Journal of Naval Sciences and Engineering

Barbaros Naval Sciences and Engineering Institute
Barbaros Deniz Bilimleri ve Mühendisliği Enstitüsü

Deniz Bilimleri ve Mühendisliği Dergisi

Volume/Cilt:15
Number/Sayı:2
November/Kasım 2019

PRINTED BY/BASKI
Turkish Naval Academy Printing House/Deniz Harp Okulu Basımevi

CORRESPONDENCE AND COMMUNICATION ADDRESS/YAZIŞMA VE HABERLEŞME ADRESİ

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NATIONAL DEFENSE UNIVERSITY
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JOURNAL OF NAVAL SCIENCES AND ENGINEERING

MİLLİ SAVUNMA ÜNİVERSİTESİ
BARBAROS DENİZ BİLİMLERİ VE MÜHENDİSLİĞİ ENSTİTÜSÜ
DENİZ BİLİMLERİ VE MÜHENDİSLİĞİ DERGİSİ

Volume/Cilt: 15 Number/Sayı: 2 November/Kasım 2019 ISSN: 1304-2025

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VOLUME: 15 NUMBER: 2 NOVEMBER 2019 ISSN: 1304-2025

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CİLT: 15 SAYI: 2 KASIM 2019 ISSN: 1304-2025

Journal of Naval Sciences and Engineering
2019, Vol. 15, No.2, pp.99-111
Computer Engineering/Bilgisayar Mühendisliği

RESEARCH ARTICLE

TRAFFIC MANAGEMENT IN SDN-BASED OPTICAL NETWORKS

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Date of Receive: 19.09.2019 **Date of Acceptance: 14.11.2019**

ABSTRACT

This paper investigates Routing and Wavelength Assignment (RWA) problem in Optical Networks. Optical Networks are critical for handling increased bandwidth demands; and it is difficult to manage lightpath requests due to the lack of network resources. To overcome this challenge, a queuing theory based framework for Optical Networks is proposed with Software-Defined Networking (SDN) paradigm. Here, traffic management is controlled by a centralized controller. More specifically, in the considered scenario, a controller is modeled with a queuing approach, and lightpath requests between source and destination node pairs are scheduled. The thorough evaluations show that the assigned lightpath can be increased with the proposed queuing based SDN model in Optical Networks.

Keywords: *Optical Networks, Traffic Management, SDN, Routing and Wavelength Assignment.*

SDN TABANLI OPTİK AĞLARDA TRAFİK YÖNETİMİ

ÖZ

Bu çalışma, optik ağlarda Yönlendirme ve Dalga Boyu Ataması (RWA) problemine odaklanmaktadır. Optik Ağlar, artan bant genişliği taleplerinin yerine getirilmesi için kritik öneme sahiptir ve kısıtlı ağ kaynakları nedeniyle gelen ışık yolu isteklerini yönetmek zordur. Bu problem çözümüne yönelik, Yazılım Tanımlı Ağ (SDN) paradigması ile optik ağlar için bir kuyruk teorisi temelli model önerilmiştir. Burada, trafik yönetimi bir denetleyici tarafından kontrol edilmektedir. Daha spesifik olarak, ele alınan senaryoda, merkezi bir kontrolör, kuyruk yaklaşımı ile modellenmiş, kaynak ve hedef düğüm çiftleri arasındaki ışık yolu talepleri planlanmıştır. Kapsamlı değerlendirmeler, ışık yolunun tesisinin optik ağlarda önerilen kuyruk teorisi yaklaşımı ve SDN paradigması ile geliştirilebileceğini göstermektedir.

Anahtar Kelimeler: *Optik Ağlar, Trafik Yönetimi, Yazılım Tabanlı Ağlar, Yönlendirme ve Dalga Boyu Ataması.*

1. INTRODUCTION

Optical Networks have a significant role in the operation of Internet, availability of the resilient and survivable communication services. Conventional optical networks assign a full wavelength to each traffic demand. This results in low utilization of the available spectrum since it is difficult to manage lightpath requests due to the lack of network resources.

Routing and Wavelength Assignment (RWA) arises as one of the fundamental designs and control problem in optical networks [1-3]. In the first step, a lightpath is set up and a route is determined. Then, a wavelength is assigned to the lightpath. If there is no available wavelength for the lightpath on the selected route, the connection request is blocked. This problem is more complicated than traditional routing problem [4-6] since routing and wavelength assignment is jointly considered. Optical networks are critical for handling increased bandwidth demands. The challenge is that the bandwidth on the lightpath is allocated for the connection until it is terminated. In addition, a wavelength is associated along the route. If there is no wavelength conversion, the lightpath occupies the same wavelength along the route. This results with inefficient utilization and increases the blocking probability.

To overcome this challenge, Software Defined Networking (SDN) is a promising solution with a programmable and flexible configuration. SDN enables to manage the topology with a centralized controller so that there is no need to change in the existing network infrastructure and the controller schedules the lightpath demands and controls the traffic.

Several works have studied the RWA problem in optical networks. For instance, based on the traffic arrivals, static and dynamic lightpath establishment [7] is considered. In static scenarios, traffic demand is fixed and known. Thus, the routes are predetermined for all lightpaths. The main objective is to manage the demands while minimizing the wavelengths. By contrast, in dynamic scenarios, the demands arrive one by one at random between source and destination node pairs and the aim is to minimize the blocking probability of demands. Although the RWA problem has been investigated, the solutions have been generally proposed to minimize the number of wavelengths [8]-[9]. SDN approach has not received the same attention.

Hence, the main objective of this paper is to set up lightpaths and then assign the wavelengths in order to minimize the amount of blocked connections and maximize the number of established connections with SDN paradigm. In the paper, a dynamic traffic pattern is considered. Here, the customers submit to the requests for lightpaths. According to the number of submitted requests at any time, network resources may not be sufficient to establish a lightpath between the corresponding source and destination node pairs. In this case, the request is blocked. To avoid the blocking scenario, the controller is modeled with a queuing model so that the requests are evaluated even if there is no available resource.

The rest of the paper is organized as follows: Section 2 describes the proposed SDN-based optical network architecture. Section 3 explains RWA scheme and queuing model. Section 4 evaluates the performance of the proposed model and finally Section 5 concludes the paper.

2. NETWORK ARCHITECTURE

The considered SDN-based optical network architecture has two main components: control plane and data plane as seen in Figure 1. OpenFlow protocol enables to communication between control plane and data plane.

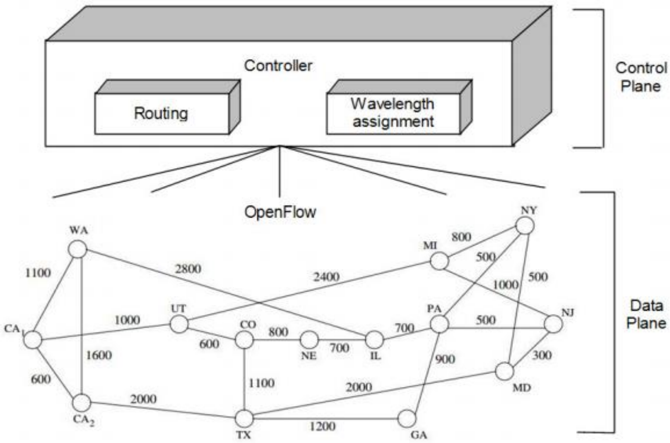


Figure 1. Proposed network architecture with SDN paradigm.

In optical networks, the amount of network resources is limited. Thus, a limited number of lightpath requests can be served at each time interval. In data plane, lighpath requests are created with a random fashion between source and destination node pairs. Control plane manages the lightpath requests between the corresponding node pairs. It enables low cost, improved operation, effective response to failures, and dynamic lightpath assignment to actual demand. The control plane executes two functions: (i) Routing and (ii) Wavelength Assignment.

Fixed and alternate paths are defined for each source-destination node pair by control plane. After the list of primary and secondary paths is created in a routing table, all wavelengths are ordered. Then, an appropriate path and wavelength for the requested lightpath are searched. Finally, if there is no available resource, the lightpath requests are waited in the queue in order to check the availability of the resources in the next time slot.

Moreover, depending on network status, two types of customers are determined.

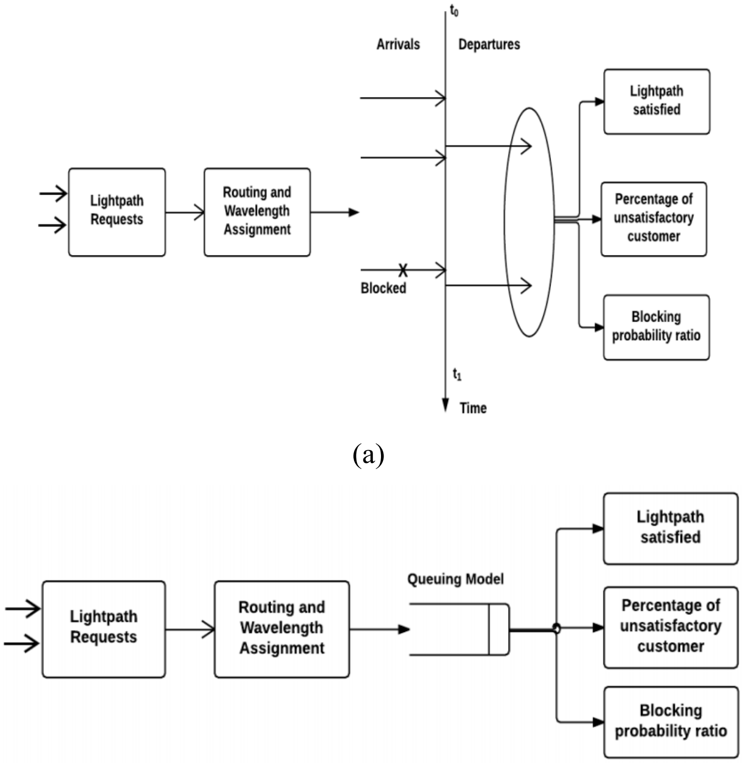
- *Unsatisfactory Customer:* According to the total number of requested lightpaths at node pairs, demands between source and destination are served with a limited manner. These customers are unsatisfactory customers. In particular, new coming demands can result with the degradation of the satisfaction of the customers due to the limited network resources.

- *Satisfied Customer:* The satisfied customers are those who can find an appropriate path and wavelength assignment between the corresponding source and destination.

3. PROPOSED SCHEME

In the paper, two scenarios are considered to address RWA problem as seen in Figure 2.

- *Without queue:* Here, lightpath requests are considered in each time slot separately. When a request arrives at a time, available routing paths and wavelength assignments are defined spontaneously. However, if there is no available resource, the lightpath requests are dropped as seen in Figure 2(a). Moreover, when more ligthpaths are detected for the same routing path as available, one of them is randomly selected and the other ligthpaths requests are dropped.
- *With queue (with SDN paradigm):* Lightpath requests are modeled with M/M/1/K queuing model as seen in Figure 2(b). Here, at first, primary and secondary paths are checked for source and destination node pairs and then wavelengths are assigned. When the lightpath for the connection has been established, the network state is updated. However, if there is no available resource for lightpath requests, requests are waited in the queue to serve next slots by minimizing the amount of connection blocking.



(b)

Figure 2. (a) Proposed scheme without queuing approach (b) Proposed scheme with queuing model (with SDN paradigm).

3.1. Routing

Dijkstra's algorithm is a shortest path algorithm between source and destination node pairs. Each path is checked with minimum distance. Then a feasible solution is assigned to the first free wavelength with Dijkstra's algorithm. Path lengths are the sums of the link weights.

It is assumed that shortest path for each source-destination node pair is predetermined as fixed routing in the network topology. Then, a fixed alternate routing is established for each node pairs in the routing table. Note that this route does not share any links with primary route.

Moreover, it is assumed that there is link fault in the network and the wavelengths along the path are not tied up such that it will enable to prevent high blocking probabilities.

3.2. Wavelength Assignment

When lightpath requests arrive, lightpaths are assigned to the wavelengths. In the paper, it is assumed that the number of wavelengths is fixed, also assigned according to First-Fit. In this scheme, all wavelengths are numbered from 1 to W, where W is the maximum number of wavelengths supported on a fiber, and then wavelength list is ordered depending on wavelength number. Then, a free wavelength is found for the request. In every step, available lower-numbered wavelength is selected. Here, if the lightpaths share the same route, the wavelengths for these lightpaths are assigned differently.

The main objective of this scheme is to reduce the blocking probability in the network. Moreover, an advantage of this scheme is that it requires no global information so that the First-Fit does not introduce any communication overhead.

3.3. Queuing Model

M/M/1/K queuing model is considered to model the lightpath requests. K is the maximum number of lightpaths that is being waited in the system. The arrivals are independent of the number of lightpaths in the system and exponentially distributed. The service times are also assumed to be exponentially distributed and independent so that the mathematical calculations are traceable. Assigned lightpath, ψ, is determined as the ratio of total number of lightpaths that successfully served, L^B, to the number of entire requested lightpaths, L^S, at time interval t_0 and t_1, as given in Equation 1.

$$\psi = \frac{E(L^B)}{E(L^S)} 100 \qquad (1)$$

where

$$E(L^B) = 1 - \frac{1-\rho}{1-\rho^{K+1}} \tag{2}$$

and

$$E(L^S) = \sum_{i=0}^{K} nP_n \tag{3}$$

where ρ is the traffic intensity and $\rho = \lambda / \mu$. λ represents the lightpath arrival rate, and μ is service rate, n is the number of lightpaths.

$$P_n = \rho^n P_0 \tag{4}$$

where P_0 is the probability that there is a feasible path and wavelength for the requested lightpath as given in Equation 5.

$$P_0 = \frac{1-\rho}{1-\rho^{K+1}} \tag{5}$$

The number of requested lightpaths that waits in the queue is given in Equation 6.

$$E(L^q) = \sum_{i=0}^{K} (n-1) P_n \tag{6}$$

The ratio of total number the waited lightpaths in queue is as follows. Please note that this also represents to the ratio of unsatisfactory customers.

$$E(L^q) = \frac{\sum_{i=1}^{n} E(L^q)}{\sum_{i=1}^{n} n_i} 100 \tag{7}$$

The blocking probability of a customer can be expressed as follows:

$$P(n=K) = P_K = \frac{(1-\rho)\rho^K}{1-\rho^{K+1}} \tag{8}$$

4. PERFORMANCE EVALUATION

The performance of the proposed schemes, which are without queue and with queue (with SDN paradigm), is evaluated in this section. In the first approach, when a connection request arrives, if there is no available path or a wavelength assignment for a route, this request is blocked. However, in the SDN approach, the controller is responsible to manage optical network topology, establishes and schedules the lightpaths for node pairs.

Here, 14-node National Science Foundation Network (NSFNET) is employed as demonstrated in Figure 3. Each link contains 2 fibers, and each fiber supports 8 wavelengths. The capacity of a wavelength is assumed to be 10 Gbps. A dynamic traffic pattern is considered. Lightpath requests are created with a random fashion between source and destination node pairs.

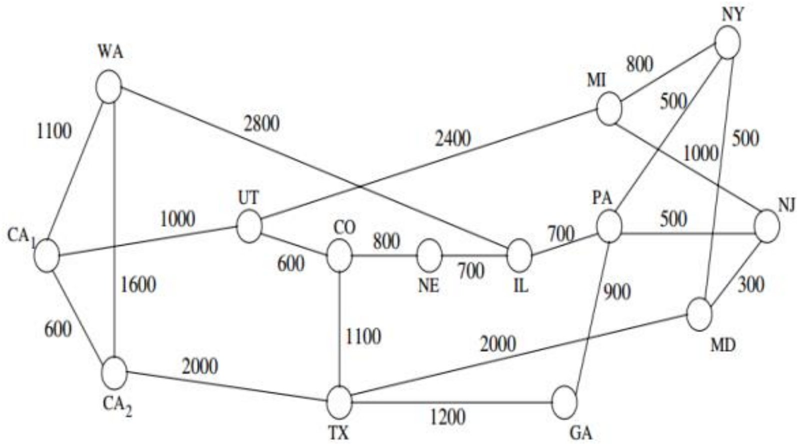


Figure 3. The 14-node NSFNET network topology showing approximate distances between the nodes in km.

In this respect, Figure 4 shows the assigned lightpath for different traffic loads. This is determined as the ratio of total number of lightpaths that successfully served to the number of all requested lightpaths.

As seen in Figure 4, SDN-based optical networks achieve more lightpath in each traffic load. The explanation for the observation is that if there is no available network resource, the requested lightpaths are waited and scheduled in the next time intervals with a centralized controller. Here, controller has the global information of the network so that it can manage the lightpaths. With SDN approach, the lightpath is approximately enhanced 6% in optical networks.

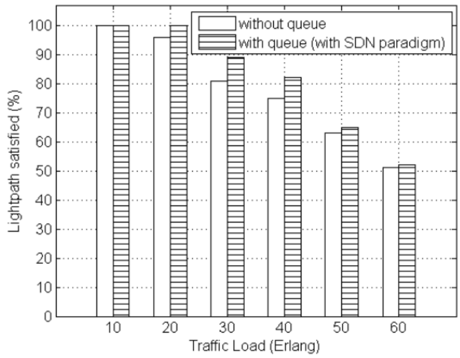


Figure 4. Lightpath satisfied w.r.t traffic load.

In addition, Figure 5 shows the ratio of total unsatisfactory customer in the optical network topology. Here, when there is no sufficient resource, lightpaths are waited in the queue to handle in the next time slots. This enables degradation in the ratio of unsatisfactory customers. Queuing model enables to serve more unsatisfactory customers when compared to without queuing model.

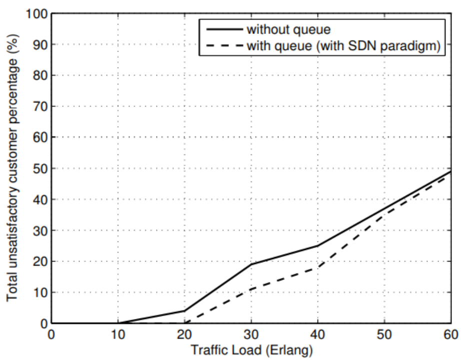


Figure 5. Total unsatisfactory customer percentage.

Figure 6 shows the blocking probability ratio. Here, unsatisfactory customers waiting in the queue are restricted in order to manage network resources. In the M/M/1/K model, K is maximum number of lightpaths that can be waited in the system. Here, SDN-based optical networks achieve better blocking probability performance under different traffic load. However, it is observed that when the traffic load increases, the performance of the SDN-based optical networks will show more slowly increase due to the high number of existing lightpaths in the topology. It can be seen that SDN-based optical networks achieve better performance when compared to conventional optical networks.

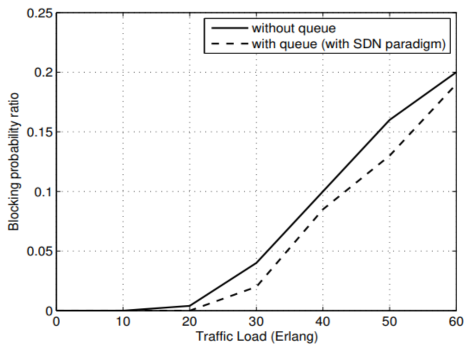


Figure 6. Blocking probability ratio w.r.t traffic load.

5. CONCLUSION

In this paper, the Routing and Wavelength Assignment problem is analyzed with SDN paradigm in optical networks. In order to enhance the assigned lightpath and decrease the blocking probability, SDN based queuing model is proposed. A centralized and programmable controller is modeled to manage all requested lightpaths in the topology. It is observed that SDN paradigm in optical networks is a suitable option to serve more customers. The ongoing work involves the effect of the dynamic traffic patterns for Optical Networks.

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Journal of Naval Sciences and Engineering
2019, Vol. 15, No.2, pp. 113-128
Social Sciences/Sosyal Bilimler

REVIEW

A CRITICAL EVALUATION OF PETER LEESON'S ARGUMENTS ABOUT PIRACY

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Date of Receive: 14.10.2019 **Date of Acceptance:** 15.11.2019

ABSTRACT

The purpose of this review is to critically evaluate Peter Leeson's paper in which he argues that piracy as profit-seeking criminal activity may produce socially desirable outcomes and achieve a social order and then, concludes that criminals' self-interested and profit-seeking activities are capable of producing public benefits in the context of invisible hand. More precisely: the purpose is to critically discuss and evaluate Leeson's general conclusion, line of reasoning and to present counter-arguments in the context of invisible hand and pirates' relative racial tolerance policy towards black sailors in their crews. Leeson tries to investigate the political economic and social impacts of piracy in the late seventeenth and early eighteenth century and argues that black crew members' economic and social status in pirate ships were more progressive compare to the legitimate merchant ships. Leeson reads black crew members' status in pirate ships as an improvement in racial equality, economic and social justice. Therefore, he concludes that self-interested and profit-seeking criminal activities are capable of producing socially laudable outcomes. In contrast to Leeson, the argument in this review is that self-interested and profit-seeking criminal activities are not capable of producing socially laudable outcomes.

Keywords: *Piracy, Thievery, Social Contract, Invisible Hand, Self-interest Seeking.*

PETER LEESON'IN KORSANLIK İLE İLGİLİ ARGÜMANLARININ ELEŞTİREL BİR DEĞERLENDİRMESİ

ÖZ

Bu derlemenin amacı; Peter Leeson'un kâr amacı güden bir suç faaliyeti olarak korsanlığın sosyal olarak arzu edilebilir sonuçlar üretebileceğini ve sosyal bir düzen sağlayabileceğini savunduğu ve akabinde, suçluların kişisel çıkar ile kâr amacına dayalı faaliyetlerinin görünmez el bağlamında kamu yararı üretebileceği sonucuna varmış olduğu çalışmasını eleştirel olarak değerlendirmektir. Daha açık olarak; amaç Leeson'un varmış olduğu genel sonucu, akıl yürütme çizgisini eleştirel olarak tartışıp değerlendirmektir ve karşı argümanları, görünmez el ile korsanların mürettebatındaki siyahi denizcilere karşı göreli ırksal tolerans politikası bağlamında sunmaktır. Leeson, korsanlığın on yedinci yüzyılın sonlarında ve on sekizinci yüzyılın başlarındaki politik ekonomik ve sosyal etkilerini araştırmaya çalışmaktadır ve siyahi mürettebat üyelerinin korsan gemilerindeki ekonomik ve sosyal statüsünün, meşru ticari gemilerdekilere kıyasla daha ilerici bir konumda olduğunu savunmaktadır. Leeson, siyahi mürettebat üyelerinin korsan gemilerindeki statüsünü ırksal eşitlik, ekonomik ve sosyal adalet alanlarında bir gelişme olarak okumaktadır. Bu nedenle, kişisel çıkar ile kâra dayalı suç faaliyetlerinin sosyal olarak övgüye değer sonuçlar üretebileceğini savunmaktadır. Leeson'un aksine, bu yazıda, kişisel çıkar ile kâra dayalı suç faaliyetlerinin sosyal olarak övgüye değer sonuçlar üretemeyeceği savunulacaktır.

Anahtar Kelimeler: *Korsanlık, Hırsızlık, Toplum Sözleşmesi, Görünmez El, Kişisel Çıkar Arayışı.*

1. INTRODUCTION

The paper I wish to critically evaluate is "The Invisible Hook: The Law and Economics of Pirate Tolerance" [1]. Peter Leeson has published multiple fascinating papers and books about political, economic, social and legal aspects of piracy. But for the sake of this review, I wish to focus on "The Invisible Hook: The Law and Economics of Pirate Tolerance." In this paper, the main idea is that self-interested and profit-seeking criminal activities are capable of producing socially desirable outcomes. Leeson tries to draw this conclusion by focusing on the impacts of pirates' group policies and practices in the late seventeenth and early eighteenth century which is the main subject of his paper.

Leeson investigates the political economic and social impacts of pirates' activities, practices and racial tolerance policy towards black crew members. He argues that piracy as a form of criminal activity can produce socially progressive and constructive outcomes in the context of invisible hand and therefore, it can be concluded that even criminal self-interest seeking can produce socially beneficial outcomes compare to the legitimate self-interest seeking. In contrast to Leeson, I contend that criminal self-interest seeking can not produce socially beneficial outcomes in the context of invisible hand.

This paper is divided into five sections. Following this first introduction section, I will discuss Leeson's conclusion regarding the impacts of criminal activities in the economic and social context. Then, in the third section, I will explain Leeson's arguments about pirates' activities and racial tolerance policy towards black crew members. In the fourth section, I will present critical counter-arguments about piracy and will share conceptual mistakes from Leeson's paper. In the last section, I will try to draw a brief conclusion about all of these.

2. CRIMINAL ACTIVITIES IN THE ECONOMIC AND SOCIAL CONTEXT

Leeson focuses on the concept of thievery in order to understand and appreciate the underpinnings of pirates' organized structure. He evaluates thievery as a conditional necessity of self-interest seeking behavior in the context of piracy. He chooses to pay particular attention to the thievery when claiming the ability of criminal activities in producing progressive and constructive outcomes for society as his general conclusion. This treatment seems narrow. Thievery is necessary, but not sufficient element in order to define the concept of criminal activity as a whole. I will mention this as a conceptual mistake in the following sections. But for the sake of this section: I will discuss thievery -as a form of criminal activity which is linked to piracy- in the economic and social context in order to argue its inefficiency in producing beneficial and desirable outcomes, unlike Leeson's general conclusion in his paper.

It is universally acknowledged that there is incompatibility / tension between the available resources and human beings' needs or desires. The competition between finite resources and infinite needs or desires plays a crucial and decisive role in daily lives. The finite resources and risk for scarcity require individuals to make rational and profit maximizing choices in order to avoid / eliminate potential risks and to fulfill the needs or desires effectively in the long term.

Thomas Robert Malthus, for instance, has focused on the inequality between human population and production in Earth. Malthus has believed that a critical comparison between human population and production is necessary in order to understand and examine the commencement, development and functioning of society. In *An Essay on the Principle of Population*, he has argued that human population has a tendency to grow geometrically and production for subsistence has a tendency to grow arithmetically when unchecked or uncontrolled. Thus, Malthus has emphasized the tension between human population and production in Earth as challenge and obstacle for the improvement of society [2]. This challenge has been interpreted as an active motivator / trigger for individuals to establish preventive authority above them in order to minimize potential risks and conflicts regarding the finite resources, risk for scarcity and protection of property.

Our imperfect and unbalanced world is full of with opposing interests, conflicts and struggles. In this respect, the relation / tension between human population and production, opposing interests, risk for scarcity, security concerns, uncertainty, unpredictability and instability can be evaluated as key reasons or justificatory elements for offensive and defensive actions among human beings. The variety and complexity of the reasons and outcomes regarding these actions have triggered the need for a collective, rational and judgmental agreement above all human beings. At this point, we should discuss the position of thievery in the light of all of these and ask ourselves if thievery can be conceptualized as a reflection of offensive and defensive actions in order to survive and to eliminate conflicts? Moreover, can thievery produce socially positive and constructive outcomes? A critical historical look towards the development of private property, civil society, formation of states and binding legal authority can be read as signs of will in adopting defensive and preventive measurements and in achieving self-control for the elimination of irregular, uncertain and anarchic elements that thievery also includes. Therefore, I believe that conceptualizing thievery as a constructive and beneficial activity implies a historical and moral contradiction.

Hereupon, I wish to refer to John Locke's version of social contract theory and Adam Smith's invisible hand theory in order to criticize Leeson's conclusion about the impacts of thievery and criminal actions in the economic and social context. At this point, political philosophical framework of social contract can be part of our guide in criticizing Leeson's conclusion about the impacts of thievery and criminal actions in general.

Social contract theory has been used in order to appreciate the connection between nature and politics. John Locke has conceptualized the theory of social contract as a necessity for peaceable living. This theory implies collective and binding agreement among human beings in order "to join and unite into a community, for their comfortable, safe and peaceable living one amongst another, in a secure enjoyment of their properties and a greater security against any that are not of it" [3]. It can be argued that the formation and determination of political authority by human beings' consent underpin social contract theory which emphasizes the need for security and conflict resolution.

In the state of nature -a hypothetical and methodological model that implies the natural status of human beings before being subject to any superior agreement, political power or legal code above them- there was no civil society and judge. But this environment that lacks of civil authority and judge can not be evaluated as immoral, since human beings are naturally concerned with social and moral principles [4].

Human beings have an intrinsic tendency for moral compass in deciding what is right and what is wrong and share a sense of collective duty and social responsibility towards one another. Human beings' intrinsic tendency for morality and sociality has a divine source. Locke has argued that all human beings are God's property, which means that they can not be subject to any authority on Earth without giving their consent. This divine and natural equality in the state of nature implies the principles of reciprocity, altruism, tolerance, independency and state of being free from any coercive or autocratic power. This state of equality and liberty -by nature and God- commands human beings not to harm one another's "life, health, liberty or possessions" [5], in Locke's expressions.

This moral command is part of the divine law of nature which expresses a collective duty and social responsibility for comfortable and peaceful lives. Thus, if a human being would violate the law of nature (harm one another's property), then it would be rightful and reasonable for others to punish the crime since it threatens the state of equality, freedom and peace. At this point, the issues of crime and lawfully / justly punishment and boundaries of the law of nature can be evaluated as most decisive elements in deciding to abandon the state of nature, to agree on a social contract, to enter into a civil society and to establish a political authority which can properly remedy the irrationalistic and unjust characters that govern / effect human beings' actions and judgment adversely and thus, disrupt human beings' security and happiness [6]. Social contract is necessary for the functionality and improvement of mutually peaceful relationships.

Simply summarize all of these: individuals become subject to political power and legal authority tacitly or explicitly under the binding obligation of social contract. Locke's version of social contract identifies the reasons for human beings' need of a secure and peaceful environment which is essentially connected with the protection of property rights and justice. Political authorities' legitimacy and settlement -which has a civil and humane foundation- depends upon meeting this need -of a collective security and protection- lawfully / justly [7].

Thievery and criminal activities in general threaten this collective and harmonic framework that individuals have preferred to establish and follow in order to avoid or punish unjust, dysfunctional and violent actions. Leeson seems to take a position that tends to interpret pirates' internal structure in accordance with the underpinnings of functional civil societies. But he seems to ignore the external impacts of irregular, uncertain and anarchist structure of thievery and a society or social order can not be sustained in the long term if it has irregular, uncertain and anarchist structures. Thievery, this paradox, threatens the development of civil society and therefore, it can not be able to provide publicly desirable and effective outcomes and can not achieve a social order as Leeson concluded by referring to Adam Smith's theory of invisible hand as well.

Adam Smith's theory of invisible hand explains how self-interested individuals unintentionally or unknowingly contribute to the well-being of society. Self-governed and self-interested individuals promote to the functionality and continuity of society. This situation is like a sample of natural design or order. The existence and development of society depends on the interdependency and cooperation between individuals. Thus, individuals have a natural tendency for mutually beneficial behaviors without intervention. Invisible hand as metaphoric socio-economic explanation in converting individualism into collectivism -by emphasizing socially beneficial and constructive outcomes of self-interested choices and behaviors- emphasizes natural and voluntary exchange activities for public good [8].

Smith's notions of self-interest seeking, ability for rational and profit-maximizing decision making process, free and voluntarily choice are connected with moral values and ethics which also govern human nature. Human beings are both individualistic and social creatures. They have both economic and social characteristics. They have social, unsocial and selfish passions. They may concern for both private and public interest. Besides, rationality may not be the prominent and dominant characteristics that govern human beings' choices and behaviors [9]. Leeson does not have this kind of a comprehensive perspective towards the causes and effects of piracy.

I think Leeson's notion of collectivism (mainly refers to the crew members in pirate ships and black sailors within) does not reflect Smith's notion of collectivism (mainly refers to the formation, development and continuity of society) accurately and completely. It can be argued that self-interest seeking can not be evaluated as merely selfish or internal concept from Smith's point of view.

There are both positive and negative outcomes and both individualistic and collectivistic characteristics regarding human beings' choices and behaviors. Justifying the potentiality and actuality of thievery as a constructive and positive form of crime implies a threat for the functionality of society and notion of justice. In general: Leeson does not focus on the difference between self-interest seeking and selfishness / public interest and private interest in understanding and investigating the motivations and effects of pirates' behaviors. It seems that behavioral economic references in this paper are limited and superficial. Therefore, I argue that Leeson fails to appreciate the intertwined connection between economics and moral values which results in the development and continuity of societies in the context of invisible hand.

Achieving a social order or establishing a society should include moral values and justice as well from Smith's point of view. At this point, prioritizing the notion of justice is essential and necessary strategy. Justice underpins the continuity of society. Smith emphasized the risk for corruption of moral sentiments in making the existence, survival and admiration depending on material wealth and capital [10]. Thus, I argue that piracy and thievery include a risk or threat in corrupting moral sentiments and justice that contribute to the well-being and functionality of society.

To summarize this section: mutual desire or will -that can not be discussed separately from moral values and justice- should be a necessary condition for exchange activities and profit-maximizing strategies. But thievery implies a threat of violence and force to the public interest. Therefore, the probability of Leeson's conclusion (criminal actions are capable of producing publicly beneficial outcomes) given its premises (pirates' activities in the late seventeenth and early eighteenth century produced publicly beneficial and desirable outcomes in the form of invisible hand) is low in the context of social contract and invisible hand theories.

3. LEESON'S ARGUMENTS ABOUT THE ECONOMICS OF PIRATES' RACIAL TOLERANCE POLICY

Leeson's arguments about the economics of pirates' racial tolerance policy towards black sailors are as follow: Both pirates and legitimate merchant ships hired black sailors into their crews. But the conditions were more progressive in pirate ships, then in legitimate merchant ships for black sailors. Leeson argues that pirates as well-organized, capitalistic, predatory firms, societies and enterprises provided better conditions and rights for black crew members compare to the legitimate merchant ships and this was a racial tolerance policy in the self-interested and opportunistic form [11].

Leeson argues that black crew members were better off in pirate ships and the reason for this progressive racial tolerance policy was mainly economic rather than enlightened ideas or moral values. Leeson makes a comparison between pirate ships and legal merchant ships regarding the cost and benefits of slavery trade and argues that there was a greater racial equality, economic income and incentives for blacks in pirate ships. Therefore, he defends that "analogous to Adam Smith's invisible hand, whereby legitimate persons' self-interest seeking can generate socially desirable outcomes, among pirates there was an invisible hook, whereby criminal self-interest seeking produced a socially desirable outcome in the form of racial tolerance" [12].

Pirates mainly focused on illicit profit-seeking activities and thus, developed rational policies and strategies in accordance with this purpose. Pirates needed to decide effectively in order to choose the best alternative for their interest. They tried to measure and manage potential risks and impacts. At this point, Leeson explains that pirates had their own management and governance system of costs and benefits in the context of self-interest seeking [13]. This specific, kind of personalized and flexible internal governance strategy, according to Leeson, contributed to the idea of self-governance in public. Since pirates needed to jointly steal or obtain, they all had a right for ownership and also vote in affecting and shaping the crew's management and governance system which reflects a democratic and constitutional political economic structure.

Pirates as rational economic actors aimed to capture large ships and to attain useful goods and gold that could finance them in the long term. Pirates could not rely on a legal authority while stealing. They had to operate in accordance with their own costs and interests. This was the main reason for the development of self-governance and racial tolerance policy towards black sailors. Thus, social justice, economic opportunities and incentives were larger in pirate ships for black sailors than in legitimate merchant ships. Black sailors, as part of pirate ships, could receive large payments or compensation from plunder as long as they contributed which emphasizes the capitalistic, reciprocal and incentive characteristics of piracy from Leeson's perspective [14]. Leeson argues that pirates' both collective and individualistic ownership and their illicit group identity should be evaluated as decisive reasons in adopting a racial tolerance strategy and in achieving a social order.

It seems that there was no need to adopt racist attitude for most of the pirates, since they were the outsiders of law and authority anyways. The group identity, motivation and cooperation between crew members were strong due to the conditions of this environment or in Leeson's word: of this "floating society" [15].

To summarize Leeson's arguments: pirates used black people for their own interests, just like legitimate merchant ships, but the circumstances in pirates' ships were more progressive and beneficial for black people back then, compare to the legitimate merchant ships. Pirates' racial tolerance policy created desirable and democratic reflections (such as improvements in racial equality, economic and social justice) in public. Therefore, Leeson concludes that criminal activities can produce socially desirable, constructive and beneficial outcomes in the context of invisible hand.

4. CRITICAL COUNTER-ARGUMENTS ABOUT THE ECONOMICS OF PIRATES' RACIAL TOLERANCE POLICY

Leeson emphasizes that pirates are self-interested, opportunistic and rational actors. Therefore, he tries to read the rational motives and triggers behind pirates' behaviors in the context of invisible hand, but ignores the irrationalistic and anarchistic characteristics that also underpin pirates' behaviors. Leeson does not focus on the irrationality and complexity in human nature and internal / external causes and effects of illicit group identity in general. In his paper, anarchic and behavioral context is limited, because Leeson evaluates them as well-organized and rational capitalistic firms. But that seems problematic and narrow.

Max Weber, for example, has evaluated the concept of capitalism as a peaceful exchange. He has attracted attention to the connection between rationalism and capitalism, but also argued that "a capitalistic economic action as one which rests on the expectation of profit by the utilization of opportunities for exchange, that is on (formally) peaceful chances of profit" [16]. Thus, piracy can not be evaluated as a form of capitalism, unlike Leeson's argument. Apart from this issue, Leeson uses some metaphors from Adam Smith in order to justify his conclusion about criminal activities, but does not mention Smith's core arguments about the connection between morality and economics. Simply put: his efforts in making the concept of invisible hand suitable for the consequences of profit-seeking criminal activities do not refer to the whole point from Adam Smith's perspective.

Leeson does not discuss the terrifying reputation that pirates possessed in society back then and how that may help to increase a prejudice towards black people since some of them would prefer to be part of this structure from Leeson's point of view. In this respect, the outcomes of piracy may affect black people and their status in society adversely too. Leeson seems to fail to present both internal and external views and reflections about piracy. Leeson cares for the public opinion and benefits, but can not manage to present a comprehensive psychological and social framework about the views and reflections of piracy in society. Besides, Leeson does not share the psychological elements that underpin pirates' group identity. We can not find details about how all of the crew members could cope with collective responsibility and possible guilt psychology regarding the outcomes of their actions. There is an ambiguity in referring to the notion of collectivism in Leeson's paper anyways and lack of a detailed psychological and social framework about piracy contributes to this as well.

Leeson investigates only specific period and area of piracy. He tries to justify his general conclusion about criminal activities by comparing two "business" units (pirate ships and legal merchant ships) and actors within. But still, he tries to draw a general political economic and social conclusion that can be permanently valid and sound for the world that we live in. His general assumption about the potentiality and actuality of criminal activities seems controversial and can be critically examined as an example of hasty generalization and false dichotomy regarding economic and social justice.

In addition to these: there was a temporal proximity between the golden age of piracy and domination of mercantilist political economic experiences which emphasize the importance of commercial activities and colonization overseas for the accumulation of capital and wealth [17]. In this respect, power and authority on seas have been evaluated as key strategy in competitive international environment. Nations needed to minimize the cost of labor in order to increase the frequency of their overseas journeys and discoveries. It can be argued that the development and temporarily domination of mercantilist policies effected the mobilization of black sailors both in pirate ships and legal merchant ships. But Leeson seems to ignore this historical background that effected pirates' behaviors and policies towards black sailors.

I wish to mention some conceptual mistakes from Leeson's paper in order to conclude this section. Leeson shares his conclusion regarding the outcomes of criminal activities from a superficial point of view. In his paper, the concept of criminal activity includes piracy and thievery within a specific period and area. This perspective seems narrow. Like it is mentioned before: thievery is necessary, but not sufficient sample for us in order to define the concept of criminal activity as a whole. Therefore, I think Leeson fails to appreciate different and multiple aspects of criminal activities -and also piracy- in his paper.

Leeson tries to share classic capitalistic concepts in order to understand pirates' motivations and desires. In doing so, he tries to refer to the concepts of pragmatism and rationalism as if they are interchangeable. But this is problematic. Pragmatism is defined as "an approach that evaluates theories or beliefs in terms of the success of their practical application" and rationalism is defined as "the practice or principle of basing opinions and actions on reason and knowledge rather than on religious belief or emotional response and the theory that reason rather than experience is the foundation of certainty in knowledge" in Oxford Dictionary [18].

Practical and decisive consequences matter for the concept of pragmatism. Pragmatism implies a deterministic framework within the actual consequences. Reason and logic matters for the concept of rationalism rather than consequences and individualistic / collectivistic experiences. At this point, Leeson seems to refer to these two concepts as if they are commensurable in the context of piracy and invisible hand. He does not seem to appreciate the conceptual differences between pragmatism and rationalism in investigating pirates' motivations and desires.

5. CONCLUSION

Leeson aims to challenge the traditional view about piracy. He desires to present a different kind of historical and at the same time contemporary view about pirates' policies towards black sailors. He adopts comparative and interpretive perspective in the political economic and social context. But he fails to share multi-layered, comprehensive and critical variables regarding pirates' choices and behaviors in the form of self-interest seeking. His interpretation about the desires and motivations that underpin pirates' behaviors is reductive. His line of reasoning which adopts historical and comparative political economic perspective in the context of pirates' racial tolerance policies towards black sailors as a starting point in order to draw a generalized and contemporary conclusion regarding self-interested, profit-seeking criminal activities includes inconsistencies.

In general: there are both rational and romantic interpretations about the outcomes of pirates' activities which is contradictory. There are theoretical and conceptual problematics about Leeson's arguments, conclusion and inductive methodology. Therefore, in contrast to Leeson, I contend that criminal profit-seeking is not capable of producing socially desirable outcomes. That also automatically implies that pirates' policies and activities in the late seventeenth and early eighteenth century did not produce socially desirable and laudable outcomes in the context of invisible hand or in his paper's title: "the invisible hook".

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Journal of Naval Sciences and Engineering
2019, Vol. 15, No.2, pp.129-157
Chemical Engineering/Kimya Mühendisliği

RESEARCH ARTICLE

THE EFFECTS OF EXHAUST GAS RECIRCULATION ON EMISSIONS AND PERFORMANCE OF A SPARK IGNITION ENGINE

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Date of Receive: 05.03.2019 **Date of Acceptance: 26.11.2019**

ABSTRACT

The development and production of modern spark-ignition engines are very important to market and regulations requirements which demand low cost, high-performance engines with low fuel consumption and reduced emissions of pollutant. Because these parameters are directly related to the combustion process in an engine cylinder, many kinds of research have been achieved to identify these parameters which affect combustion efficiency and pollutant formation in this engine cylinder. In this study, a thermodynamic cycle model has been developed and used to predict the effects of Exhaust Gas Recirculation (EGR), which is used to reduce the Nitrogen Oxide (NO) in exhaust gas, on emission levels and performance of a spark-ignition engine. The model simulates full thermodynamic cycle of a spark-ignition engine and includes heat transfer, combustion, gas exchange process, thermal dissociation of water and carbon dioxide, and chemical equilibrium in engine cylinder.

Keywords: *Cycle Model, Spark-Ignition Engine, Exhaust Gas Recirculation, Nitrogen Oxide, Emission.*

EGZOZ GAZI GERİ VERİLMESİ YÖNTEMİNİN BİR BUJİ İLE ATEŞLEMELİ MOTORUN EMİSYON DEĞERLERİ VE PERFORMANSI ÜZERİNE ETKİLERİ

ÖZ

Çağdaş buji ile ateşlemeli motorların geliştirilmesi ve üretimi, düşük maliyet, düşük yakıt tüketimi ile yüksek performanslı motorlar ve azaltılmış kirletici emisyonları talep eden pazar ve mevzuat gereksinimleri için çok önemlidir. Bu parametreler buji ile ateşlemeli bir motor silindiri içindeki yanma işlemi ile doğrudan ilişkili olduğu için, buji ile ateşlemeli bir motor silindiri içerisindeki yanma verimini ve kirletici emisyonlarını etkileyen bu parametrelerin tanımlamasını yapan birçok araştırma başarıyla yapılmıştır. Yapılan bu çalışmada, bir termodinamik çevrim modeli geliştirilerek, egzoz gazındaki azot oksit (NO) yüzdesini azaltmak amacı ile kullanılan Egzoz Gazı Geri Verilmesi Yönteminin buji ile ateşlemeli bir motorun egzoz emisyon değerleri ve performansı üzerine etkilerini tahmin etmek için kullanılmıştır. Kurulan model, buji ile ateşlemeli bir motorun tüm termodinamik çevrimini yansıtmakta ve motor silindiri içindeki yanma olayını, ısı transferini, gaz değişimini, yanma ürünlerinin ısıl ayrışmasını ve kimyasal dengeyi içermektedir.

Anahtar Kelimeler: *Çevrim Modeli, Buji ile Ateşlemeli Motor, Egzoz Gazı Geri Verilmesi, Azot Oksit, Emisyon.*

1. INTRODUCTION

The reciprocating internal combustion engine has found its widest use in the automotive industry, although this type of engine has been utilized in numerous other applications as well. The higher power to weight or volume ratio, relatively lower cost and easy maintenance of the engine have made it popular for land transport. The development and production of the modern spark-ignition engines is very important to market and legislation requirements which demand low cost, high-performance engines with low fuel consumption and reduced emissions of pollutant [1]. These factors are directly related to the combustion process in the cylinder of engine, many kinds of research have been achieved to identify the parameters which affect the combustion efficiency and pollutant formation [2, 3, 4, 5, 6].

Motor vehicles are responsible for a significant amount of environmental pollution, especially in urban areas. Road-traffic emissions come from a number of sources. They include exhaust pipe emissions and contributions from friction processes and resuspended road dust. This results in a complex mixture that includes particulate matter and gaseous pollutants, such as nitrogen oxides (nitric oxide and nitrogen dioxide), carbon monoxide and volatile organic compounds, all of which pose risks to health [7]. The relative amounts depend on engine design and operating conditions but are of order: NOx, 500 to 1000 ppm or 20 g/kg fuel; CO, 1 to 2 percent or 200 g/kg fuel; and HC, 3000 ppm or 25 g/kg fuel [8].

Figure 1 shows emissions of nitrogen oxides, which increased steadily during the 1980s, by about 25%, owing to increasing road traffic. They fell by 20% from 1991 to 1998, mainly owing to the introduction of three-way catalysts in new passenger cars. The gradual increase in sales of diesel-powered passenger cars in some countries may result in higher nitrogen oxide emissions [7].

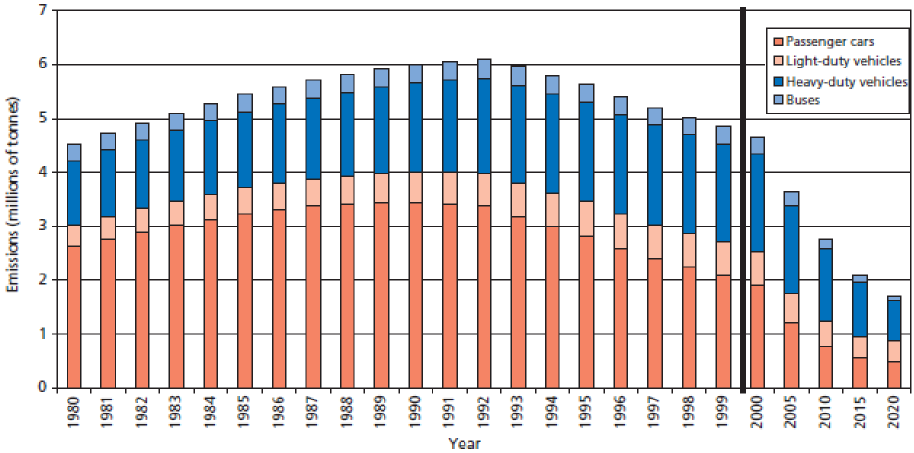

Figure 1. Total traffic emissions of nitrogen oxides in the EU countries [7].

Figure 2. shows emissions of carbon monoxide in general decreased from 1981 to 1998, mainly owing to the introduction of three-way catalysts. This trend is expected to continue [7].

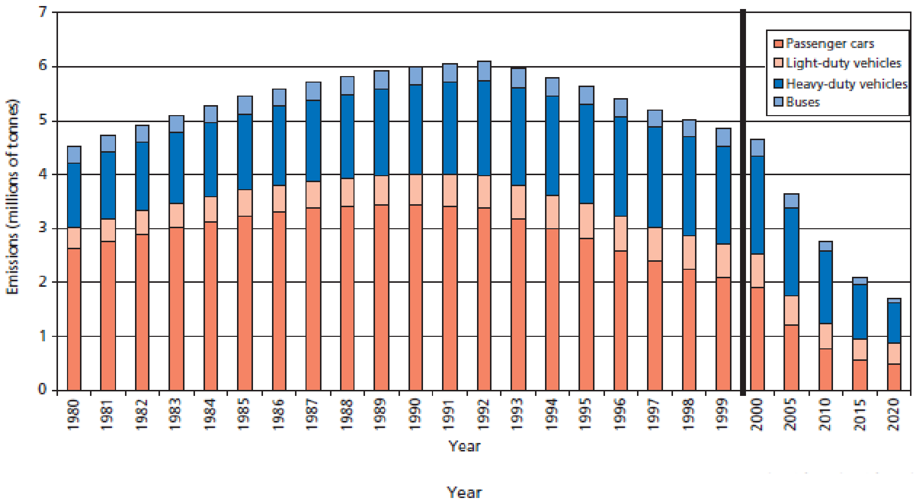

Figure 2. Total traffic emissions of carbon monoxide in the EU countries [7].

Non-stoichiometric combustion is the consequence of the mode of operation and design constraints on the reciprocating engines, which releases high toxic CO, NO and HC emissions to the atmosphere. All people are at risk for CO poisoning. Unborn babies, infants, the elderly, and people with chronic heart disease, anemia, or respiratory problems are generally more at risk than others. Breathing CO can cause headache, dizziness, vomiting, and nausea. If CO levels are high enough, you may become unconscious or die. Exposure to moderate and high levels of CO over long periods of time has also been linked with increased risk of heart disease. People who survive severe CO poisoning may suffer long-term health problems.

NO mainly impacts on respiratory conditions causing inflammation of the airways at high levels. Long term exposure can decrease lung function, increase the risk of respiratory conditions and increases the response to allergens. NO_x also contributes to the formation of fine particles (PM) and ground level ozone, both of which are associated with adverse health effects.

The design of automobile engines is very important to reduce these emissions. On the other hand, design and operating parameters affect levels of emissions, and these parameters affect engine performance and efficiency. The equivalence ratio has a strong influence on the formation of NO_x and on the oxidation of CO and unburned HCs, but the extent to which these emissions can be controlled through fuel-air ratio adjustment alone is limited. Other combustion parameters that can influence emissions include the ignition timing and design parameters. The compression ratio determines the peak pressure and hence peak temperature in the cycle. The piston and cylinder head shapes and the valve geometry influence the turbulence level in the engine and therefore the rate of heat release during combustion [17].

The processes by which pollutants form within the cylinder of a spark-ignition engine are compression, combustion, expansion, and exhaust which form four different phases of the engine operating cycle. NO forms throughout the high-temperature burned gases behind the flame through chemical reactions involving nitrogen and oxygen atoms and molecules, which do not attain chemical equilibrium. The higher the burned gas temperature, the higher the rate of formation NO. As the burned gases cool during the expansion stroke the reactions involving NO freeze, and leave NO concentrations far in excess of levels corresponding to equilibrium at exhaust conditions. CO also forms during the combustion process. With rich fuel-air mixtures, there is insufficient oxygen to burn fully all the carbon in the fuel to CO2; also, in the high-temperature products, even with lean mixtures, dissociation ensures there are significant CO levels. Later, in the expansion stroke, the CO oxidation process also freezes as the burned gas temperature falls [8].

The unburned HC emissions have several different sources. During compression and combustion, the increasing cylinder pressure forces some of the gas in the cylinder into crevices, or narrow volumes, connected to the combustion chamber; the volumes between the piston, rings, and cylinder wall are the largest of these. Most of this gas is unburned fuel-air mixture; much of it escapes the primary combustion process because the entrance to these crevices is to narrow for the flame to enter. This gas, which leaves these crevices later in the expansion and exhaust processes, is one of unburned HC emissions. Another possible source is the combustion chamber walls. A quench layer containing unburned and partially burned fuel-air mixture is left at the wall when the flame is extinguished as it approaches the wall [8].

Mathematical modeling has been one of the tools in meeting the challenge of reduced exhaust emissions and achieving good fuel economy. Since, mathematical modeling of the engines has been a subject of research helping to define key controlling variables, giving clearer insight to the physical processes and its ability to predict behavior under different operating conditions and in general powerful tool in engine design [8].

The main purpose of this study is to develop a computer program to calculate the cylinder pressure, burnt and unburnt gas temperatures, and NO concentration rate in burnt gas of a spark-ignition engine. A thermodynamic model is developed for a SI engine cycle, which is often called Otto cycle, to obtain the engine characteristics of emissions and performance. By using this model, cylinder pressure and gas temperatures are calculated as a function of crank angle and NO formation rate and performance of engine are investigated for the various stoichiometric ratio, λ, values. The details of the model and computer program can be found in Öğüçlü [6].

2. THERMODYNAMIC MODEL OF ENGINE CYCLE

The combustion process mathematical model is based on a homogeneous fuel-air combustible mixture, in which flame spreads from the spark plug. Engine cylinder is assumed to consist of two different regions which are separated by thin flame front. These are unburnt and burnt gas regions. The pressure in these regions is same, but all other gas mixture properties (such as temperature, specific heat values, ratio of specific heats) are different. Then, compression, combustion, and expansion processes in engine cycle are calculated using basic thermodynamic relations.

For compression process, with assumption of adiabatic compression, cylinder pressure and unburnt gas temperature are determined from relations for adiabatic compression. Thermodynamic coefficients and empirical functions for calculation of specific heat values of mixture of reactants and products are taken from Turns [9] and from Heywood [8].

For combustion and expansion processes, a relation between cylinder pressure, P, and crank angle, θ, has been obtained by applying the first law of thermodynamics to engine cylinder [10]. This equation includes volume change, combustion and heat transfer relations.

In this study, combustion rate is calculated from burnt gas mass fraction equation, $X(\theta)$ given by Vibe [11], and heat transfer rate is determined by using Annand heat transfer relationship [12]. The rate of volume change is also calculated from engine geometry. Then, to solve the cylinder pressure equation step by step for the crank angle, θ, the Euler's Method is used.

The products of combustion of fuel-air mixture are calculated by using dissociation of water and carbon dioxide, and preparing a chemical mass balance for Carbon, Hydrogen, and Oxygen. Then, with these calculated values, burnt and unburnt gas properties are determined from empirical relations.

After calculation of cylinder pressure *P*, unburnt and burnt gas temperatures, T_u and T_b, respectively, are determined by using basic thermodynamic relations. The heat transfer either to or from cylinder wall and burnt gas decompositions are considered. The properties of unburnt and burnt gases are calculated by using the first law of thermodynamics for engine cylinder. Then, by using these pressure and temperature values, engine performance parameters and fuel consumption are calculated.

To calculate NO formation relation, Zeldovich mechanism equations given by Hanson & Salimian [13] have been used. The assumption, that N_2, O_2, O, and OH concentrations equal equilibrium amounts and N atoms are in steady state condition, has been used. Also, to solve this equation, the Euler's Method is used.

The fuel – air mixture, which is inducted into engine cylinder at atmospheric conditions, mixes with the residual gas from the previous cycle and with the EGR gas. In this study, the EGR gas is expressed as a volume percentage of air and fuel mixture. This mixing process changes the fresh fuel–air mixture pressure and temperature. At the first stage of this study, the final mixture properties are obtained by using basic thermodynamic relations.

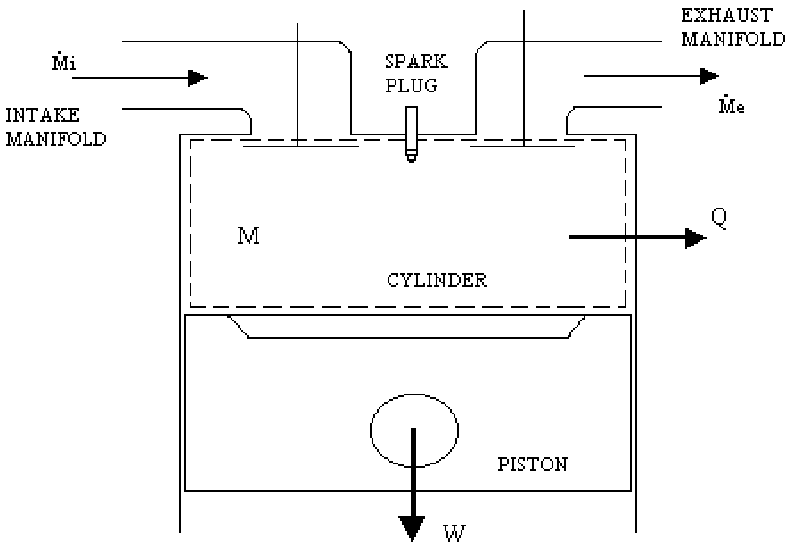

Figure 3. Engine Cylinder Thermodynamic System.

2. 1. Cycle Analysis

In this study, engine cylinder is considered as a control volume which includes all burnt and unburnt gases. Unburnt gas enters cylinder from the intake valve at flow rate, m_i and burnt gas exits cylinder from exhaust valve at flow rate, m_e , as shown in Figure 3.

There is a uniform fuel and air mixture in cylinder at end of intake time. Cylinder volume, gas pressure and gas temperature at end of intake time are P_1, V_1, and T_1. Since temperature difference between unburnt gas and cylinder wall is small, we can assume that compression of this gas is approximately adiabatic. Then cylinder pressure can be calculated from adiabatic compression equation, from crank angle at which intake valve closes to angle at which spark plug ignites fuel and air mixture.

After performing of the first law of thermodynamic for engine cylinder, we have an equation of cylinder pressure change with crank angle (*dP/dθ*), in terms of cylinder volume (*V*), gas pressure and gas temperature at end of intake time (P_1 and V_1), and volume change (*dV/dθ*), combustion rate change (*dX/dθ*) and heat transfer change (*dQ/dθ*) with crank angle [17],

$$\frac{\mathrm{dP}}{d\theta}=\frac{\frac{\mathrm{dQ}}{d\theta}-\frac{k_b}{k_b-1}P\frac{\mathrm{dV}}{d\theta}-m\left[a_b-a_u-\left[\frac{k_b-k_u}{k_b-1}\right].c_{V_u}T_1\left(\frac{P}{P_1}\right)^{\frac{k_u-1}{k_u}}\right]\frac{\mathrm{dX}}{d\theta}}{m.(1-X).c_{V_u}.\left[\frac{k_b-k_u}{k_b-1}\right].\left[\frac{k_u-1}{k_u}\right].\frac{T_1}{P}.\left[\frac{P}{P_1}\right]^{\frac{k_u-1}{k_u}}+\frac{V}{k_b-1}} \qquad (1)$$

where k_b and k_u are the ratio of specific heats of burnt and unburnt gases respectively, and c_{Vu} is the specific heat of unburnt gas. Parameters a_b and a_u include the reference temperature terms and the energies of formation of burnt and unburnt gases respectively and m denotes the total mass of the burnt and unburnt gases in the cylinder [17].

2. 2. Combustion Rate

The combustion rate has been calculated from burnt gas mass fraction

(m_b/m) equation, *X(θ)* given by Vibe [11]. It is a simple function and it forms of three different parts which are (i) a delay from time spark is fired until cylinder pressure increases, which is the result of combustion, (ii) an accelerating combustion rate in which a large part of air-fuel mixture is burned, (iii) and slowing combustion rate until the end of combustion duration. Vibe equation is given as below,

$$X(\theta) = 1 - \mathrm{Exp}\left[-6.908\left(\frac{\theta - \theta_0}{\Delta\theta_c}\right)^4\right] \quad (2)$$

where θ_0 is the crank angle at which the spark is fired and $\Delta\theta_c$ is the combustion duration as crank angle degrees.

2. 3. Heat Transfer Calculation

In the first law (see Equation (1)), Q is net heat transfer either to or from engine cylinder liner wall. In this cycle modeling, heat transfer is calculated by using Annand heat transfer relationship [12]. This heat transfer relation consists of convection and radiation heat transfer terms and is given as below,

$$\frac{\mathrm{dQ}}{\mathrm{dt}} = \mathrm{hA}_t(T_g - T_w) + \mathrm{CA}_t(T_g^4 - T_w^4) \quad (3)$$

where h is the convective heat transfer coefficient (W/m^2K), A_t is the total heat transfer area (m^2), T_g and T_w represent the mean gas temperature (K) and the mean wall temperature (K) respectively. The radiation coefficient C is given as $4.5x10^{-9}$ W/m^2K^4 by Annand [12].

2. 4. Rate of Volume Change

The compression ratio is given by

$$\varepsilon = \frac{V_c + V_d}{V_c} \quad (4)$$

where V_c is clearance volume (m^3) in which cylinder piston is at Top Dead Center (TDC) and V_d is displacement volume (m^3) between TDC and Bottom Dead Center (BDC).

Engine cylinder volume can be calculated from Equation (5) and stroke length deviation for crank angle can be calculated by Equation (6);

$$V(\theta) = V_c + \frac{\pi D^2}{4} S(\theta) \tag{5}$$

where,

$$S(\theta) = r\left[1 - \text{Cos}\theta + \frac{1}{\lambda}\left(1 - \sqrt{1 - \lambda^2 \text{Sin}^2\theta}\right)\right] \tag{6}$$

where λ = r / L, and L is piston connecting rod length (m) and r is crank shaft length (m).

Then, displacement volume change for the crank angle can be calculated by Equation (7);

$$\frac{\text{dV}}{d\theta} = \frac{\pi D^2}{4} \text{rSin}\theta \left[1 + \frac{\lambda \text{Cos}\theta}{\sqrt{1 - \lambda^2 \text{Sin}^2\theta}}\right] \tag{7}$$

and total wall area can be calculated by Equation (8);

$$A_t = \frac{4V_c}{D} + \pi D\left[r(1 - \text{Cos}\theta) + L\left(1 - \sqrt{1 - \lambda^2 \text{Sin}^2\theta}\right)\right] \tag{8}$$

2. 5. Combustion Stoichiometry

The burnt gas properties are calculated by assuming chemical equilibrium among six combustion products. The products of the reaction are numerous. Major products of lean combustion are H_2O, CO_2, O_2, and N_2; while for rich combustion, they are H_2O, CO_2, CO, H_2, and N_2. On the other hand, there are the minor species of equilibrium combustion of hydrocarbons in air. These are the atoms O and H, and the diatomic species OH and NO. But in this study, only the stoichiometric equation (see Equation (9)) is considered,

$$C_mH_n + a(O + 3.762N_2 + 7.656\mathrm{w}H_2O) \rightarrow \mathrm{bCO_2 + cCO + dH_2}O + \mathrm{eH_2 + fO_2} + 3.762\mathrm{aN_2} \qquad (9)$$

Equation (9) includes dissociations of water and carbon dioxide. In this equation, *a* is the ratio of moles number of O_2 in air-fuel mixture to moles number of fuel. *a* can be associated with the stoichiometric ratio, λ ; as $a=\lambda(m+n/4)$. When fuel type and λ are given, *a* is calculated.

The numbers of moles; *b*, *c*, *d*, *e* and *f* are dependent on the degree of dissociation of the reacting substances. To solve for the five unknowns, five simultaneous equations are required. The way to obtain these equations is preparing a chemical mass balance by considering the basic equilibrium reactions.

With these known values, the gas mixture properties can be calculated and the first law of thermodynamics for the modeling can be solved. The fuel, which is indicated by the formula "C_mH_n", is assumed to be iso-octane; where m = 8 and n = 18.

2. 6. Gas Exchange Processes

The fuel-air mixture, which is introduced into the engine cylinder at atmospheric pressure, P_a, and temperature, T_a, conditions, mixes with residual gas from previous cycle and with recycled gases from EGR. Therefore, this process changes pressure and temperature of final mixture, before compression stroke. At the first stage of this study, thermodynamic properties of the final mixture are calculated from basic thermodynamic relations. To calculate the final mixture properties, parameters such as induction air pressure, P_i and exhaust discharge pressure, P_e are kept constant. Figure 4 shows Gas Exchange Processes in the Engine Cylinder.

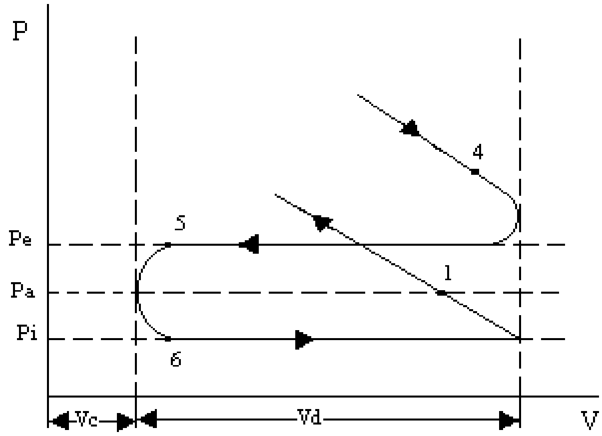

Figure 4. Gas Exchange Processes in the Engine Cylinder.

In the Figure 4, point 1 represents the crank angle where the intake valve closes (IVC), point 4 represents the crank angle where the exhaust valve opens (EVO), point 5 represents the crank angle where the inlet valve opens (IVO) and point 6 represents the crank angle where the exhaust valve closes (EVC).

2. 7. Solution Procedure

The cylinder pressure, P can be calculated by using Equation (1) with the combustion rate, $X(\theta)$, given by Vibe, and with the expression for heat transfer given by Annand. After cylinder pressure, P is calculated, unburnt and burnt gas temperatures, T_u and T_b, are determined respectively. In this study, to calculate cylinder pressure from the Equation (1), the Euler's Method is used. The unburnt gas temperature, T_u, is calculated from adiabatic compression equation and then the burnt gas temperature, T_b, is calculated. Further details of the cycle model can be found in Öğüçlü [6]. Euler method consists of the following formulas;

$$\frac{dP}{d\theta} = \frac{P_{i+1} - P_i}{\Delta\theta} = f(\theta_i, P_i) \qquad (10)$$
$$P_{i+1} = f(\theta_i, P_i)\Delta\theta + P_i$$

where P_i denotes Pressure value at the current step (kPa), P_{i+1} is Pressure value at next step (kPa) and $\Delta\theta$ denotes step size in crank angle degrees. For θ_1 = Spark Timing, θ_0 ; first Pressure value, P_1 is calculated from relation between pressure and volume in adiabatic compression.

3. POLLUTANT EMISSION FORMATION AND CONTROL IN COMBUSTION

The combustion products are known as a source of environmental damage, with the continuous increase in the combustion of hydrocarbon fuels. The most important combustion products are carbon dioxide and water. Now the carbon dioxide is just being a significant source in atmosphere for the greenhouse effects. On the other hand, Nitrogen Oxides (NO_x) are less known products of combustion. In the last half of the 20^{th} century, it has become apparent that NO and NO_2, collectively called NO_x, is a major contributor of photochemical smog and ozone in the urban air, more general, the troposphere. Furthermore, NO_x participates in a chain reaction that removes ozone from strarosphere with the consequence of increased ultraviolet radiation reaching the earth's surface. Consequently, minimization of NO_x production has become a most important topic in combustion [15].

3. 1. Nitrogen Oxides

Most important air pollutants are nitrogen oxides, and their most important source is combustion. Motor vehicles are responsible from a large partition of nitrogen oxides emissions, but electric power plants also release nitrogen oxides. Nitric oxide, NO, and nitrogen dioxide, NO_2 are called as NO_x. Combustion generates both nitric oxide, NO, and nitrogen dioxide, NO_2, but large partition of nitrogen oxides are spreaded as NO. Because NO is turned into NO_2 in atmosphere. NO is formed through several mechanisms. These mechanisms are classified into the following three categories [16]:

1. The extended Zeldovich (or thermal) mechanism in which O, OH, and N_2 species have their equilibrium values and N is in steady state condition

2. Mechanisms whereby NO is formed more rapidly than predicted by the thermal mechanism above, either by (i) the Fenimore CN and HCN pathways, (ii) the N_2O-intermediate route, or (iii) as a result of superequilibrium concentrations of O, and OH radicals in conjunction with extended Zeldovich scheme.

3. Fuel nitrogen mechanism, in which fuel-bound nitrogen is converted to NO.

3. 2. Thermal NO_x Formation

The thermal or Zeldovich mechanism has two chain reactions as shown in Equations (11) and (12).

$$N_2 + O \leftrightarrow NO + N \quad (11)$$

$$N + O_2 \leftrightarrow NO + O \quad (12)$$

which can be extended by adding the reaction (see Equations (13)).

$$NO + H \leftrightarrow N + OH \quad (13)$$

The constants for these reactions mentioned in Equations (11), (12) and (13) are given in the following equations [13].

$$k_{1f} = 1.8 \text{ x } 10^{11} \exp[-38{,}370 / T(K)] \ (m^3 / kmol\text{-}s) \quad (14)$$

$$k_{1r} = 3.8 \text{ x } 10^{10} \exp[-425 / T(K)] \ (m^3 / kmol\text{-}s) \quad (15)$$

$$k_{2f} = 1.8 \text{ x } 10^{7}\ T(K) \exp[-4{,}680 / T(K)] \ (m^3 / kmol\text{-}s) \quad (16)$$

$$k_{2r} = 3.8 \text{ x } 10^{6}\ T(K) \exp[-20{,}820 / T(K)] \ (m^3 / kmol\text{-}s) \quad (17)$$

$$k_{3f} = 7.1 \text{ x } 10^{10} \exp[-450 / T(K)] \ (m^3 / kmol\text{-}s) \quad (18)$$

$$k_{3r} = 1.7 \text{ x } 10^{11} \exp[-24{,}560 / T(K)] \ (m^3 / kmol\text{-}s) \quad (19)$$

The reaction constants R_{NO} and R_N can be calculated by Equations (20) and (21);

$$R_{NO} = k_{1f}[N_2][O] - k_{1r}[NO][N] + k_{2f}[N][O_2] - k_{2r}[O][NO] + k_{3f}[N][OH] - k_{3r}[NO][H] \quad (20)$$

$$R_N = k_{1f}[N_2][O] - k_{1r}[N][NO] - k_{2f}[N][O_2] + k_{2r}[O][NO] - k_{3f}[OH][N] + k_{3r}[H][NO] \quad (21)$$

To calculate R_{NO} and R_N, we need concentrations of O, H, and OH. Most of the reaction occurs after the combustion reactions completed and before important heat is released with the flame due to the reaction rate, which is rapid simply at the highest temperatures. Therefore, we can assume that N_2, O_2, O, H, and OH concentrations have their equilibrium amounts and N atoms are in steady state condition.

Now, the reaction constants can be written as Equation (22),

$$k_{1f}[O]_e[N_2]_e = k_{1r}[NO]_e[N]_e \quad (22)$$

Then, reaction constants become,

$$R_1 = k_{1f}[O]_e[N_2]_e = k_{1r}[NO]_e[N]_e \quad (23)$$

similarly, at equilibrium,

$$R_2 = k_{2f}[O_2]_e[N]_e = k_{2r}[O]_e[NO]_e \quad (24)$$

$$R_3 = k_{3f}[OH]_e[N]_e = k_{3r}[H]_e[NO]_e \quad (25)$$

and the quantities α and β are defined as Equation (26),

$$\alpha = \frac{[\mathrm{NO}]}{[\mathrm{NO}]_e}$$
$$\beta = \frac{[N]}{[N]_e} \tag{26}$$

therefore, reaction constants Equations (20) and (21) are expressed as,

$$R_{\mathrm{NO}} = R_1 - R_1\alpha\beta + R_2\beta - R_2\alpha + R_3\beta - R_3\alpha$$
$$R_N = R_1 - R_1\alpha\beta - R_2\beta + R_2\alpha - R_3\beta + R_3\alpha \tag{27}$$

Then, by using the assumption that N atoms are in steady-state condition, $R_N = 0$, β_{SS} becomes as Equation (28)

$$\beta_{\mathrm{SS}} = \frac{R_1 + R_2\alpha + R_3\alpha}{R_1\alpha + R_2 + R_3} = \frac{\kappa + \alpha}{\kappa\alpha + 1} \tag{28}$$

where

$$\kappa = \frac{R_1}{R_2 + R_3} \tag{29}$$

Then using β_{SS} into R_{NO} equation,

$$R_{\mathrm{NO}} = \frac{d([\mathrm{NO}])}{\mathrm{dt}} = \frac{2R_1(1-\alpha^2)}{1+\kappa\alpha} \tag{30}$$

For constant temperature and pressure, Equation (30) is written as a differential equation for α ;

$$\frac{d\alpha}{\mathrm{dt}} = \frac{1}{[\mathrm{NO}]_e}\frac{2R_1(1-\alpha^2)}{1+\kappa\alpha} \tag{31}$$

and,

$$[\text{NO}] = c.y_{\text{NO}}$$
$$[\text{NO}]_e = c.y_{\text{NOe}} \qquad (32)$$
$$c = \frac{P}{\text{RT}}$$

Equation (32) can be written into Equation (26),

$$\alpha = \frac{[\text{NO}]}{[\text{NO}]_e} = \frac{y_{\text{NO}}}{y_{\text{NOe}}} \qquad (33)$$

and into Equation (31).

$$\frac{d\alpha}{\text{dt}} = \frac{1}{y_{\text{NOe}}}\frac{\text{dy}_{\text{NO}}}{\text{dt}} \qquad (34)$$

Therefore, the rate equation for NO formation and decomposition is obtained as Equation (35).

$$\frac{\text{dy}_{\text{NO}}}{\text{dt}} = \frac{1}{c}\left[\frac{2R_1(1-\alpha)}{1+\kappa\alpha}\right] \qquad (35)$$

and Equation (35) is arranged for crank angle,

$$\frac{\text{dy}_{\text{NO}}}{d\theta} = \frac{\text{RT}}{P\omega}\left[\frac{2R_1(1-\alpha^2)}{1+\kappa\alpha}\right] \qquad (36)$$

where, y_{NO} is NO mole fraction (kmol / kmol), y_{NOe} denotes NO equilibrium mole fraction (kmol / kmol) and c ; concentration in moles (kmol / m^3).

When $\alpha < 1$ and $dy_{NO}/d\theta > 0$, NO tends to compose; when $\alpha > 1$ and $dy_{NO}/d\theta < 0$, NO tends to dissociate [17].

3. 3. Calculation of Nitrogen Oxide Formation

In this study, to calculate Nitrogen Oxide mole fraction, y_{NO} from Equation (36), the Euler's Method is used. This method consists of the following formulas;

$$\frac{dy_{NO}}{d\theta} = f(\theta, y_{NO}) \tag{37}$$

$$\frac{dy_{NO}}{d\theta} = \frac{(y_{NO})_{i+1} - (y_{NO})_i}{\Delta\theta} = f[\theta_i, (y_{NO})_i] \tag{38}$$

$$(y_{NO})_{i+1} = f[\theta_i, (y_{NO})_i].\Delta\theta + (y_{NO})_i \tag{39}$$

where, for θ_1 = Spark Timing, θ_0 ; $(y_{NO})_1 = 0$.

3. 4. NOx Control Strategies

For processes in which thermal NO formation is important; time, temperature, and oxygen availability are main factors which influence NO_x yields. NO_x emissions are maximum at $\Phi = 1$ and decrease fast with increasing or decreasing equivalence ratio. On the other hand, maximum efficiency also is achieved near this equivalence ratio for many practical devices.

The NO_x control strategies in the internal combustion engines can be classified into four stages:

1. Reducing peak temperatures can significantly reduce NO_x emissions. In spark ignition engines, this can be achieved by mixing exhaust gases with the fresh air or fuel.

2. Another way to lower combustion temperature in spark ignition engines is to retard the spark timing.

3. The amount of thermal NO_x produced in a device is strongly linked to time that combustion products spend at high temperatures. Therefore, in the design of a combustion system, temperature – versus – time relationship is key to the control of NO emissions.

4. Staged combustion, in which a rich – lean or lean – rich combustion sequence takes place, is also a NO_x control strategy.

If maximum temperature in the cylinder can be decreased, NO_x emissions decrease. One of the ways to decrease maximum temperature is to mix fuel-air mixture with combustion products. This is known as Exhaust Gas Recirculation (EGR) in spark ignition engines [12]. The using of combustion products instead of excess air has two benefits [9]:

1. the addition of excess O_2 increases NO_x formation,

2. because of the presence of H_2O and CO_2, the specific heat of the gas increase. This reduces the combustion temperature.

3.5. Validation of Model

To show the validity of presented model, the predictions of cycle pressure values are compared with experimental data reported in the literature [10] for the conditions and the engine specifications given in Table 1. Figure 5 shows a comparison of cylinder pressure values as a function of crank angle, which are taken from presented model and experimental data reported in Taylor [10], for the stoichiometric ratio, $\lambda = 0.84$.

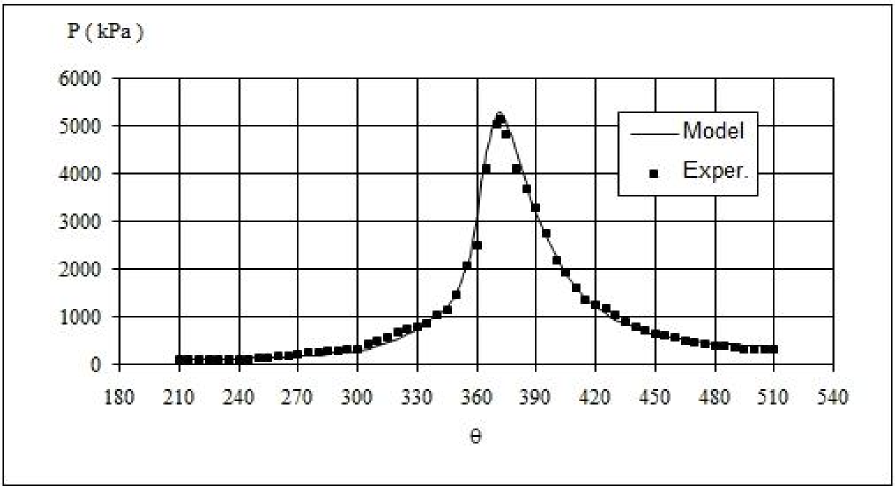

Figure 5. Comparison of Cylinder Pressure Predictions of Presented Model and Experimental Results from Taylor [10].

Table 1. Cooperative Fuel Research (CFR) Engine specifications [10].

Bore	D = 0.08255 m
Stroke	S = 0.1143 m
Rod Length	L = 0.2 m
Displacement Volume	$V_d = 0.000612\ m^3$
Compression Ratio	$\varepsilon = 8.35$
Engine Speed	n = 1200 rpm
Fuel	iso-octane
Stoichiometric Ratio	$\lambda = 0.84$
Spark Timing	$\theta_0 = 20^o$ Before Top Dead Center
Combustion Duration	$\Delta\theta_c = 40^o$
Inlet Temperature	$T_i = 353$ K
Inlet Pressure	$P_i = 99.3$ kPa
Exhaust Pressure	$P_e = 104.11$ kPa
Inlet Valve Opens	IVO= 15^o Before Top Dead Center
Inlet Valve Closes	IVC= 30^o After Bottom Dead Center
Exhaust Valve Opens	EVO= 30^o Before Bottom Dead Center
Exhaust Valve Closes	EVC= 15^o After Top Dead Center

From the Figure 5, we can see that the presented model predicts higher pressure values than the experimental results. The peak pressure calculated in the model is significantly higher than the measured peak pressure in the experiment. This result may be partly due to the assumptions used in the combustion model. The model assumes complete combustion of all the fuel. However, in the actual engine cycle, partial combustion and sometimes no combustion can occur particularly under marginal conditions. The higher pressure predicted by the model may be resulted from the higher energy release from the complete combustion of all the fuel. Consequently, the comparison between the presented model and experimental results reported in the literature, appears satisfactory. The presented model's calculations are in a good deal with experimental data, as seen in the Figure 5, so it can be said that the presented cycle model allows the conduct of this parametric study with acceptable accuracy.

4. PERFORMING CYCLE MODEL AND RESULTS

The computer program, which is used to calculate the values of the cylinder pressure, unburnt and burnt gas temperature, and NO formation rate in this study, consists of three stages. In the first stage, the values of Engine Geometry and Operating Conditions, and Fuel and Air Properties are put into program. Then, the unknown values of pressure and temperature are calculated in the second stage of program, according to values given in the first stage. After the calculating of pressure and temperature values with the given tolerance, the NO formation rate and Engine Performance values are obtained. In the last stage of the program, these calculated values are shown in the various graphics and tables. The details of computer program can be found in Öğüçlü [6]. The efficiency of an internal combustion engine is usually reported in terms of the Specific Fuel Consumption (SFC) which is the mass of fuel consumed per unit of work output (g/kWh or kg/MJ). It is inversely proportional to the thermal efficiency of the engine [19]. The work output per engine cycle is presented in terms of the Mean Effective Pressure (MEP) which is the work done on the piston divided by the displacement volume. It increases as manifold pressure increases [19].

4. 1. Engine Geometry and Operating Conditions

The parameters of Engine Geometry and Operating Conditions, Fuel and Air Properties are chosen as follows,

Stoichiometric Ratio	; $\lambda = 1.05$
Engine Speed	; n = 3000 rpm
Spark Timing	; $\theta_0 = 27^o$ Before Top Dead Center (BTDC)
Combustion Duration	; $\Delta\theta_c = 51$ Crank Angle Degrees
Compression Ratio	; $\varepsilon = 8$
Bore	; D = 73 mm
Stroke	; S = 72 mm
Rod Length	; L = 120 mm
Crank Arm Length	; r = 36 mm
Number of Cylinders	; z = 4
Fuel	; Iso-octane (C_8H_{18})
Intake valve opening time	; 20^o Before Top Dead Center (BTDC)
Intake valve closing time	; 30^o After Bottom Dead Center (ABDC)
Exhaust valve opening time	; 30^o Before Bottom Dead Center (BBDC)
Exhaust valve closing time	; 20^o After Top Dead Center (ATDC)
Inlet Temperature	; $T_i = 330$ K
Inlet Pressure	; $P_i = 95$ kPa
Exhaust Pressure	; $P_e = 105$ kPa
Atmosphere Temperature	; $T_a = 300$ K
Atmosphere Pressure	; $P_a = 101.325$ kPa
Saturation Pressure of Water	; $P_g = 3.169$ kPa (at 300 K)
Relative Humidity	; ϕ = % 40

4. 2. Results

With given parameters in Section 4.1., the computer program calculates the cylinder pressure, gas temperatures, and NO concentration rate in burnt gas. Figure 6 and Figure 7 show the Cylinder Pressure and NO Concentrations in the Burnt Gas for a various percentage of EGR, respectively.

From these results, we can see that the Exhaust Gas Recirculation can reduce NO formation in spark ignition engines. The effect of the recirculated gases is to decrease the maximum temperatures in the flame zone [20]. The effect of EGR is to increase the heat capacity of the burned gases for a given quantity of heat release, thus lowering the combustion temperature [9]. Due to the use of EGR, NO concentration reduces significantly. This can be seen clearly from Figure 7. Recirculation of exhaust gases is a common technique which is used to control oxides of nitrogen in internal combustion engines. And, the exhaust gas recirculation is effective measure for NO emission control. But, the degree of control of NO by this method is limited. Because, the use of the EGR in spark ignition engines causes the fuel consumption and the power output penalties. The EGR reduces the cylinder pressure, hence, it reduces engine power output. This reduction can be seen from clearly Figure 6. We can see that the loss of power (or pressure) is important, while the EGR percentage increases the loss of pressure increases. If the EGR is employed to control NO emissions, the engine size must be increased to meet a particular power requirement.

For 10% EGR, the computer program gives Engine Performance Results as;

Mean Effective Pressure	; MEP = 938.6 kPa
Specific Fuel Consumption	; SFC = 224.344 g / kW-h
Efficiency	; η = 0.3656
Power	; P = 32.34 kW
Peak Cylinder Pressure	; P_{max} = 5070.68 kPa
Peak Burned Gas Temperature	; T_{bmax} = 2698 K
Peak Unburned Gas Temperature	; T_{umax} = 927 K
Exhaust NO Concentration	; y_{NO} = 6989 ppm

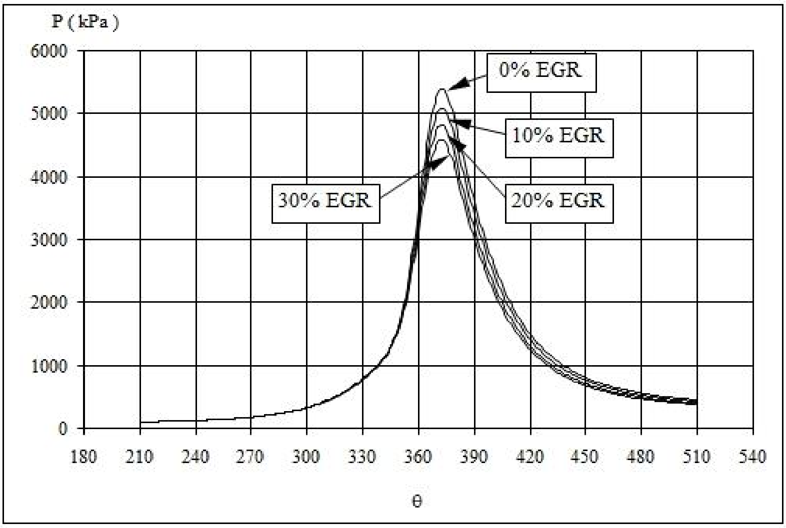

Figure 6. Cylinder Pressure for various percentage of EGR.

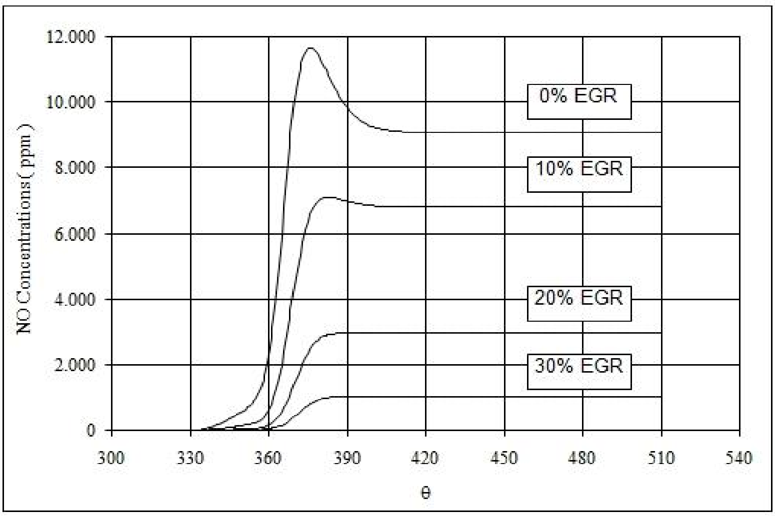

Figure 7. NO Concentrations for various percentage of EGR.

5. CONCLUSION AND FURTHER WORKS

A computer program for the simulation of thermodynamic processes, which take place in a spark ignition engine cylinder, is developed. This computer program can calculate the cylinder pressure, burnt and unburnt gas temperatures, and NO concentration rate in burnt gas of a spark ignition engine. And the Exhaust Gas Recirculation in the spark ignition engine is also employed. The hypotheses developed in the literature for the formation mechanism of NO_x emissions were reviewed and used to calculate the NO formation rate in the burnt gas. The graphical representation of the cylinder pressure, burnt and unburnt gas temperatures, and NO concentration in burnt gas as a function of crank angle is achieved.

The comparison between model and experimental results shows that model satisfactorily simulates the cycle of a spark ignition engine. However, several areas in the model need further development. Therefore, the inclusion of detailed calculations of the gas exchange processes, the blow-by gas model, and the heat transfer coefficient into the cycle simulation model can provide more detailed results. With the extensions mentioned, the computer program can be used as a useful design tool.

Consequently, this thermodynamic model and the computer program can be used by automotive engineers for predicting engine performance, Nitric Oxide emission level, and effects of Exhaust Gas Recirculation in spark ignition engines. Hence, by using these results, they can select the optimum spark timing and fueling schedules or improve combustion chamber design.

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Journal of Naval Sciences and Engineering
2019, Vol. 15, No.2, pp.159-172
Computer Engineering/Bilgisayar Mühendisliği

RESEARCH ARTICLE

ENERGY MANAGEMENT MODEL FOR INTELLIGENT TRANSPORTATION SYSTEM

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Date of Receive: 19.09.2019 **Date of Acceptance: 14.11.2019**

ABSTRACT

Energy saving technologies for smart vehicles have great importance because of decreasing total energy consumption. It is estimated that the cost of energy will increase in the near future. Here, Road Side Units (RSUs) are the dominant contributing components to the overall energy consumption in Intelligent Transportation Systems (ITS). This paper investigates the energy efficiency of RSUs by proposing an energy management model for ITS. Energy efficiency can be achieved if as many as possible RSUs switch off while maintaining an acceptable quality of service. The aim is to present a way to improve total energy efficiency by scheduling RSUs with a switching on/off model so that total energy consumption of RSUs can be managed.

Keywords: *Energy Management, Smart Cities, Intelligent Transportation System, Kriging.*

AKILLI ULAŞIM SİSTEMLERİ İÇİN ENERJİ YÖNETİMİ MODELİ

ÖZ

Akıllı araçlar için enerji tasarruflu teknolojiler, toplam enerji tüketimini azalttığı için büyük öneme sahiptirler. Akıllı Ulaşım Sistemleri'nde, Yol Kenarı Baz İstasyonları toplam enerji tüketiminde en fazla etkiye sahiptirler. Yakın gelecekte, enerji maliyetinin de artması beklenmektedir. Bu kapsamda, Akıllı Ulaşım Sistemleri'nde bir enerji yönetim modeli önererek, Yol Kenarı Baz İstasyonlarının enerji etkinliği araştırılmaktadır. Enerji verimliliği, maksimum sayıda Yol Kenarı Baz İstasyonlarının kapatılması ile sağlanabilir, ancak önerilecek modelin servis kalitesini düşürmeden etkin bir şekilde yönetilmesi gerekmektedir. Bu kapsamda, Yol Kenarı Baz İstasyonlarının enerji tüketimini azaltmak için Yol Kenarı Baz İstasyonlarının kullanımını planlayan bir model geliştirilmesi amaçlanmıştır.

Anahtar Kelimeler: *Enerji Yönetimi, Akıllı Şehirler, Akıllı Ulaşım Sistemleri, Kriging.*

1. INTRODUCTION

The expansion of smart city technologies creates both challenges and opportunities in Intelligent Transportation Systems (ITS). On one hand, smart vehicles can communicate with each other and provide high quality data to prevent accidents and increase traffic safety. On the other hand, any interruption in a service is essential. In particular, it is a challenge to meet Quality of Service (QoS) of a task in smart vehicles because of the mobility and limited communication range of RSUs.

One of the earliest technological advances was the ability of equipped with onboard units (OBUs) of vehicles. The U.S. FCC (Federal Communications Commission) has allocated 75 MHz in the 5.9 GHz frequency band for Dedicated Short Range Communication in 1999. With the recent advances in smart city technologies and rapid growth of mobile communications and devices, vehicles are designed to increase situational awareness and improve traffic safety, efficiency and comfort. Vehicles are equipped with advanced technologies in order to communicate with nearby vehicles and Road Side Units (RSU) in ITS.

Energy saving technologies for smart city have been widely studied in order to manage increasing data traffic and decrease total energy consumption. Here, RSUs are the dominant contributing components to the overall energy consumption in ITS. It is estimated that the cost of energy will increase in the near future and it is crucial to keep the supply-demand balance [1]. Therefore, in order to improve energy efficiency of RSUs, the position of RSUs and their coverage areas have a great importance. There exist many vehicular applications that can be effectively used in ITS for many purposes. However, many challenges significantly limit the performance of these applications such as task allocation of RSUs and task execution by considering energy constraints.

While the basic task of ITS is quite simple-enabling communication between vehicles and RSUs, the connectivity is needed to achieve this basic task. In [2]-[3], the challenges of ineffective resource allocation and RSU overload are investigated in ITS. In [4]-[5], power control mechanisms are proposed to increase energy efficiency. Although many approaches have been proposed in the literature to address the challenges of energy consumption and connectivity, none of these approaches provides a management to decrease energy consumption with the help of power estimation mechanism.

To this end, this paper focuses on reducing energy consumption of RSUs in ITS. To achieve this, an energy management model is presented for ITS. In the model, minimum number of active RSUs is determined to serve all vehicles on the road. Depending on the distribution of vehicles within the communication range of each RSU, vehicles are assigned to particular RSU and then the number of active RSUs is minimized. To achieve this, a controller estimates the power level of vehicles with a spatial estimation method. Kriging is used to find the appropriate signal levels of vehicles so that RSUs are managed efficiently. Here, the location of vehicles, velocity and heading are given to the proposed model as an input. Then, the controller decides the mode of each RSU to reduce energy consumption.

The remainder of this study is organized as follows: Section 2 defines the considered scenario and model development. Section 3 gives the used data and methodology. Section 4 evaluates the results of the proposed model and finally Section 5 concludes the paper.

2. MODEL DEVELOPMENT

RSUs are deployed along the road in order to serve the vehicles within the coverage areas as seen in Figure 1. Vehicles can only connect one single RSU at a time. The controller takes the vehicle information as an input including vehicle location, velocity, heading, distance between vehicle and RSU and signal level. IEEE 802.11p based communication is used for V2R (Vehicle-to-Road Side Unit).

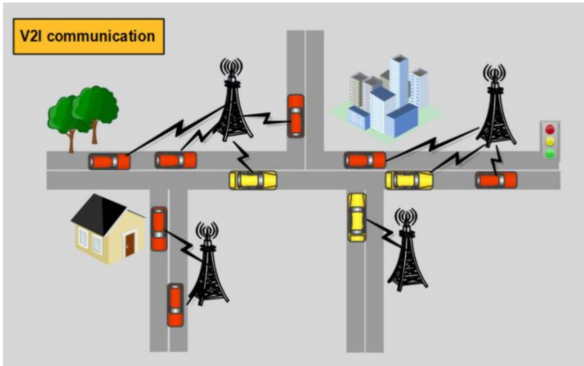


Figure 1. The considered architecture.

In the paper, the aim is to manage RSUs by controller so that the mode of RSUs can be scheduled in terms of switching on/off. For instance, in Figure 2, the controller checks the distribution of vehicles in each RSU. Then, vehicles within the RSU-3 can be assigned to a new RSU according to their positions. Here, the power levels of vehicles are estimated to connect a particular RSU and then RSU-3 is switched off. The modules are explained in the next subsections.

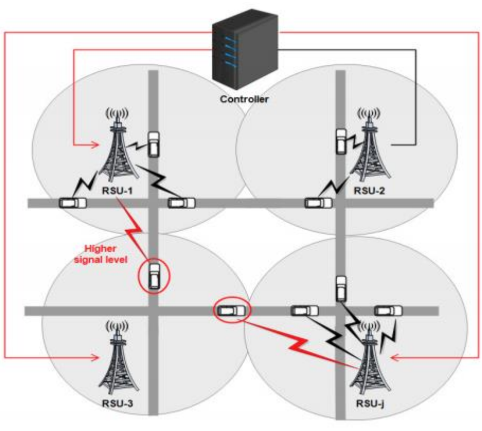


Figure 2. The proposed model development.

2.1. Applying ArcGIS

ArcGIS (Geographic Information System (GIS)) [6] is an application which is used to create maps, manage the geographic data and perform spatial analysis. In this paper, ArcMap, which is one of the main components of ArcGIS, is used. It creates maps, performs spatial analysis, manage geographic data and share results in both 2D and 3D environment.

Spatial analysis tool is used to analyze geographic data in ArcMap. The used geographic data and spatial analysis tool will be explained in the next subsection.

2.2.1. Kriging

Ordinary Kriging module [7] is used in ArcMap as a spatial analysis to estimate the vehicle's power level at the position (t, x_0, y_0) at time t, so that vehicles are assigned to a new RSU as seen in the Figure 2.

Kriging is an interpolation method to predict a variable at an unknown position from the observed values at nearby locations in geostatistics. In Kriging, the variation and distance between known data points are weighted according to spatial covariance. Then, unknown value is estimated by using the obtained weights that are based on the surrounding data points. The covariances and weights are determined according to network topology and distance between vehicles.

Ordinary Kriging is chosen for model development. Ordinary Kriging predicts weighted linear combinations of measured data while minimizing variance of the errors. It uses semivariogram analysis to define spatial correlation of two sample positions; it does not depend on their absolute position but only on their relative position.

It is assumed that there are N vehicle locations $(x_i, y_i; i = 1,...,N)$ in the communication range of a RSU. In addition, signal level is initially known and, demonstrated as $Z(t, x_i, y_i)$ at the location (x_i, y_i). With the help of this information, each vehicle is assigned to one RSU.

To keep the estimate unbiased, it is important to define the weights of nearby vehicles within the communication range of one RSU. Then, optimal signal level can be estimated. In Ordinary Kriging, the weighted linear estimator for location $Z(t, x_0, y_0)$ is expressed in Equation 1.

$$Z^*(t, x_0, y_0) = \sum_{i=1}^{N} w_i Z(t, x_i, y_i) \tag{1}$$

where $Z^*(t, x_0, y_0)$ represents power level at location (x_0, y_0). Weight, w_i, is a coefficient.

The weights are calculated to minimize error variance. It is implemented by solving the following equation for the Kriging weights.

$$\gamma(h_{i,j}) w_i = \overline{\gamma}(h_{i,0}) \tag{2}$$

Here, $\overline{\gamma}(h_{i,0})$ provides a weighted scheme. When the covariance between data samples and the position being detected enhances, the accuracy of the estimation will increase so that nearest samples have significant weights and the covariance between near points will increase.

To solve the weights, Equation 2 is multiplied on both sides by γ^{-1} so that Equation 3 is given as follows:

$$\begin{aligned} \gamma(h_{i,j}) w_i &= \overline{\gamma}(h_{i,0}) \\ w_i &= \gamma^{-1}(h_{i,j}) \overline{\gamma}(h_{i,0}) \end{aligned} \tag{3}$$

where γ represents semivariogram and is a function based on the distance between vehicles. It is determined in Equation 4.

$$\begin{aligned} \gamma(h_{i,j}) &= \gamma(x_i y_i - x_j y_j) \\ &= \frac{1}{2} E[(Z^0(t, x_i, y_i) - Z^0(t, x_j, y_j))^2] \end{aligned} \tag{4}$$

Exponential model in Ordinary Kriging is used for the analysis as given in the following equation. The reason to choose this model can be explained as follows: The main characterizations of ITS are the mobility of vehicles and vehicle directions. In this method, we observe that the covariance between

RSUs and vehicles depends on the distance between them and Kriging makes the calculations according to these distances.

$$\gamma^{\exp}(h_{i,j}) = C_0 + C_1(1 - \exp(\frac{-3h_{i,j}}{a}) \quad (5)$$

where C_0 represents nugget effect, that enables discontinuity at the origin. Semivariogram value at the origin is 0 in theory. The value of "a" represents the range that is a covariance value as constant and longest distance between RSU and vehicle.

The spatially estimated power of the vehicle at (x_0, y_0) is given as follows:

$$Z^{\exp}(t, x_0, y_0) = \sum_{i=1}^{N} w_i^{\exp} Z^0(t, x_i, y_i) \qquad \forall i \in N \quad (6)$$

Figure 3 shows the obtained exponential semivariogram model. In the figure, an estimation process can be observed. Here, it is checked whether a vehicle can be connected to a new assigned RSU depending on the distance between vehicles and RSUs.

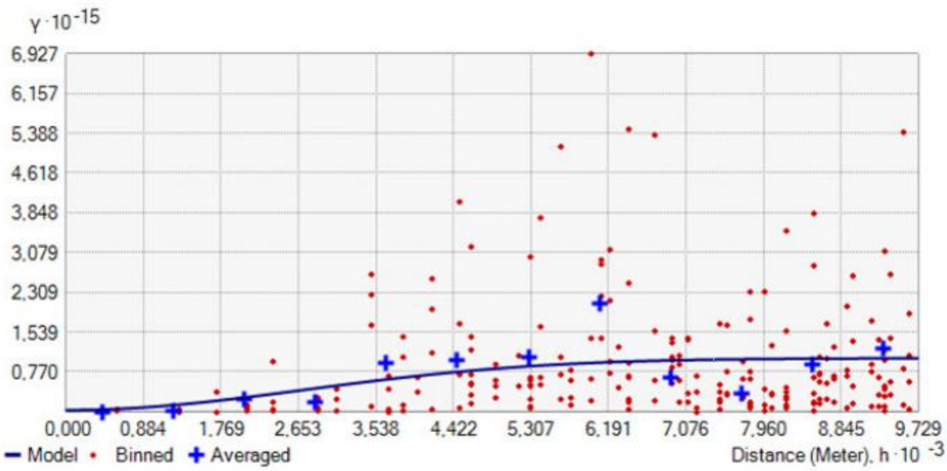


Figure 3. The Semivariogram Model.

Figure 4 shows an example of the power estimation process for a vehicle to connect a new assigned RSU. Here, one of the challenges is the limitation for power. The maximum power limit is 33 dBm for non-government services in ITS and 44.8 dBm for government services. Therefore, each estimation is checked after the proposed model run and the maximum limitation is assigned as 33 dBm.

In Kriging, when the covariance between each of sample point increases, the accuracy of the estimation will improve. This means that when the data points are closer to each other, then nearest samples carry significant weight so that error variance is minimized and optimal and unbiased estimates are obtained. Semivariogram calculates the distance between all vehicle pairs within the range of a RSU and this information provides the clustering of the available sample data in the topology. Here, clustering is done with the help of semivariogram. Therefore, Ordinary Kriging estimates the unknown values based on distance and clustering.

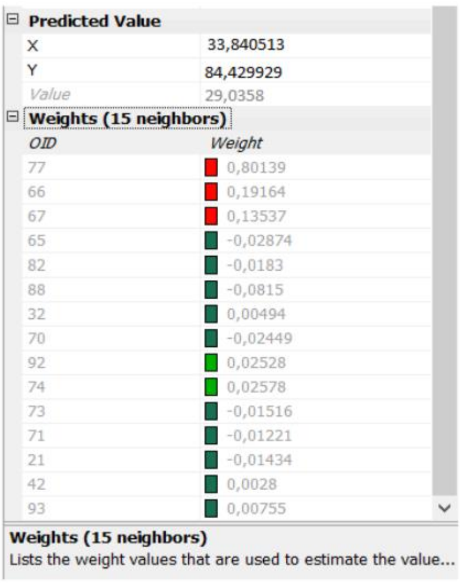


Figure 4. Estimation process.

3. DATA AND METHODOLOGY

In order to observe vehicles' movement, traces of real vehicle from the King County, Washington obtained from CRAWDAD (A Community Resource for Archiving Wireless Data at Dartmouth) [8] are used. This dataset contains the measurement of the performance of short range communications between vehicles. It is contributed by R. M. Fujimoto, R. Guensler, M. P. Hunter, H. Wu, M. Palekar, J. Lee, J. Ko.

The used data for the simulation includes the time, vehicle latitude and longitude, direction, speed and signal strength (dBm). Some modifications are done over the original data. As a modification, power strength is adjusted 23 dBm at initial situation for all vehicles. Then, the power level is calibrated with the spatial interpolation method.

For the experiments, a subset of these traces covers 27Kmx47Km of area and movements from different time periods. Figure 5 shows the density map of the studied area.

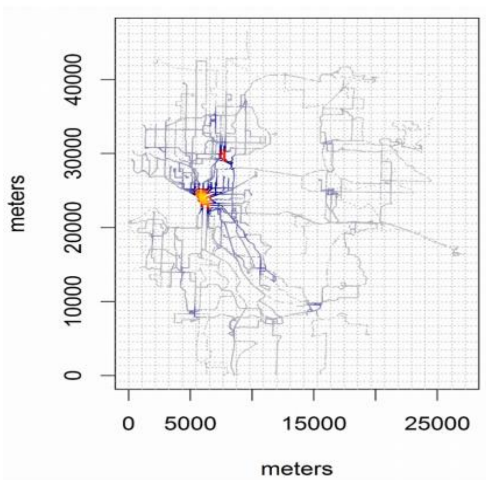


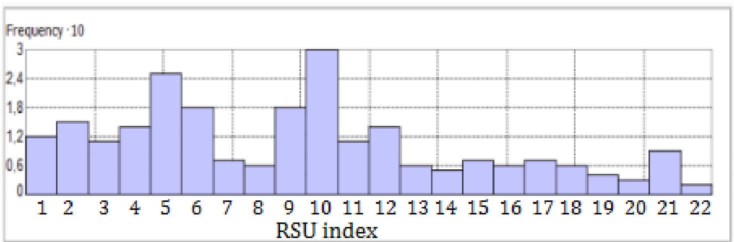
Figure 5. Density map of the area in study.

4. MODEL PREDICTIONS AND RESULTS

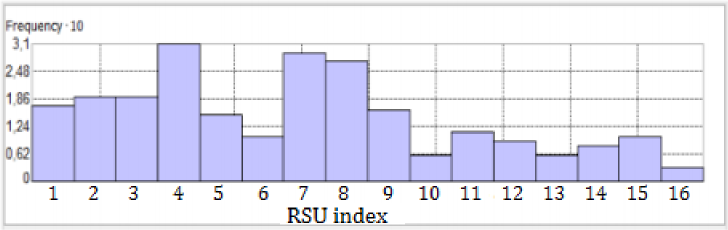
In this section, the proposed energy management model is evaluated in ITS. Exponential scheme in Ordinary Kriging is used to predict vehicles' signal level. The controller schedules to RSUs to decrease energy consumption of RSUs.

It is assumed that RSUs are deployed along the road with a full coverage of the environment with mean inter-RSU distance of 300m as defined in IEEE 802.11p. At initial, vehicles have allocated 23dBm to connect to the RSUs. Depending on the distribution of vehicles, 3 traffic densities are considered: low traffic, medium traffic and high traffic. Traffic density is defined by the number of vehicles per square kilometer. 760, 1140 and, 1920 vehicles are simulated for the traffic densities, respectively.

Figure 6 shows the density of vehicles in each RSU in low traffic density. Here, total number of RSUs is equal to 22. At initial situation, each RSU serves the vehicles within the communication range of itself. The density of vehicles is showed in Figure 6(a). On the other hand, after the proposed model is applied, RSUs are scheduled and 6 RSUs are switched off. Figure 6(b) illustrates the distribution of each RSU after the proposed energy management model is implemented.



(a)



(b)

Figure 6. The density of vehicles within RSUs (a) Initial situation (b) After the proposed model.

Moreover, Figure 7 demonstrates the energy efficiency over the simulation time for each traffic density. When the traffic density is low and medium, energy efficiency is achieved 29% and 18% with the proposed energy management model, respectively. However, it is observed that when the traffic density increases, energy efficiency cannot be achieved as seen in the Figure 7. Here, all RSUs need to be active for a full coverage of the environment depending on the distribution of vehicles in each RSU. However, it is clear that the model effectively decides the minimal number of RSU to serve all vehicles in the environment and enables energy efficiency.

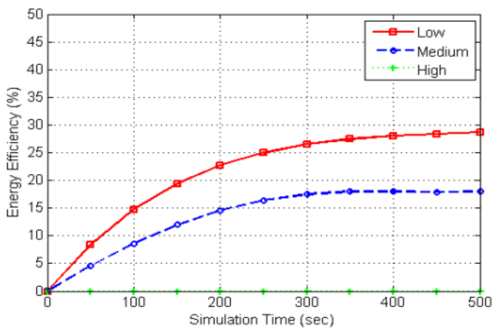


Figure 7. Energy efficiency for different traffic densities.

5. CONCLUSION

In this paper, an energy management model is proposed for ITS to schedule RSUs and thereby decrease the energy consumption. At first, the optimal signal level of vehicles is estimated with the help of ArcGIS so that vehicles connect to new assigned RSUs. Then RSUs are scheduled depending on the distribution of vehicles and as many as possible RSUs are switched off to decrease energy consumption in ITS. The ongoing work involves the effect of the connectivity algorithms among vehicles and between vehicles to RSUs.

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Journal of Naval Sciences and Engineering
2019, Vol. 15, No.2, pp.173-196
Naval Architecture and Marine Engineering/Gemi İnşaatı ve Gemi Makineleri Mühendisliği

RESEARCH ARTICLE

VIRTUAL REALITY APPLICATIONS ON SHIPS IN USE

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Date of Receive: 19.07.2019 **Date of Acceptance: 05.11.2019**

ABSTRACT

Virtual Reality (VR) technology is one of the rapidly developing technologies. It's widespread usage varies from entertainment to education and engineering. While technological advancements in displays, graphic cards and processors let VR born, its underlying laws has not specified for every part of life. This paper examines applications of Virtual Reality on ships and other marine structures. Their implementation has been elucidated from two perspectives: hardware and software solutions, approximate cost analysis, mathematical equations for design, modeling, construction and inspection, as well as the co-operation and training of people as if they were on board. Two main articles are examined. It's found that some shipbuilders tried to develop their own software at first. But nowadays taking advantage of game engines is more preferred while the mathematical equations behind them are still reasonable.

Keywords: *Virtual Reality (VR), Ship, Naval Architecture.*

KULLANIMDAKİ GEMİLER ÜZERİNDE SANAL GERÇEKLİK UYGULAMALARI

ÖZ

Sanal Gerçeklik (VR) teknolojisi hızlı gelişen teknolojilerden biridir. Kullanımı, eğlenceden eğitim ve mühendisliğe kadar geniş bir çeşitlilik göstermektedir. Ekranlar, ekran kartları ve işlemcilerdeki teknolojik ilerlemeler VR'ın doğumuna izin vermiş, fakat hayatın her parçası için temel kuralları belirlenememiştir. Bu çalışma gemiler ve diğer deniz yapılarındaki Sanal Gerçeklik uygulamalarını incelemektedir. Geniş kapsamlı iki makale ele alınmak suretiyle uygulamaya geçirilişleri, farklı bakış açılarıyla ortaya çıkarılmıştır: donanım ve yazılım çözümleri, yaklaşık maliyet analizi, tasarım, modelleme, inşa ve teftiş etmek için gerekli olan matematiksel denklemler ve bunların yanında insanların sanki gemideymiş gibi birlikte çalışması ve eğitilmesi. İki ana makale incelenmiştir. Bazı gemi inşacılar başlangıçta kendi yazılımlarını geliştirmeye çalışmıştır. Ancak günümüzde arkalarında yatan matematiksel denklemler hala geçerli iken oyun makinelerinden faydalanmak daha çok tercih edilmektedir.

Anahtar Kelimeler: *Sanal Gerçeklik (VR), Gemi, Gemi İnşa.*

1. INTRODUCTION

In our global world technology is going on advancing each day. The countries and companies who started these advances are becoming leaders. These who can overtake the innovations can survive, while the others doomed to the failure. In last years, people wear some strange helmets and dive into an unreal world that is called Virtual Reality (VR). Instead of a small branch of computer engineering or entertainment, it's becoming part of our lives.

While virtual reality (VR) and Augmented Reality (AR) is widely used various areas of life to make simulations, shipbuilding industry must catch up with the latest technology. Some companies that are aware of the power of that technology have already begun to develop and use their own software. From the early design stages to the maintenance, ship companies benefit virtual reality. The ship builders, that can show the stages of construction to all the engineers at the same time, are reduce the errors and minimize the cost. Yacht sellers, who make feel the clients as inside of their new toy, are the leaders for now. The navies and shipping companies, that can train their crew in the virtual reality, eliminates the human errors.

Virtual and Augmented Reality are becoming the milestones of ship production and maintenance. This paper contains the most needed solutions of virtual reality to use on ships and other marine structures. While in 2012 Spain designed an aircraft carrier thanks to VR, in 2018 American Navy introduced its Virtual Reality simulation for aircraft carriers bridge [1-3].

2. LITERATURE SURVEY

Since virtual and augmented realities are new developments at naval architecture, only some interested people who keep up with the technology have some publishes. These publishes mostly written by the same people who are workers or owners of the companies that use VR and AR technologies currently. So impartiality of these publishes must be questioned.

Rodrigo Pérez Fernández and Verónica Alonso from marine sector of building company have some publishes about Virtual and Augmented Realities at international magazines [4]. Alexandros Ginnis develops virtual and mixed reality software for ships, besides being an Associate Professor at National Technical University of Athens [5]. Dennis Morais works in shipbuilding and writes on his blog [6]. These leaders have written articles and advanced their companies at the same time. Each group of writers focuses on different aspects of VR applications for ships.

"Virtual Reality in a shipbuilding environment" written by Rodrigo Pérez Fernández and Verónica Alonso in November 2014, tells settling Virtual Reality solutions for shipyards. Properties of virtual reality rooms and hardware are discussed in detail. On the other hand, case studies such as Implementation of a Virtual Design center for Spanish Navy's NAVANTIA warship could get articles of same team of writers. It's stated that besides numerous shipbuilding magazines over the last five years are full of articles about the application of Virtual Reality for 3D ship models, most of CAD suppliers are busy with developing the Virtual Reality concept for their software [4].

"VELOS - A VR Environment for Ship Applications: Current Status and Planned Extensions" written by A.I. Ginnis and others point out designing multi-user Virtual Environment simulations to improve the early steps of ship design. Writers claims that much effort has been devoted to the development of sophisticated models for performing advanced evacuation analysis of passenger ships which need to be advanced taking advantage of Virtual Reality. Virtual Environment for Life on Ships (VELOS) is a multiuser Virtual Reality (VR) system that supports designers to assess passenger and crew activities on a ship for both normal and hectic conditions of operations and to improve the ship design accordingly. It aims to use real human in escape scenarios in a system [5].

"VR in Shipbuilding" written by Denis Morais summarizes the current situation of VR technology in the big picture of 2017's November [7]. In his following annual reviews, he states that no satisfactory progress has done till 2019 [8-9] Writer has been internationally recognized for his published blogs, articles and papers and continues to provide insights on innovative solutions for the marine industries. He has worked hand in hand with industry partners all around the world to solve their most difficult business and technology challenges. This depth of understanding of both the current and future state of technology and the business of shipbuilding serve. It's stated that writer leads ship building industry towards the delivery of innovative products and services [6-7].

Each group of writers is the prime movers of the Virtual Reality on ships. This article examines the short history of this new technology and gathers the revolutionary rules and ideas relating to VR.

3. FUNDAMENTALS OF VR APPLICATIONS

Basically VR offers a panoramic view that person feel inside of the scene even though the scene is unreal. For 2019's technology, the main distinguishing element is display technique:

1. Virtual Reality room

2. Head mounted display (HMD)

Both systems are similar. Virtual Reality room is any room that is covered with screens which let collaborative working, it can be covered completely reminding a cube which is called Cave Automatic Virtual Environment (CAVE). Screen and the virtual environment is fixed, while the people inside move. Head mounted systems offer individual solution as the distance between screen and eye is expressed in millimeters. Person looks wherever he/she wants while the computer or cell phone computes the direction and view thanks to the sensors.

3.1 Visualization System

For the visualization, tree type of screen come forward: 3D projectors, 3D displays and helmets that are also called head mounted display (HMD). 3D displays are bright enough to be seen even in a luminous environment. It is also easy to set up almost everywhere. The biggest problem is size/price rate when it is compared to 3D projectors. For the big rooms, it costs too much expensive. For the lower cost projectors must be preferred. The costs of 3D displays is shown in Table 1, while costs of 3D projectors in 2011 is given in Table 2 and the costs of the whole solutions according to the screen type is listed in Table 3. Prices on the tables are belongs to 2015 year's Spain. In 2019, these prices are similar [4].

Helmets are the cheapest solution for VR applications. It provides a total immersion in all directions as a function of how the head is moved and it will see all the space around. Even though Fernández stated that that just one person can use the helmet at time, technology of 2018 permits users to interact these people, using VR helmets. Even though price of helmets in 2011 is shown at the Table 3 that is prepared by Fernández, Google cardboard, which costs less than 10 € must be in the options. Cardboard make people's mobile phones become a Virtual Reality display [4].

Dennis Morais claims that there are many clients that he has engaged with who have invested in the relatively inexpensive VR hardware such as the Oculus Rift and the HTC Vive. The cost of VR hardware continues to drop with Oculus Rift and Touch controllers [7].

Table 1. Cost prices for 3D displays, depending on the size and considering two different screen resolutions (from [4]).

Screen resolution	**Maximum screen size**	**Cost**
FULL HD	65"	5.000 €
4K	84"	15.000 €

Table 2. Cost prices for 3D projectors, depending on the size and considering the same range of products than before (from [4]).

Screen resolution	**Maximum screen size**	**Cost**
WXGA	2.5 m x 1.4 m	2.000 €
FULL HD	3 m x 1.68 m	5.000 €
FULL HD	4 m x 2.25 m	25.000 - 50.000 €
4K	6m x 3.17 m	< 120.000 €

Table 3. Prices of helmets and different manufacturers vary depending on the incorporating (from [4]).

Screen resolution	**Cost**
640 x 480	1.000€
800 x 600	5.000€
1280 x 1024	15.000€
FULL HD	30.000€

4. MODELING FOR VIRTUAL REALITY

The details of the display or processors are related to the hardware and develop over time. However, the essence of VR is the software used to model the real world and the accepted source.

Ship software companies produce their own software and use widely known hardware. Diversity of hardware makes users experiment more realistic, while software organizes all the correlation. Even though some other applications are available, this paper discourse mainly two softwares:

FViewerVR™ and VELOS. Differences of two systems are summarized on Table 4.

Table 4. Comparison of FViewer™ and VELOS.

	FVieverVR™	**VELOS**
Main purpose	Visual design review for shipyard	Experimental review for escaping simulations
Stages that are used	Design and Building Stages	Design and Early Design Stages
Costumer target	Shipyards, Design Offices	Designers
Number of users at the same time	1-10 (in room)	Numerous (Avatars can be used)
Aplication in real life	Navantia Naval Ship	Ro-Ro / Ro-Pax ship

FViewerVR™ is designed as a Virtual Reality kit of a CAD software. So its applications are limited with some basic commands such as clip plane to view a certain part of ship, shown on Figure 1. It uses dummies that are shown in Figure 2, to check ergonomic design. Any number of dummies can be added with different statures, postures and orientations. Software automatically detects and warns the user about clashes between the dummy and the model objects. An annotation manager makes all the attached information accessible together with the product model identification for the objects. The annotation information can be exported for processing in other applications. Also Review comments are attached to the model as annotations while objects with attached information may be highlighted to easily identify them in the model [4].

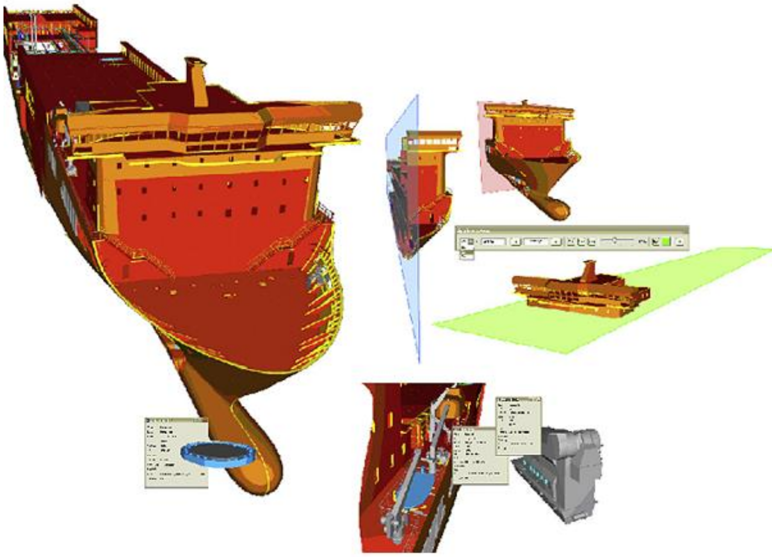

Figure 1. The interior view of a ship with clip plane (Source: [4]).

Figure 2. Ergonomic check of the design using dummies (Source: [1]).

Most of these properties of FViewerVR™ are similar to the CAD software and it may induce the opinion of being a primitive software. But it is needed to understand that such modules render image and computes lights, colors, textures etc. besides shapes.

Virtual Reality requires too much GPU power. So, FViewerVR™ uses OpenGL™, like VELOS, which is the most widely adopted graphics standard for high performance applications. Some different techniques are used to make rendering of big scenes faster which makes it possible to visualize an entire ship using the adequate hardware. The geometry is organized in KD-trees which partition data structures in geometry. KD-trees make fast occlusion culling possible, in other words, display is shown in higher quality and faster at the same time [4].

VELOS aims to calculate the needed time to evacuate the passengers and find the errors in the design, rather than being an ordinary CAD drawing or viewing software. So besides using VR headset, its obligatory to use a lot of parameters. The most crucial parameters are relevant to deciding velocity vectors of agents which is a part of motion behavior. Splitting motion behavior into three separate levels as; action selection, steering and locomotion will make understanding easier. In the action selection level, goals are set and plans are devised for the action materialization. The steering level determines the actual movement path, finally locomotion provides the articulation and animation details [5].

Steering is decided with vectors. After seeking, a target point is determined to move with the velocity that is computed as a weighting factor. The relation is shown [5]:

$$f = w \frac{q - p}{\|q - p\|} \tag{1}$$

where p is agent's position, q is the seek point and w is an appropriate weighting factor. In case of an obstacle, the velocity is dropped [5]:

$$v_{new} = c.\left(v_{prev} + f\right), \text{where } c = \min\left\{\frac{v_m}{\|v_{prev} + f\|}, 1\right\} \quad (2)$$

where v_m is the agent's maximum allowable velocity.

Last two equations are made to decide the movement vectors of the avatars controlled by the computer, but it is known that twenty steering behaviors such as Seek, Arrive, Wander, Separation, Cohere, Leader Follow, Obstacle Avoidance & Containment, Path-following, Pursuit, Flee, Evade are used at the design of VELOS. Ginnis have adopted these behaviors from the works of two scientists, C.W. Reynolds and R. Green [10-11]. Adding these steering behaviors make the simulation more realistic not only for VR, but also for the most simulations that works with moving people on board.

VELOS level up the simulation with modeling behaviors of a group of people, which called crowd modeling. Even though IMO circulars have some recommendations for modeling of people's movement, writers claim that VELOS's method is more realistic than the simplified approaches proposed in IMO circulars [12]. These circulars have some restrictive assumptions and omissions as ship motions, fire or smoke, crew assistance and passenger grouping effects, while VELOS's enhanced crowd modeling corrects these calculation mistakes that IMO ignores.

VELOS divides enhanced crowd modeling as:
1. Modeling Ship Motions and Accelerations
2. Passenger Grouping
3. Crew Assistance
4. Influence of Fire

4.1 Modeling Ship Motions and Accelerations

VELOS have some different methods to reckon motions of ship. It is possible to acquire data from precomputed ship motions. Accelerations during time can be either estimated via numerical differentiation of ship motions or imported from the experimental measurements. If location history by time of a given P point on board is known, we can calculate rotational motions (pitch, roll and yaw), linear velocity (v_p) and acceleration ($\dot{v}_p$), angular velocity (ω_B) and acceleration ($\dot{\omega}_B$) on the Q point of the ship. VELOS uses following well-known relations from rigid-body kinematics at every Q point on ship [5]:

$$Q = P + \omega_B \times r_{pq}, \;\; \dot{v}_q = \dot{v}_p + \omega_B \times (\omega_B \times r_{pq}) + \dot{\omega}_B \times r_{pq} \qquad (3)$$

where, r_{pq} is the vector formed by P and Q.

On the other hand, inclination on ship will hinder agent motion accordingly. VELOS appoints upper and lower thresholds; lower one discards plane motions with negligible effect on agent's motion, while the upper one cause movement inability, as the limit of agent's balancing capabilities. While the formula, that is underpinned by experimental data relating to threshold angles and the weight function is given below [5, 13-15].

$$f_i = \lambda(\varphi) \; g_p / \|g_p\| \qquad (4)$$

where g_p is the projection of g value, $\lambda(\varphi)$ is a suitable weight function that is decided by the angle φ formed between gravitational acceleration and the normal to the deck plane.

Rough weather conditions lead loss of balance on sailors because of sliding and tipping. VELOS suggest 3 adjustments depend on T_{LATp} and T_{LONa}. First relation is set for the consideration of tips to port, and second relation to aft [16-18]:

$$T_{LAT_p} = \frac{1}{g}\left(\frac{1}{3}h\ddot{\eta}_4 - \ddot{D}_2 - g\eta_4 - \frac{1}{h}\ddot{D}_3\right) > \frac{1}{h} \quad (5)$$

$$T_{LON_a} = \frac{1}{g}\left(\ddot{D}_1 + \frac{1}{3}h\ddot{\eta}_5 - \frac{d}{h}\ddot{D}_3\right) > \frac{d}{h} \quad (6)$$

Variables of these formulas are the basic personal parameters determining balance of people on board. d, h and l stands for half-shoe width, the distance to person's center of gravity in vertical axis and half-stance length respectively, shown in Figure 4. Usually values of l/h lie in the interval (0.20, 0.25) while for d/h lie in (0.15,0.17). In the equations, η_1 (surge), η_2 (sway), and η_3 (heave) represent the translational movement, while η_4 (roll), η_5 (pitch) and η_6 (yaw) represent the rotational components of ship motion along the x−, y− and z− axis of the ship coordinate system respectively, as they are seen in the Figure 3. These components are also used to find the displacement of P(x,y,z) point according to the equation of $D=(D_1,D_2,D_3)=(\eta_1,\eta_2,\eta_3)+(\eta_4,\eta_5,\eta_6)\times(x, y, z)$.

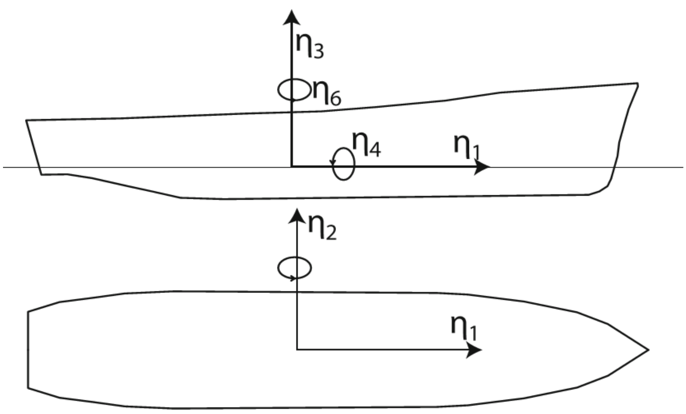

Figure 3. Ship coordinate system (Source: [5]).

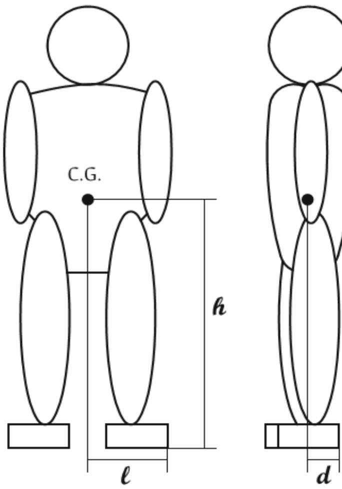

Figure 4. Person's center of gravity, half-stance and half-shoe width (Source: [5]).

Three implementation of the Equation 5 and 6 in the simulation are listed below:

1. Using new function of k values between 0 and 1, $\tilde{v}_m$ values that represent the maximum allowable velocity dropped according to the following rule [5]:

$$\tilde{v}_m = k \,.\, v_m \qquad (7)$$

where: $0.20 < T_{LAT} < 0.25 \wedge 0.15 < T_{LON}$

$$k \begin{cases} = 1, & if\ T_{LAT} < 0.20 \wedge T_{LON} < 0.15 \\ = (-20T_{LAT} + 5), & if\ 0.20 < T_{LAT} < 0.25 \wedge T_{LON} < 0.15 \\ = (-20T_{LAT} + 5)(-50T_{LON} + 8.5), & if\ 0.20 < T_{LAT} < 0.25 \wedge 0.15 < T_{LON} < 0.17 \\ = (-50T_{LON} + 8.5), & if\ T_{LAT} < 0.20 \wedge 0.15 < T_{LON} < 0.17 \\ = 0, & if\ T_{LAT} < 0.25 \wedge T_{LON} > 0.17 \end{cases}$$

The values of k are made visible with a color pot shown in the Figure 5.

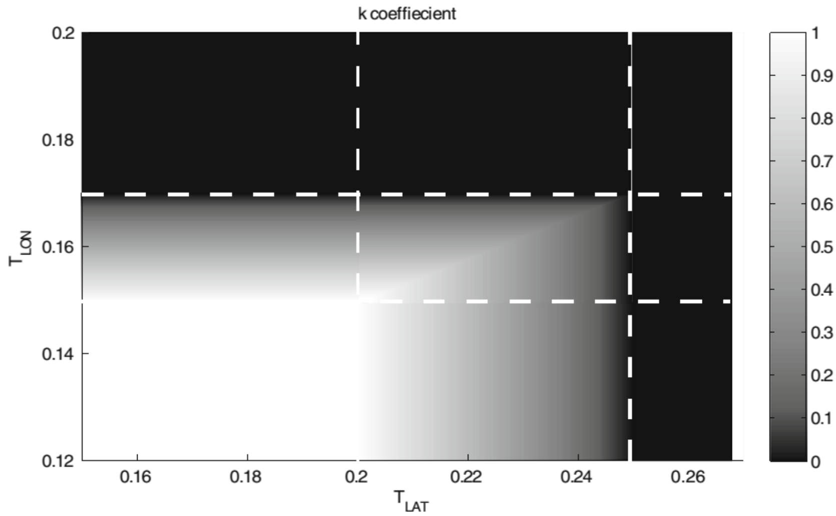

Figure 5. Color plot of k-coefficient values (Source: [5]).

2. Some steering behaviors are changed. It is claimed that such scenario would increase the wander behavior %10 and decrease the obstacle avoidance and separation contribution that determine both speed and direction of walking people in the simulation.

3. Parameters of each individual steering behavior are adjusted.

4.2 Passenger Grouping

Modeling ship motions and reactions of humans are not enough for a realistic human flow. People in hurry may wait or go back for someone instead of escape from the shortest path. Considering social reactions of people, VELOS uses Enhanced-Cohere behavior which clusters agents that are not only geometrically close to each other, but also belong to the same group, like families, co-operating crew and crew guided groups. For that purpose, people are endowed with ID to appoint different v_m values [24].

VELOS implement 3 different subgroups to make grouping more realistic. Calculating the locations of all the members of the group, standard cohere behavior, draws s-p steering vector [5]:

$$s = \frac{1}{\sum_i w_i} \sum_i (w_i \, p_i) \tag{8}$$

where $w_i = \frac{1}{\|p - p_i\|}$

In this equation position of the person symbolized as p, and the rest of group members as p_i, to calculate the s-p direction for each of 3 levels of subgroups below:

Grouping Level 0:

This level targets group members or leaders for the short-term using the last equation for the standard cohere behavior.

Grouping Level 1:

This level aims to create cohesion in the group, sharing a common ID. In case a member left the group, the others are not affected.

Grouping Level 2:

This level has the same properties with Level 1. In addition, group leaders are responsible for the one who leave the group. The leader or leaders are needed to take some corrective action, such as waiting or looking for the missing member.

4.3 Crew Assistance

In a real evacuation scenario crew knows escape routes better than the passengers. So if someway stuck, they can lead people alternative routes. VELOS effect passengers' behaviors according to crew members using triggers. Benefits of crew assistance have been shown by test cases.

4.4 Influence of Fire

In case of a fire, crew and passengers encounter some frustrating feelings which make incapable of running. Smoke, made by fire, obscures seeing while heat and toxic products on the air make people sick and unconscious. The program decides the influence of fire products on the behaviors of agents using Health Reduction Rate function [5]:

$$\mathrm{HRR}(t) = F\big(\alpha T(t) + bC_{CO}(t)\big), \left[\frac{\mathrm{Health}_{units}}{\mathrm{second}}\right] \tag{9}$$

where F describes the used functional model, T is the temperature (°C) and C_{CO} the carbon monoxide concentration (ppm) of the space [5].

In addition, mortality and ability of walking is decided by the Health Index function [5]:

$$\mathrm{HI}(t) = 1 - \int_0^t F(\alpha T(t) + bC_{CO}(t))dt \tag{10}$$

All of these relationships determine the basic parameters that the user feels during an escape scenario. Since these are for the movement of people in extreme situation, these results are reasonable for most of similar ship simulations [4].

Because calculating fire spreading is already a hard occupation, VELOS prefers to import pre-computed time-series of fire spread. In this way, setting the time when fire puts on or explosion happens is enough to attain the needed parameters for using Health Reduction Rate and Health Index functions as well as visual and auditory properties of ship.

5. VIRTUAL REALITY SOFTWARE

Apart from some CAD/CAM suppliers, developed their own software, some people can use game engines which are cheaper, such as Unity and Unreal. But even these game engines request a certain amount of money when they are used for commercial issues. According to Fernandéz, most of the software require a product license for projection channel ranging between 10,000 € and 300.000 € [4].

Morais claims that some shipbuilding companies have succeeded in creating VR solutions after spending years and a lot of money on software development. However now most companies are using some general gaming engine such as Unity or Unreal. These game engines require money, but it's more cost-effective for the purpose of getting more innovation from software vendors that are focused on VR [7].

6. TESTS OF VIRTUAL REALITY SYSTEMS

FViewerVR™ application is known to be used by the Spanish Navy in the construction process at the NAVANTIA ship's Virtual Design Center. Four different construction sites were coordinated in the VR room at Cartagena shipyard. It is stated that this application helps to provide the following advantages [1]:

Cost reduction: The experienced staff of the Spanish Navy recognized the problems with the location of the equipment on the ship. They could propose construction drawings for changes and new drawings in the 3D model, rather than large and high-priced changes in the production stage.

Space understanding: Putting dummies in realistic positions helps people understand the real distances within the ship's compartments.

Commercial activities: The whole ship has been introduced to new customers before it was built. Customers realized the complexity and appreciated the details of the model. The walkthrough navigation has informed new customers in-depth understanding of the ship's structure, such as decks, bulkheads, ladders. [1]

VELOS software was tested in a Ro-Pax ship evacuation scenario. Every variation of scenario are simulated 3000 times each, to find the weakness of ship [5].

Crew assistance: Ginnis says 3 variation of tests are done to measure the effect of crew assistance. In the first variation, passengers follow the designated escape route without crew assistance, while they take crew assistance at second and third variations. Average travel time for variations 1, 2 and 3 are equal to 147 s, 112 s and 113 s, respectively. Importance of crew assistance to evacuate passengers is proven by VELOS.

Fire event: Simulation is run 360 times to compare evacuation with and without fire. It is shown that in case of fire %30 of the passengers could not reach the muster station because of fire obscuring and toxic gases resulting fatalities.

Ship Motions' Effect: Considering ship motions 3 variation of tests have done with VELOS. First variation for without motion modeling, second variation for kinematic modeling of motion effects through inclination behavior, and the third one for dynamic modeling using tipping coefficients implementation.

Travel times resulted for both inclination and tipping coefficient modeling are approximately 70 seconds and considerably higher than the still water case which is around 50 seconds.

7. FUTURE WORKS

Computer Aided Modeling solutions have every time an impact on people, showing illustrations in different colors. People who have no knowledge about industry, can watch some views, and comment. Advertising to the customers who have never worked in ship building is much easier with VR technology. In a very close future, the companies that do not use VR and AR in their advertisements, cannot sell their products to the wealthy and illiterate customer in shipbuilding. Training procedure costs time, money and labor. Universities and companies which do not use VR and AR might share the same fate: failure.

Currently there are some ship building companies which have already built their own software [7]. However, ship builders began to paying some money to the game engines for more realistic effects. Next years' shipping industry can only cope with the adaptation to VR instead of creating an innovation. As a conclusion, some shipyards might need to employ some game developers to use these game engines efficiently.

Now VR technology only lets people move their heads offering a panoramic 3D view. AR technology adds some new characteristics with body movements. Because this technology is still developing, some features relating to ship building and marine life to be determined. These features can be listed as:

1) Swinging platform which imitates the behaviors of a ship between waves

2) Walking band which for the movement of feet

3) Moving walls and handrails for the sense of touching or bumping to a wall

4) Real objects or doors which people enter through

5) Some additional senses such as heat in case of fire, spraying water in case of rough seas, wind, odor etc.

Creating a detailed AR room is not cheap but a need. Most companies cannot attempt such a risky and expensive investment. So most probably AR technology in shipbuilding will initiate for some military trainings.

Mixed reality which offers unreal holograms in real life might be a cheaper solution for some trainings. This kind of solution can be used for fire simulations in the real environment of ship. Training crew wears glasses which is capable of adding flares at certain parts of ship. So crew members can cooperate to stop that fire in their own ship instead of using a special room for VR or AR. Studies are carried by Alexandros GINNIS and he founded his own company ShipReality Inc™ [19]. It seems not only VR and AR, but also MR will meet the requirements of ships in the future

8. CONCLUSION

Variables for Virtual Reality software and hardware solutions, used for ships are shown. Regarding the software, the use of advanced CAD applications ensures an accurate ship 3D model that can be used in Virtual Reality navigations with the aid of specific tools with the necessary capabilities for the visualization and navigation. From the hardware side, some advantages have been introduced that we can see in the market, both from the simplest and portable to the most sophisticated and complex ones.

It's seen that, in 2011, VR was used mainly for review of ships using CAD applications. Then it became an unreal ship environment for some real and unreal people to escape. Both VELOS and FViewer™ operated successfully. FViewer's™ success was proven at the building process of Navantia warship, while VELOS was proven in a Ro-Pax ship. It is possible to use some of the same data that is given on this report, relating to software and hardware solutions in the next VR solutions.

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The articles submitted to JNSE to be published are free of article submission, processing and publication charges. The accepted articles are published **free-of-charge** as online from the journal website and printed.

DENİZ BİLİMLERİ VE MÜHENDİSLİĞİ DERGİSİ (DBMD)
YAYIN KURALLARI

Yazıların Gönderilmesi: Dergiye gönderilen makaleler başka bir yerde yayımlanmamış ya da yayımlanmak üzere gönderilmemiş olmalıdır. Yayımlanması istenilen yazılar aşağıda verilen adresten sisteme yüklenmeli (tercih edilen) veya aşağıdaki adrese bir kopya kâğıda basılı olarak, aynı zamanda e-mail adresine de dijital olarak gönderilmelidir. Dergimize makale gönderen yazarların makaleleriyle birlikte "Yayın Hakkı Devir Formu"nu da göndermeleri gerekmektedir. "Yayın Hakkı Devir Formu"na DBMD web sayfasındaki "Telif Hakkı" sayfasından erişilebilmektedir.

Sistem Adresi:
http://dergipark.gov.tr/jnse

Adres:
Dr. Mehmet Bilge Kağan ÖNAÇAN
Barbaros Deniz Bilimleri ve Mühendisliği Enstitüsü
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34942 Tuzla/ İSTANBUL/TÜRKİYE

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Yazı Türleri: Dergide; orijinal yazılar, derlemeler, teknik notlar, kitap incelemeleri, editöre mektuplar ile konferans ve toplantıların genişletilmiş raporları yayımlanır.

Yazıların Değerlendirilme Süreci: Makalenin Ön Kontrol Süreci:

- Makalenin içeriği ve yazım formatı incelenir ve iThenticate yazılımı ile benzerlik taraması yapılır.
- Makalenin İngilizce özetinin, Türkçe öz ile uygunluğu ve yazım dili kontrol edilir.
- Benzerlik oranı %40'ın üzerinde olan makale reddedilir. Benzerlik oranı %20 ile %40 arasında olan (tek bir kaynakla benzerlik %5'ten fazla olmamalıdır), yazım formatına uymayan ya da İngilizce ve Türkçe özetinde düzeltme gereken makale yazara bildirilir ve "iki hafta" içerisinde makalenin düzeltilmesi istenir. Aksi takdirde makale çekilmiş kabul edilir.

Dergimiz, makale değerlendirme sürecinde **çift-kör** hakemlik sistemini kullanmaktadır. Buna göre değerlendirme sürecinde hakem ve yazarlar birbirlerinin bilgilerini görememektedir. Bu yüzden, yüklenen ön yükleme formatında yazar(lar)ın isim, adres ve bağlı olduğu kuruluş(lar) yer almamaktadır. Makale değerlendirme sürecindeki adımlar aşağıdaki gibidir;

- Baş editör tarafından makaleye editör atanır.
- Editör makale için hakemleri atar.
- Hakem değerlendirmesi sonucunda makale reddedilebilir, kabul edilebilir veya makalenin düzeltilmesi istenebilir.
- Hakem görüşlerinin çoğunluğu doğrultusunda makale ret edilmişse süreç sonlandırılır ve makale reddedilir.
- Makale için düzeltme istenirse hakem görüşleri doğrultusunda yazarın düzeltmeleri en geç "üç hafta" içerisinde yapması istenir.
- Makale kabul alırsa düzenleme aşamasına geçilir.

Değerlendirme sürecine ilişkin iş akış sürecine, dergi web sayfasından erişilebilir.

DBMD'ye yayımlanmak üzere gönderilen makaleler; makale gönderim, işlem ve yayın ücretinden muaftır. Kabul edilen makaleler, **ücretsiz** olarak basılı şekilde ve dergi web sayfasından çevrimiçi olarak yayınlanmaktadır.

JOURNAL OF NAVAL SCIENCES AND ENGINEERING (JNSE)
WRITING RULES

General: Manuscripts must be prepared in MS Word, single-spaced with justify. Font: Times New Roman, 12 points. Margins: left 4,5 cm- right 3,5 cm, top 5 cm- bottom 7 cm, header 3,25 cm- footer 6 cm, gutter 0. Paper type: A4. Page numbers should be on the middle of bottom of page with -1-, -2-, -3- etc format. Using footnotes is not allowed.

Body of Text: Follow this order when typing manuscripts: Title, Authors, Abstract, Keywords, Title (Turkish), Abstract (Turkish), Keywords (Turkish), Main Text, Appendix (if any), References.

Title: Title should reflect objectives of the paper clearly, be easily understandable and not exceed 15 words.

Abstract: Each paper should have an abstract with 100-200 words and have a structured form, i.e. standard structure of an article (background, purpose, material and methods used, results, conclusion).

Keywords: Author must provide some keywords (between 3 and 5) that will be used to classify the paper.

Paper Length: The manuscript should be minimum 2000 words or 5 pages, maximum 7000 words or 25 pages including references.

Unit: International System of Unit (Système Internationale d'Unités; SI) (https://www.britannica.com/science/International-System-of-Units) should be used for all scientific and laboratory data.

References: Referring to references should be in the text by using reference numbers in parenthesis (i.e. [2]).

List of References: Publications cited in the text should only be presented in a list of references following the text of the manuscript. References should be listed according to their orders in which they are cited in the manuscript, i.e., [1] cited first, [2] cited next, and so on. An example of a reference list is below.

Examples:

[1] Berndt, T. (2002). "Friendship Quality and Social Development", ***Current Directions in Psychological Science***, vol.82, no.3, pp.114-140. **(Single authored article)**

[2] Rother, M. and Shook, J. (1999). "Learning to See: Value Stream Mapping to Create Value and Eliminate Muda", ***The Lean Enterprise Institute***, vol.22, no.4, pp.3-4**. (Multi-authored article)**

[3] Okamoto, G. (1999). ***Smart Antenna Systems and Wireless LANs,*** Boston: Kluwer Academic Publishers. **(Single Author Books)**

[4] Author, A. (Year). "Title of document", Retrieved from http://wwwwwwwwwwwwwwwwwwww wwwwwwwwwwwwwww (Access Date: 00.00.0000). **(Internet Sources)**

[5] Lastname, F.N. (Year). Title of dissertation (Doctoral dissertation). University Name, Institute Name, City. (Retrieved from Name of database). **(Published Dissertation)**

[6] Bergmann, P. G. (1993). Relativity, ***In the New Encyclopedia Britannica,*** (Vol. 26, pp. 501-508). Chicago, IL: Encyclopedia Britannica**. (Encyclopedia)**

[7] Author, A. A. (Year, Month Day). "Title of article", ***Title of Newspaper***. Retrieved from http://www.someaddress.com/full/url/wwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwww wwwwwwwwwww wwwwwwwwwwwwwww. **(Newspaper article)**

[8] Önaçan, M.B.K., Uluağ, M., Önel, T. and Medeni, T.D. (2018). "Selection of Plagiarism Detection Software and Its Integration into Moodle for Universities: An Example of Open Source Software Use in Developing Countries". Ricardo Queirós (ed.), Emerging Trends, Techniques, and Tools for Massive Open Online Course (MOOC) Management, ***IGI Global***, 250-265, pp. 255. **(Book chapter)**

Abbreviations and Acronyms: Standard abbreviations and acronyms should be used for each related discipline. Acronyms should be identified at the first occurrence in the text. Abbreviations and acronyms may also be attached to main text as an appendix.

Equations and Formulas: Equations and formulas should be numbered consecutively. These numbers must be shown within parentheses being aligned to right. In the text, equations and formulas should be referred with their numbers given in parentheses. Comprehensive formulas, not appropriate to be written in the texts, should be prepared in figures.

Figures and Tables: Figures and tables should be numbered consecutively. In the text referring to figures and tables should be made by typing "Figure 1" or "Table 1" etc. A suitable title should be assigned to each of them.

DENİZ BİLİMLERİ VE MÜHENDİSLİĞİ DERGİSİ (DBMD) YAZIM KURALLARI

Genel Bilgiler: Yazılar; Microsoft Word'de tek satır aralığı ve iki yana yaslanarak hazırlanmalıdır. Yazı tipi: Times New Roman, 12 punto. Kenar boşlukları: sol 4,5 cm- sağ 3,5 cm- üst 5 cm- alt 7 cm- üst bilgi 3,25 cm- alt bilgi 6 cm, oluk 0. Kağıt ölçüsü: A4. Sayfa numaraları sayfanın alt ortasında -1-, -2-, -3- şeklinde yer almalıdır. Dipnot kullanılmamalıdır.

Yazı Yapısı: Yazı şu sırada hazırlanmalıdır: Başlık, Yazarlar, Özet, Anahtar Kelimeler, Başlık (Türkçe), Özet (Türkçe), Anahtar Kelimeler (Türkçe), Ana Metin, Ek (varsa), Referanslar.

Başlık: Başlık; açık, net, anlaşılır olmalı ve 15 kelimeyi geçmemelidir.

Öz: Yazı, 100-200 kelimelik, arka plan, amaç, yöntem, bulgular ve sonuçtan oluşan yapılandırılmış bir özeti içermelidir.

Anahtar Kelimeler: Yazıyı sınıflandırmaya yarayacak, anahtar görevi yapan 3-5 kelime yer almalıdır.

Sayfa Sayısı: Dergiye gönderilecek yazıların boyutu, kaynakça dahil asgari 2000 kelime veya 5 sayfa, azami 7000 kelime veya 25 sayfa arasında olmalıdır.

Birimler: Yazının uluslararası alanlarda da kolay izlenebilir ve anlaşılabilir olması için Uluslararası Birim Sistemine (https://www.britannica.com/science/International-System-of-Units) uygun olarak hazırlanması gerekir.

Referans: Referanslar dipnotlar ile değil metin içinde açılacak parantezlerde yer alan referans numarası ile ([2] gibi) yapılmalıdır.

Referans Listesi: Makalenin ana metninden sonra sadece yazıda gönderme yapılan eserler yer almalıdır. Gönderme yapılan eserler, ana metin içerisinde atıf yapıldıkları sıraya göre listelenmelidir, yani ilk atıf yapılan eser [1], ikinci atıf yapılan eser [2] olmalı ve bu şekilde devam etmelidir. Bir referans listesi örneği aşağıdadır.

Örnekler:

[1] Berndt, T. (2002). "Friendship Quality and Social Development", ***Current Directions in Psychological Science***, vol.82, no.3, pp.114-140. **(Tek yazarlı makale)**

[2] Rother, M. and Shook, J. (1999). "Learning to See: Value Stream Mapping to Create Value and Eliminate Muda", ***The Lean Enterprise Institute***, vol.22, no.4, pp.3-4**. (Çok yazarlı makale)**

[3] Okamoto, G. (1999). ***Smart Antenna Systems and Wireless LANs,*** Boston: Kluwer Academic Publishers. **(Tek yazarlı kitap)**

[4] Author, A. (Year). "Title of document", Retrieved from http://wwwwwwwwwwwwwwwwww wwwwwwww wwwwwwwwwww. (Access Date: 00.00.0000). **(İnternet kaynakları)**

[5] Lastname, F.N. (Year). Title of dissertation (Doctoral dissertation). University Name, Institute Name, City. (Retrieved from Name of database). **(Yayınlanmış tez)**

[6] Bergmann, P. G. (1993). Relativity, ***In the New Encyclopedia Britannica,*** (Vol. 26, pp. 501-508). Chicago, IL: Encyclopedia Britannica**. (Ansiklopedi)**

[7] Author, A. A. (Year, Month Day). "Title of article", ***Title of Newspaper***. Retrieved from http://www.someaddress.com/full/url/wwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwww wwwww wwwwwwwwwwwwwwwwwwwwwwwwwwwwww. **(Gazete makalesi)**

[8] Önaçan, M.B.K., Uluağ, M., Önel, T. and Medeni, T.D. (2018). "Selection of Plagiarism Detection Software and Its Integration into Moodle for Universities: An Example of Open Source Software Use in Developing Countries". Ricardo Queirós (ed.), Emerging Trends, Techniques, and Tools for Massive Open Online Course (MOOC) Management, ***IGI Global***, 250-265, pp. 255. **(Kitap bölümü)**

Notasyon ve Kısaltmalar: İlgili bilim alanının standart notasyon ve kısaltmaları kullanılmalı, yeni notasyonlar ise metin içinde ilk geçtiği yerde tanımlanmalıdır. Gerekli durumlarda, notasyon ve kısaltmalar ek olarak konulabilir.

Denklem ve Formüller: Denklem ve formüller ardışık olarak numaralandırılmalı ve bu numaralar sağa dayalı parantez içinde yazılmalıdır. Metin içinde denklem ve formüllere parantez içinde yazılan numaraları ile atıfta bulunulmalıdır. Metin arasında verilmesi uygun olmayan kapsamlı formüller şekil olarak hazırlanmalıdır.

Şekiller ve Tablolar: Şekiller ve tablolar, ardışık olarak numaralandırılmalıdır. Bunlara metin içinde "Şekil 1" veya "Tablo 1" şeklinde atıfta bulunulmalıdır. Her bir şekil ve tablo için uygun bir başlık kullanılmalıdır.