operate remotely. But for merchant vessels, it is inevitable. In the future, there could be option for satellite communication as well by cheap products.
On the other hand, cyber-attacks are very common nowadays on every sector related intelligent systems. To eliminate this threat, user has to be sure that surface vehicle well-protected in the name of network security. In case of running server down situations, there should be backup option like which merchant vessels have as spare equipment.

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