Application of New Techniques and Information Technology for Early Fire Detection on Ships

Primjena novih tehnika i informatičkih tehnologija u ranom otkrivanju požara na brodovima

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Summary

Damages and losses caused by fire on ships, in the last decade, have accelerated the development of new techniques, technologies and innovation, in order to increase the safety and reliability of the fire detection system. At the same time, by increasing the demand for enhanced technology for early fire detection and its prevention, advanced detection systems are being developed, whose control algorithms have the task of intelligently processing and distinguishing the real smoke or flames signals from the false ones, or real alert from the false one. By using the service that new technology provides, ship owner aims to better protect the crew, ship's inventory, and to reduce the potential costs, that may occur due to accidents caused by fire. With an overview of the latest techniques and technologies for early fire detection on ships, this paper presents improvement of characteristics of the new systems and components of detection systems, and their abilities, benefits, and applications are being analysed.

KEY WORDS
fire
ship
techniques
technology
video detection
modelling

Sažetak

Štete i gubitci nastali uslijed požara na brodovima zadnjih desetljeća ubrzali su razvoj novih tehnika, tehnologija i inovacija s ciljem povećanja sigurnosti i pouzdanosti sustava detekcije požara. Istovremeno, povećanjem potražnje za poboljšanom tehnologijom ranog detektiranja požara i njegovog sprječavanja, razvijaju se napredni sustavi detekcije čiji upravljački algoritmi imaju zadatak inteligentne obrade raspoznavanja stvarnog signala dima ili plamena, odnosno stvarne uzbune od lažne. Koristeći uslugu koju nudi nova tehnologija, brodaru je cilj kvalitetnija zaštita posade, brodskog inventara, te smanjenje mogućih troškova koji bi mogli nastati uslijed nesreće izazvane požarom. Uz pregled najnovije tehnike i tehnologije ranog otkrivanja požara na brodovima, ovaj rad prikazuje poboljšanje karakteristika novih sustava i komponenti sustava detekcije, analiziraju se njihove mogućnosti, prednosti i primjena.

KLJUČNE RIJEČI
požar
brod
tehnika
tehnologija
video detekcija
modeliranje

INTRODUCTION / *Uvod*

The increasing demands of today's ship owners for reducing the risks and for the safety of navigation, has prompted manufacturers of marine equipment and the scientific community to develop and deploy new conceptual solutions. Fire hazards can lead to disastrous consequences by causing major damage to the ship and ship's systems, ship's cargo, loss of human life, and also damage to the environment or its ecosystem. As a result, today protection against fire is a top priority in the ship's design, and this particularly applies to passenger ships. IMO rules and regulations for protection of human lives at sea (The SOLAS Convention) provide a minimum framework for fire protection.

By introducing the ship's automation we are trying to increase the reliability, safety and functionality of the ship's systems, including the fire alarm detection system. During the last decade with the development of the ship's automation, advanced systems for automatic detection of smoke and fire on board were also being developed. This was achieved with many advanced researches, in both commercial and military purposes, wherein the US Navy leads with the introduction of a robot, equipped with advanced technology, into the system for early detection of the possible fire origin. From the fire

detection system, which is technologically very demanding, high reliability and precision in its early detection are expected. That affected and forced the industry to develop a multi-sensory approach, i.e. new smart multi-sensors, then to perfect the usage of video technology (CCTV camera) for the early smoke and fire detection, the creation of new algorithms, although there is already a large number of developed old ones, the application of fuzzy logic into fire detection systems, including detectors, all with the goal of successful detection of fire and smoke on board, at the earliest stage of its formation, when the expected damages are the least.

SIGNIFICANCE OF SOLAS DIRECTIVES II-1/8-1, II-2/21 AND II-2/22 FOR DEVELOPMENT OF FIRE ALARM TECHNOLOGY / *Značaj solas propisa ii-1/8-1, ii-2/21 i ii-2/22 za razvitak tehnologije vatrodojave*

With the construction of bigger passenger ships in the last decade, and with an increase in passenger numbers, the concern, from the aspect of risk of safe return to port, for both the ship and the passengers, has also increased. Therefore, the team of the International Maritime Organization (IMO), i.e. the Maritime Safety Committee at the 82nd session at the end of 2006, had approached the review of the safety of passenger ships in emergency situations, for the purpose of improving, or creating new concepts of ship's systems, including the fire alarm system which will provide that, and adopted an amendment to the new SOLAS directives II-1/8-1, II-2/21 and II-2/22, for new ships longer than 120 meters, or which have three or more fire zones, with the beginning of application in 2010., refering to the ship's systems redundancy, caused by the rules of safe return of the ship and the passengers to the port, which provides the security and the system's ability to continue its function of avoiding deadlock, when some of the components in the chain of the system, under the new regulations, fail.

SOLAS directives II-1 / 8-1, II-2/21 and 22 as amended identify three scenarios and those are [16]:

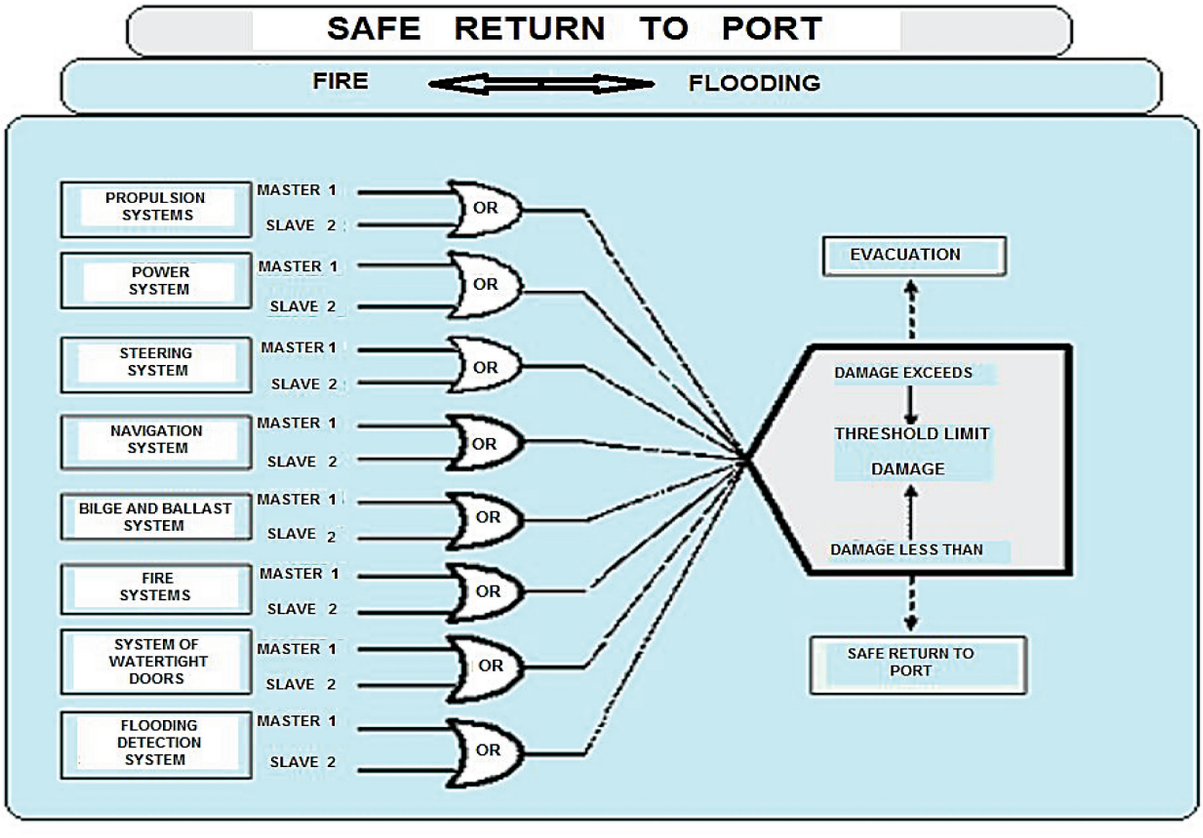
Availability of relevant systems after an accident caused by the flood, in accordance with SOLAS directive II-1 / 8-1;

Availability of relevant support systems for the safe return of the ship to the port, after an accident caused by fire, in accordance with SOLAS directive II-2/21;

Availability of relevant support systems for ship evacuation, after an incident caused by a fire, in accordance with SOLAS directive II-2/22.

From scheme 1 it can be seen that after the discovery of the cause of the accident, i.e. whether the flooding of the ship, or fire, have occurred, the threshold limit of the accident shall be determined. If the accident caused a damage greater or smaller than the threshold limit, then safe return to the port or evacuation will be initiated.

Basic systems that must ensure the operational functioning of the ship in case of damage. according to SOLAS directive (Reg. II-2/21) include [11]:



Source: Authors

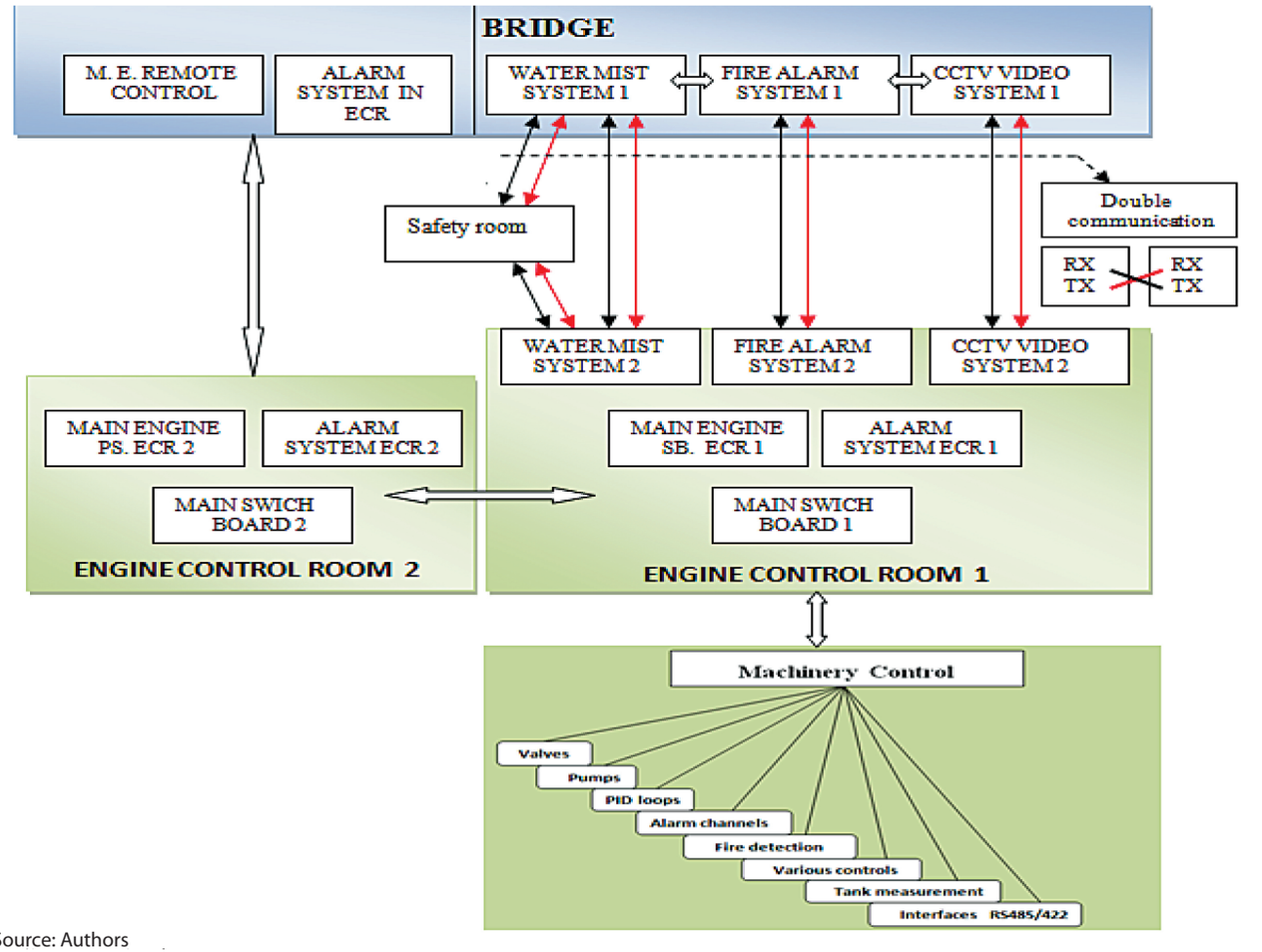
Figure 1 Terms of threshold limit of SOLAS regulations for safe return to the port

Slika 1. Uvjeti graničnog praga SOLAS propisa sigurnog povratka broda u luku

Table 1 Basic systems must ensure the operational functioning of the ship
Tablica 1. Osnovni sustavi koji moraju osigurati operativno funkcioniranje broda

1. Propulsion system (one shaft must work in case of flooding or fire);
2. Steering system (higher levels of managing);
3. Alternative system (azipod – marine propulsion unit which consists of an electric driven screw mounted in a housing that can be managed);
4. Electric Power systems (to provide energy for all systems);
5. External communication system;
6. Internal communications system, including the ship's public address system;
7. Navigation system;
8. Fire Protection systems;
9. Ballast and bilge systems (for each zone the system operates regardless of the damage on another part of the system);
10. Watertight doors;
11. System for flooding alert;
12. All others which are important for managing and damage control.

Source: http://www.imo.org/blast/blastDataHelper.asp?data_id=17253&filename=216(82).pdf.



Source: Authors

Figure 2 Display of high redundancy by SOLAS regulations for safe return to the port
Slika 2. Prikaz visoke redundancije po SOLAS propisima sigurnog povratka u luku

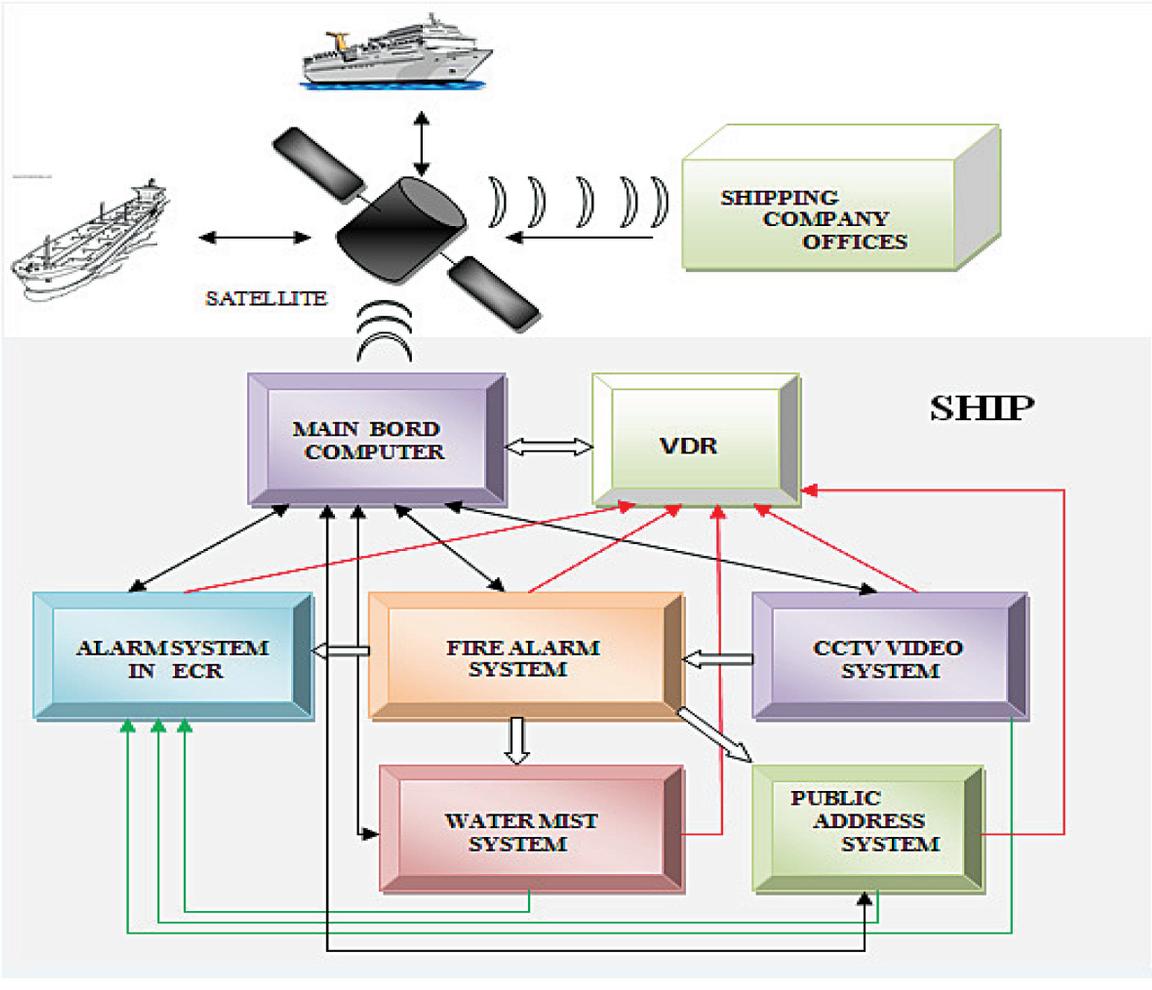
Today, individual companies have already developed unique software tools for performing overall and detailed analysis of the systems that are subject to SOLAS directives for safe return to the port. One such software tool is ISYS, which allows modeling of interconnected complex ship's systems, and their components [17]. This was done by dividing the vessel geometrically, using simple logic expressions that define their interdependency. According to IMO regulations, the ISYS software enables systems to carry out the analysis of possible scenarios based on the input data, and based on those data, the possible damage threshold. The system automatically generates the data, that can also be used for creating documentation of operational procedures for the ship's crew.

INTEGRATION OF FIRE ALARM SYSTEM INTO THE SHIP'S INTEGRATED SYSTEM / *Integracija sustava dojave požara u brodski integrirani sustav*

by integrating the ship's security systems, which also include integrated fire alarm systems, such as fire detection alarm system, fire extinguishing systems on board and a video surveillance system for the detection of smoke and flame, or beginning of a fire, and the ship's alarm system, through horizontal and vertical integration and communication using ship's dual computer network, together with the satellite communication with the central computer of shipowners on land, the safety and protection of the vessel during navigation, maneuvering and steering has increased. Most of today ship's fires, on cargo ships, are occurring in the engine rooms, while on the passenger ships, are in the superstructure, and that is why SOLAS directive Ch.II-2/Reg.4 includes protection measures in order to prevent the outbreak of such fires. Compliance with the rules and directives is checked by classification societies and port authorities.

- The integration of security functions implies:
- Detection and protection from the fire;
- Detection and protection from the gas;
- Fire extinguishing systems;
- Integrity of waters, stability of the calculation;
- Emergency stop of ventilation and machinery;
- CCTV video system;
- Drawn security protection plan;
- Interactive procedures in case of an emergency.

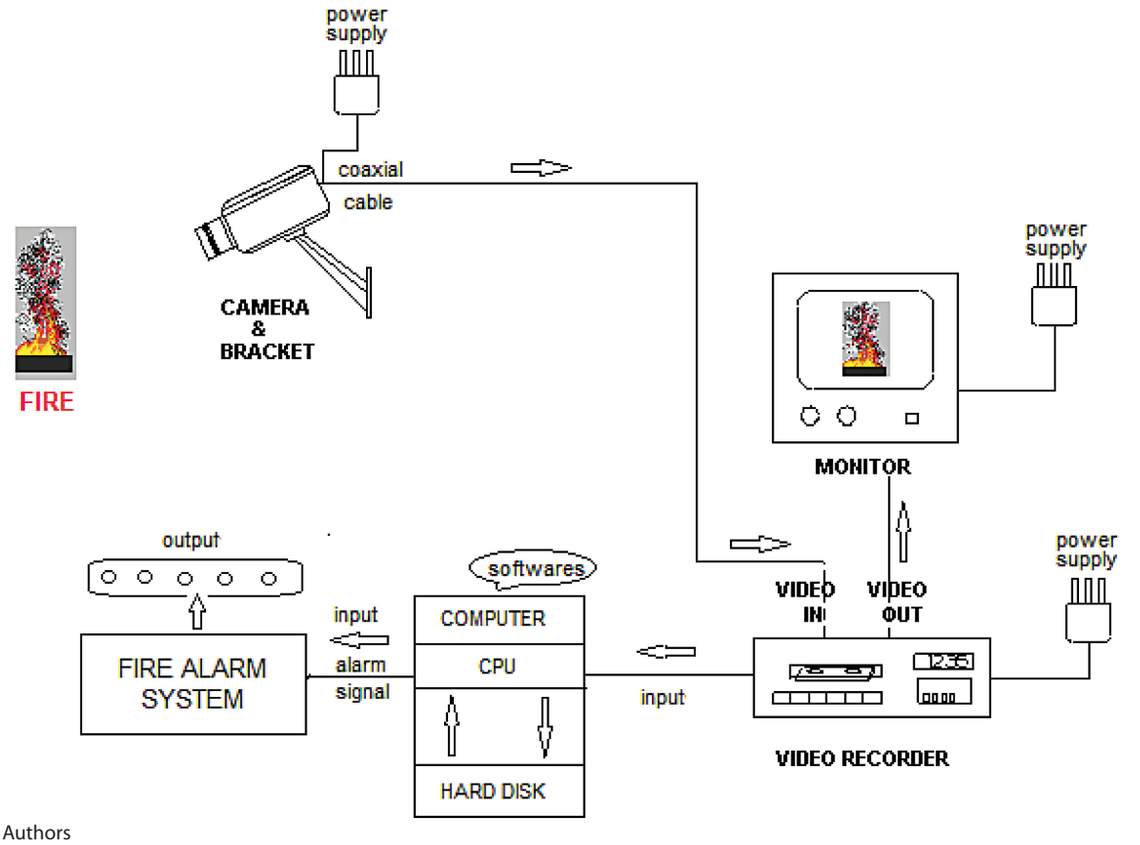
As can be seen, Figure 3 shows the integration of fire alarm systems in the ship's integrated system, with the purpose of faster and more efficient fire fighting. By centralizing all data collected, appropriate preventive response will be initiated in the shortest possible time. Advances in technology of firefighting on board,



Source: Authors

Figure 3 Architecture of connecting relations of fire detection systems and their integration into the ship integrated system

Slika 3. Arhitektura među veza vatrodojavnih sustava i njih integracija u brodski integrirani sustav



Source: Authors

Figure 4 The main components of fire detection via video camera
Slika 4. Glavne komponente otkrivanja požara video kamerom

by using fire alarm systems, has conditioned the ability of the fire alarm system to the:

- Ability for automatic location of the origin of the fire;
- Ability for automatic assessment of the size of the fire and the degree of threat;
- Ability for automatic application of adequate response;
- Effective system of suppression whose work has little impact on anything other than fire;
- Centralised and sensitive decision-making process through the ship's integrated system.

THE USE OF CCTV VIDEO TECHNIQUES IN DETECTING FIRE AND SMOKE ON SHIPS / *Upotreba CCTV video tehnike u otkrivanju vatre i dima na brodovima*

Optical flame detection has evolved over the last 30 years, while detection by video image (VID) is a newer technology that has evolved during the last 10 years. The development of technology has led to new insights, and thus to the development of new, sophisticated optical sensors, greater processor power and high electronic reliability. This has significantly improved, and provided, the possibility of automatic optical recognition of fire, even in the worst possible conditions. The best known optical sensors, before the use of video fire detection, were ultraviolet (UV) optical sensors, and infrared (IR) sensors. Originally, VID technology was developed in Europe, however, the first application of VID technology on board was in America, in 2007., by the US Navy [2].

Video fire detection makes a significant contribution to the efficiency of the fire alarm system, especially when it comes to the fire in big and large venues. Starting point for any CCTV system is a camera. As mentioned before, the CCTV system achieved its technological use on ships in the detection of smoke and flame during the last decade. However, CCTV system has achieved its extensive use on land. Based on many scientific researches, the programs have developed, which, by using smart algorithms and databases, create the basis for the use of video technology in the early detection of smoke or flames on board. The technology of video detection of smoke or flames (VSD) is based on the analysis of video signals from CCTV camera, and provides some basic guidelines as to its use in fire alarm systems [26]. The camera creates an image, which then reproduced on the monitor of CCTV system, displays the status of a certain zone on the vessel in real time. Also CCTV system, as a visual fire detection system that uses advanced algorithms for identification, provides us with effective responses to the fire, or flame, or smoke, even in challenging conditions. With features of an intelligent system for the early detection of fire and smoke in real time, the system has a feature, along with visualization and sensitivity, to cover a larger portion of the ship's area, which, unlike conventional detectors, is not possible. CCTV system is capable of, by using redundant communication, connecting seamlessly with the fire detection system.

Visual fire detectors or cameras that are mounted and placed on project specific positions, tasked with surveillance of possible incidents that cause a fire or smoke, for example in the ship's engine room, collect real-time video images which are transmitted to the control panel of visual fire alarm system, and then, by using the software, changes in the color, the spectral colors of fire, the movement of patterns, and a number of

Source: Authors

Figure 5 Display of connecting relations between CCTV video systems and fire detection alarm system on the Kornati - Jadrolinija ferryboat

Slika 5. Prikaz među veze CCTV video sustava i alarmnog sustava detekcije požara na trajektu Kornati- Jadrolinija

other parameters which indicate only flame or smoke behavior, are being analyzed. If the software estimates that collected parameters indicate the possibility of fire incident, the software will issue an alarm and, over redundant communication, forward the same to the fire detection system, which will, by following up on the registered incident, take appropriate measures in order to protect certain zones and human life, i.e. fire detection system should automatically take certain actions in order to prevent the spreading of the resulting fire, and to enable the evacuation of people from vulnerable parts of the ship, such as closing the fire protection doors, activation of the fire fighting system, deactivation of the ventilation system, etc..

Example of connection between CCTV system and fire detection system is shown in Figure 4. Video fire detection, flame images, smoke and fire recognition, monitoring and predication is still active, and very important, area of research. The success of fire or smoke detection is largely dependent on the selected algorithm. Although there are a number of algorithms that are in use, or are being developed with relatively new approach to the flame and smoke detection on board by using video image, a satisfactory efficiency for wider use on ships has not yet been achieved.

Some of fire detection algorithms are [13] :

- Wavelet video technique based on real-time detection of smoke;
- Classification of fire with pixels by using fuzzy logic and statistical models of colors;
- Intelligent fire detection in real time based on the method of video processing;
- Computer vision based on a method of fire detection in real time;
- Smoke detection based on video processing for the purpose of early warning;
- Technique of video recognition of smoke and flame;
- Fire detection in video sequence by using statistical models of color;
- The technique of automatic supervision of fire by using images with visible light.

By reviewing the literature concerning the method of analysis of color, it is revealed that this method is often applied by video systems for fire detection. Table 1. shows the history of the development of methods of color analysis for video systems [18].

Table 2 History of color analysis in video systems for fire detection

Tablica 2. Povijest analize boje u video sustavima za dojavu požara

Year	Method of color analysis for video sytems
1994	Temperature analysis of the G / D ratio
1999	Analysis of flame color (HSV)
2004	Three rules for the color of fire - pixels
2005	Analysis of flame color (RGB)
2008	Distribution of colors
2010	Colour - rule of decisions
2010	Modeling of fire by color algorithm
2010	Detection of fire in color - pixels

Table 3 Comparison of the traditional detection system and VSD system
Tablica 3. Usporedba tradicionalnog sustava detekcije i VSD sustava

DETECTION	HEAT	SMOKE	FLAME	PARTICLE	GAS	VIDEO SMOKE
RESPONSE SPEED	SLOW	FAST	VERY FAST	FAST	MEDIUM	VERY FAST
FALSE ALARM RATE	LOW	MEDIUM	HIGH	MEDIUM	MEDIUM	LOW
COST	LOW	MEDIUM	HIGH	HIGH	HIGH	CHANGEABLE
APPLICATION	CONFINED SPACES	OPEN OR CONFINED SPACES	HIGHLY FLAMMABLE MATERIALS	OPEN SPACES OF HIGH VALUE	CONTROLLED PLACES OF HIGH VALUE	LARGE AND OPEN PLACES

Source: Lawrence S.M. Chiu., Study on the video smoke detection system International Journal on Engineering,Volume 6, Number 4, p. 258-263, 2004

Source: www.sciencedirect.com

The following table shows us a comparison of the traditional system for the detection of smoke and flame, and the video system [3]. From this table, it is clear that the use of the video system has many advantages over the traditional system, such as a rapid detection of smoke or flame, the low rate of false alarms by using smart algorithms, and large spatial coverage.

FEATURES OF FUNCTIONS OF FUZZY LOGIC IN THE EARLY FIRE DETECTION / *Značajke funkcija napredne fazi logike u ranom otkrivanju požara*

The idea of advanced fuzzy logic was first perfected by professor dr. Lotfi Zadeh from the University of California, Berkeley, in 1960. Today, the general opinion is that the fuzzy logic emerged as a profitable tool to manage and control various systems and applications.

In the fire alarm systems, algorithms of light intensity, smoke density, humidity, temperature, act as fuzzy input variables, based on which the output variable decides the probability for fire. Due to possible errors and inaccuracies of fire detectors, many manufacturers of fire alarm systems use the logic of review of signal detectors, by sensing three or more times, and after confirming the veracity, allow further action to the input signal. Fire detection is based on the variables, such as: darkening of the smoke (smoke density)-(S), the rate of change of smoke darkening (ΔS), temperature (T), the rate of temperature change (ΔT), flame color (P). Most of the time, during research, three values of variables are often used, low (L-low), medium (M-medium) and high (H-high). However, if there are more values of variables, the end result of the research will also be more accurate [5]. Table 3 shows us ten fuzzy rules of detection of possibilities for fire [7].

Nowadays, multi-sensor algorithms for early detection and fire alarm system (MSFDA), are one of the most important current events in the development of marine technology for fire alarm systems. Old ship's fire alarm systems mostly use individual sensors, based on the simple logic of decision. New MSFD algorithm, developed on the bases of the fuzzy inference systems and neural networks, has contributed to the higher accuracy of the decision making whether the incident took place or not, or has the system detected smoke or flames as a possible cause of a fire on board.

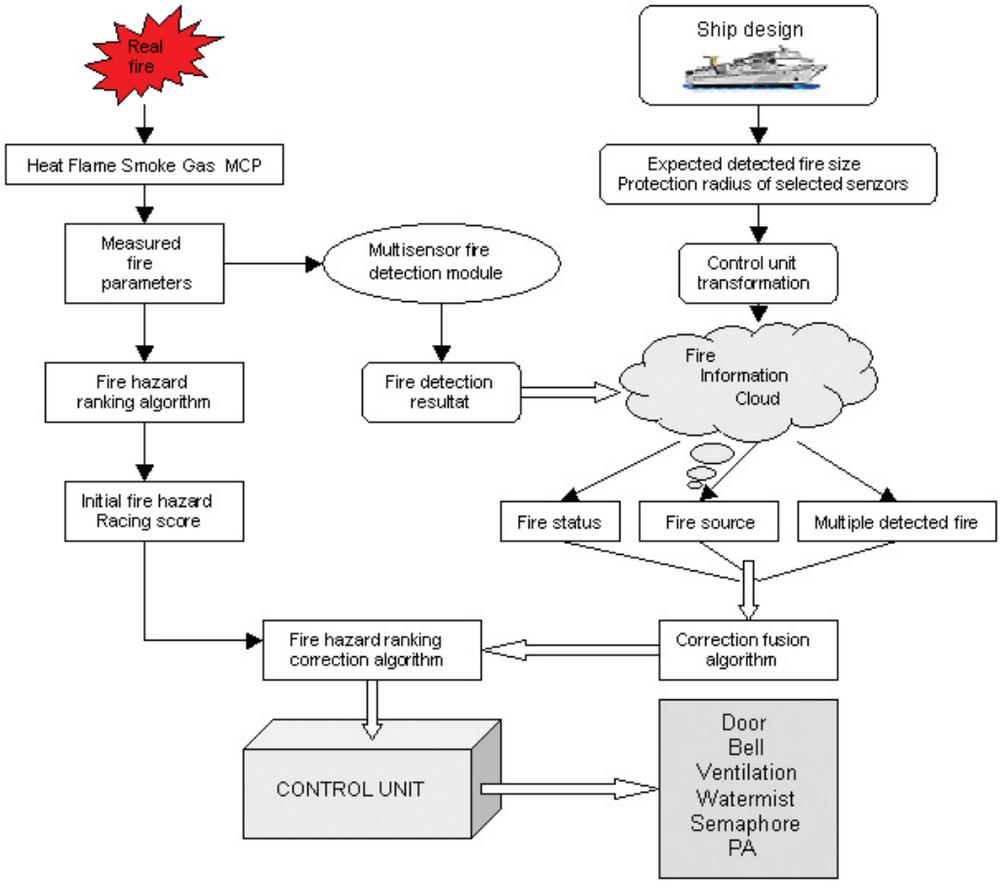
MODELING OF POSSIBLE FIRE SPREADING SCENARIOS ON BORD / *Modeliranje mogućih scenarija širenja požara na brodu*

Fires on board, depending on the type of ship and the area covered by the fire, can have disastrous and often fatal consequences. The most common fires on cargo ships are occurring in the engine rooms, while on the passenger ships, are in the superstructure, specifically cabins. Because of the frequent incidents due to fire, new SOLAS directives are adopted

Table 4 First ten phase rules for detection of fire problems
Tablica 4. Prvih deset fazi pravila za otkrivanje požarnih problema

Rul	Temp	Smoke	Light	Humidity	Distance	Output
1	L	L	L	H	Far	VL
2	L	L	L	H	Avg	VL
3	L	L	L	H	Close	VL
4	L	L	L	M	Far	VL
5	L	L	L	M	Avg	VL
6	L	L	L	M	Close	L
7	L	L	L	L	Far	VL
8	L	L	L	L	Avg	L
9	L	L	L	L	Close	L
10	L	L	M	H	Far	VL

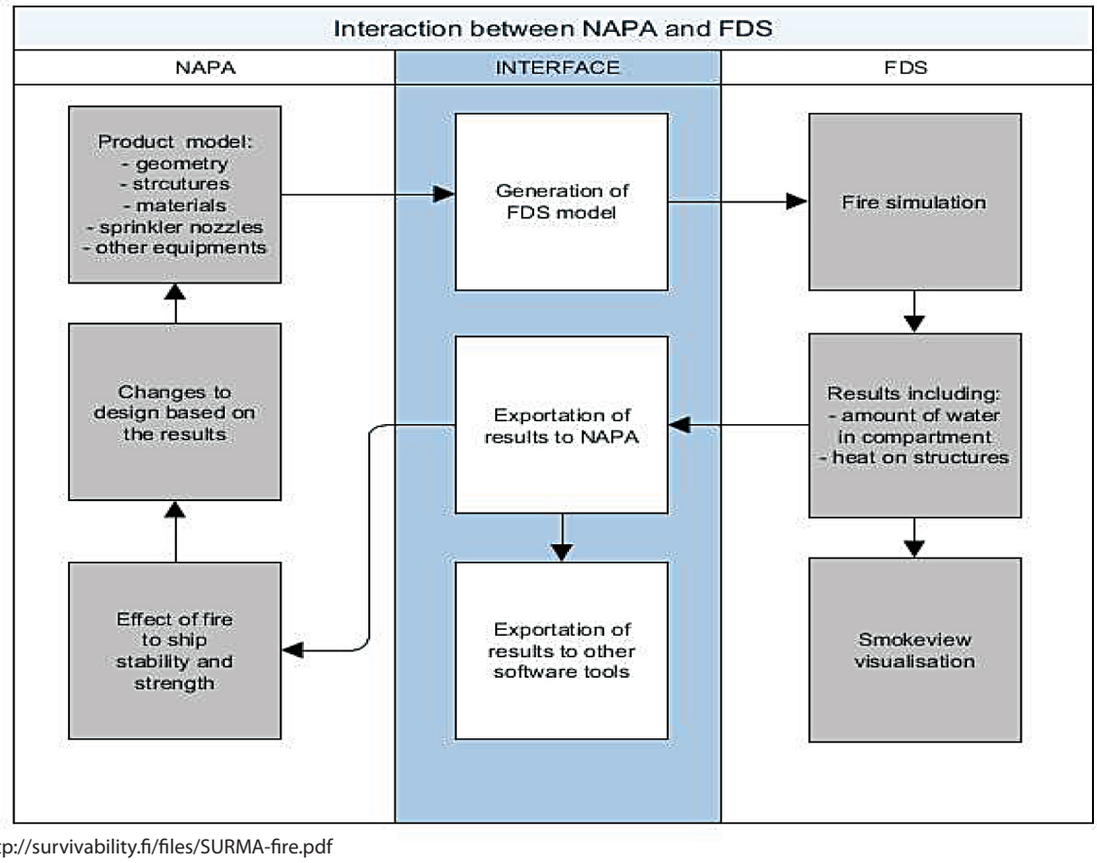
Source: Parul Mohindru, Vikshant Khanna, Rajdeep Singh., Forest Fire Detection Various Approaches., International Journal of Emerging Science an Engineering (IJESE) ISSN: 2319–6378, Volume-1, Isuse-6, April 2013



Source: Authors

Figure 6 The concept of fire algorithm model and distribution of output signals

Slika 6. Koncept modela algoritma požara i distribucije izlaznih signala



Source: http://survivability.fi/files/SURMA-fire.pdf

Figure 7 The integration of fire simulation and ship's model

Slika 7. Integracija simulacije požara i modela broda

in order to prevent fires, or at least localize them. Many scientists have invested great efforts to study the fire, and its spreading in the engine rooms and superstructure, by using various software tools. Modeling of fire behavior also includes modeling of the intensity of the resulting fire on the specific model of a ship.

In the project phase of the ship making, in the modeling of possible fire incidents, certain activities are being undertaken, such as planning of fire zones, planning of position of sensors, amount and type of sensors for the coverage of a given area, with regard to the height, width and visibility, ventilation, and ventilation openings for intake and outtake of air, especially in the engine room, position and amount of draft, construction material, etc. Obtained values, achieved by modeling, help us also in modeling the selection of systems for automatic fire extinguishing of certain ship's space.

The model of fire spreading in the ship's space mainly depends on the conditions of the space (humidity, heat), the place of fire origin, type of fuel, oil or grease in that space, materials in the surroundings. The model of fire spreading itself, is based on the production of heat and its spreading, the transfer from the burning onto the unlit material, which then becomes a new source of heat and fire.

- Some of the simulation programs for fire modeling are [29]:
- FDS (Fire Dynamics Simulator) – dynamic simulator of fire;
- FSSIM (Fire and Smoke Simulator) – simulator of fire and smoke;
- CFAST (Consolidated Model of Fire and Smoke Transport) – consolidated model of fire and smoke spreading
- ASCOS (Analisis of Smoke Control Systems) – analysis of the regulation of smoke;
- ASPIRE SDS (Aspire Smoke Detection Simulation) – simulation of smoke

CONCLUSION / *Zaključak*

Application of new techniques and information technologies for the early detection of fires on ships, have a major impact on the development of new sophisticated systems for fire detection. In addition to the detection systems, enormous attention is given to the development of detectors.

The use of fuzzy logic has contributed to greater precision of making crucial decisions whether the incident occurred or not, or whether the fire is real or false. With the modeling of the fire behavior, the possibility of modeling the intensity of the resulting fire, in the particular space, on the selected model of a ship, is also being given. By using smart algorithms and databases, bases for the use of robotics, and the latest video technology in detecting fires, are being created.

Further development of automatic fire detection, and its connection to other ship's systems, will allow the crew of the ship a better quality of supervision of the potential fire incident, and to make timely decisions for its suppression.

REFERENCES / *Literatura*

[1] Brovko, N., Bogush, R., Ablameyko, S., 2013, Smoke detection algorithm for intelligent video surveillance system, Computer Science Journal of Moldova, vol. 21, no.1 (61)

[2] Daniel T. Gottuk., Hughes Associates;, Video Image Detection Systems Installation

[3] Performance Criteria Research Project, Fire Protection Research Foundation, October 2008.

[4] Lawrence S. M. Chiu., 2004, Study on the video smoke detection system, International Journal on Engineering Performance-Based Fire Codes, Volume 6, Number 4, p. 258-263

[5] Mcgrattan, K., Hostikka, S. et al., 2008, Fire Dynamics Simulator (Version 5) Technical Reference Guide, National Institute of Standards and Technology, U.S. Department of Commerce

[6] Mirjana, M., 2014, Fuzzy logic usage in WSN for fire detection, Infoteh Jahorina Vol. 13

[7] Parul Mohindru, Rajdeep Singh, 2013, Multi-Sensor Based Forest Fire Detection System, International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-3, Issue-1

[8] Parul Mohindru, Vikshant Khanna, Rajdeep Singh, 2013, Forest Fire Detection: Various Approaches, International Journal of Emerging Science and Engineering (IJESE) ISSN: 2319–6378, Volume-1, Issue-6

[9] Percy I. Kaneshiro., Emilia Villani, Paulo E. Miyagi, 2005, Modeling of Fire Protection System in Intelligent Buildings., 18th International Congress of Mechanical Engineering, Ouro Preto, MG, November 6-11

[10] Pouya Bolourchi., Sener Uysal, 2013, Forest Fire Detection in Wireless Sensor Network Using Fuzzy Logic.; Fifth International Conference on Computational Intelligence Communication Systems and Networks

[11] S. L. Rose-Pehrsson, C. P. Minor, K. J. Johnson, J. C. Owrutsky, S. C. Wales, D. A. Steinhurst, and D. T. Gottuk, 2008, The Multi-sensory, Data Fusion Detection System for Improved Situational Awareness, ECS Transactions, U.S. Naval Research Lab 4555 Overlook Ave., SW Washington

[12] SOLAS Appendix 5: Resolution MSC.216 - Annex 3, adopted on 8 December 2006.

[13] Tuula Hakkarainen, Jukka Hietaniemi, Simo Hostikka, Teemu Karhula, Terhi Kling, Johan Mangs, Esko Mikkola, Tuuli Oksanen, 2009, Survivability for ships in case of fire. Final report of SURSHIP-FIRE project [Laivojenselviytymiskyky tulipalossa. SURSHIP-FIRE-projektin loppuraportti]. Espoo. VTT Tiedotteita – Research Notes 2497. 120 p. + app. 7 p

[14] Turgay Celik, Hasan Demirel, Huseyin Ozkaramanli, 2007, Fire detection using statistical color model in video sequences, Journal of Visual Communication and Ima Representation, Volume 18, Issue 2, Pages 176–185.

[15] Vikshant Khanna, Rupinder Kaur Cheema, 2013, Fire Detection Mechanism using Fuzzy Logic, International Journal of Computer Applications (0975 – 8887) Volume 65– No.12.

[16] Wang, L., 2011, Simulation of Smoke Motion in Fire of the Ship Engine Room with Multiplayer Structure., Brodogradnja, Vol. 62, str. 366-372

[17] http://www.imo.org/blast/blastDataHelper.asp?data_id=29555&filename=1369.pdf

[18] http://www.safety-at-sea.co.uk/software/isys/

[19] http://www.sciencedirect.com

[20] http://survivability.fi/files/SURMA-fire.pdf

[21] http://www.wiska.com/en/Products/cat/1335/CCTV/

[22] http://www.marinesafetyforum.org/upload-files/safetyalerts/msf-safety-flash-11.32.pdf

[23] http://www.kellersinc.com/image/VIDEO%20FLAME%20DETECTION%20BROCHURE.pdf

[24] http://www.hernis.com

[25] http://www.imo.org/KnowledgeCentre/IndexofIMOResolutions/Documents/MSC%20-%20Maritime%20Safety/338(91).pdf

[26] http://www.imo.org/OurWork/Safety/FireProtection/Pages/History-of-fire-protection-requirements.aspx

[27] http://www.lr.org/entities

[28] http://www.fia.uk.com

[29] http://www.mapps.l-3com.com/navigation-integrated-Bridge-System.html

[30] http://www.nist.gov/el/fire_research/fds_smokeview.cfm

[31] http://www.vnmpublication.com/IJIRES/January%202013/1.pdf

[32] http://www.consilium.se