APPLICATION OF DRONES IN MARITIME INDUSTRY

(FIRE FIGHTING)

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ABSTRACT: Fire is a major hazard to life, be it at-sea or ashore. In order to tackle the fire induced situations and ensure the safety of the crew on-board as well as on-shore, the following propositions are encompassed in this paper:

Dynamic Firefighting Drone (Octocopter): A drone used for autonomous firefighting applications on Manned and Unmanned Ships, and even on ports, using Artificial Intelligence System (AIS) and Iot (Internet of Things). The fire is tackled by automatically releasing DCP (Dry Chemical Powder) or by the Wave Extinguisher System (consisting of Sonic waves), in accordance to the situation presented and in conjunction with the AIS. On that account, it can autonomously fight or limit the fire, till a crew member arrives at the sight. Furthermore, it works as a guidance mechanism for seafarers in close vicinity of the fire or at risk in general and allows them to follow the drone to the nearest safe exit, avoiding obstacles on the selected path.

Artificial Intelligence System: The entire set up utilizes Artificial Intelligence in the Octocopter and furthers the development through Neural Network Learning**.**

Smart Rescue Equipment: The equipment works in tandem with the Drone and AIS.Vitality Band is the proposed arm band with a vitals sensor, a fall sensor and a positioning sensor, used in order to send immediate help to crew members using IoT.Clothing/Shoe Transponder is also proposed, which is a transponder attached in clothing or shoes which can be used to send automated distress signals to rest of the crew for immediate help.

Keywords: Drones, Artificial Intelligence, Fire Fighting Technology, Internet of Technology, Automated Firefighting Equipment, Smart Rescue Equipment, Neural Net

1. Introduction

Fire has always been an unwelcome visitor onboard ship. Despite the ever-increasing norms and precautions on fire-related accidents, the accidents do occur and are responsible

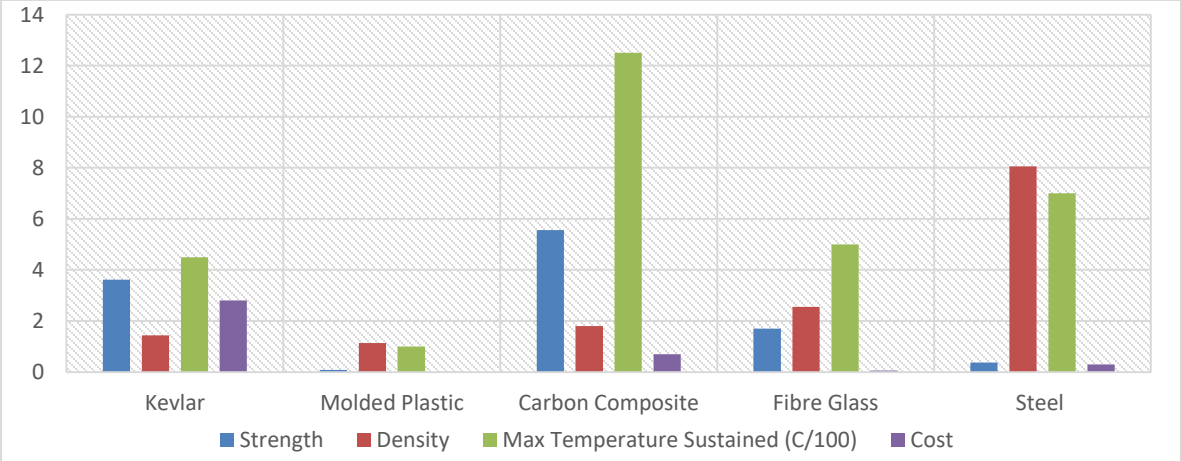
for the loss of billions of dollars' worth of cargo and many lives at sea [2]. Since the process of fighting the fire onboard ship is manual, the response time as well the probability of the fire to acquire a dangerous intensity is increased. Therefore to be better equipped to fight a fire, Artificial Intelligence can be used in tandem with the Internet of Things to make the process automated. In the event of a fire, the AI will be the first one to detect it and take necessary action, thus decreasing the role and the subsequent damage to a human during fire-fighting.

2. Drones

A drone is an aircraft of the unmanned variety and is made of light composite materials to reduce the operational weight and increase maneuverability. The said drones are equipped with different state of the art technology such as infra-red sensors, Self-Learning Artificial Intelligence, 3-D Mapping Technology and location transponders to accommodate for dynamic rolling and pitching [1]. The drones only work when automatic alarms are activated and are otherwise placed on charging stations and hencecause negligible distraction to the crew. Due to flight accessibility the drone works anywhere in the engine room including staircases, enclosed spaces and places which aren't easily accessible.

2.1. Construction [3]

The chassis of the drone needs to be made of a lightweight, heat resistant and sturdy material while also being economical. With an inclusion of metal compounds,



thermosetting plastics, the most viable recommendation is Carbon Fiber Composites. Carbon fiber composites are comparatively heat resistant, lightweight while being resilient

to physical trauma. Carbon fibers are usually combined with other materials to form a composite. When infused with a plastic resin and baked at a certain temperature, it forms carbon-fiber-reinforced polymer which has a very high strength-to-weight ratio, and is extremely rigid.

Figure 1: Comparison of Materials for the body of the Drone (Source: MDPI Journal)

2.1.1.Frame

The least possible frame diameter to lift the necessary payload weight would be 1250mm.For optimum utility these are paired with 165 mm Rail Mount and foldable legs. The said frame is made from Carbon Fiber.

2.1.2.Motor

An Octocopter requires eight motors to fly. The drone uses brushless motors since they are lighter on the battery. Recommendation: Tarot 5008/340kv motors as they are economical and reliable.

2.1.3.ESCs or electronic speed control

These are essential pieces of your drone as they are in charge of delivering power to the motors.Recommendation:Hobbywing XRotor 40A-OPTO.

2.1.4 Propellers

In order to allow flight to the drone, propellers are used to provide aerodynamic ability. Recommendations: Arms Diameter: 25mm, Motor to motor diameter: 1200m, Height: 380cm, Body size: 250 x 240mm.

2.1.5.Connectors

You will need 3.5 mm connectors to weld the motors and ESCs, and 4.5 mm connectors for the power distribution board and the power distribution board.

2.1.6.Batteries

Recommendation: 2 x 22.4V x 12000mAh Li-ion batteries.One battery is primary whereas the other one is auxiliary. These are also capable of being wirelessly charged. These batteries provide 40 minutes(with allowance of 5 minutes) of flying time with all the functionalities.

2.1.7.Gyro System

The gyroscope system should work almost instantly to the forces moving against the drone(gravity, wind etc.) to keep it stabilized. Apart from that, the system provides navigational information to the flight control systems.Recommendation: DJI A2 multi-rotors

2.1.8. Thermal Imaging Camera

A Thermal Imaging Camera will aid in better identification of fire, humans and machinery at risk of catching fire.Recommendation: Seek Compact Thermal Imager

2.1.9. Autopilot System

This will be required to aid the AI during flight time. Recommendation: PixHawk Flight Controller System.

3. Activation

The ship's pre-existing fire alarm system is used to activate the drone into action. Whenever a fire in a particular section of the engine room is ignited, it is detected by the appropriate fire detecting system as per SOLAS, which might vary from ship to ship [4]. These include:

a. Flame detectors: Detects flicker frequency of flame (25 Hz)

b. Heat Detectors: Uses bi-metallic type detecting elements

c. Smoke Detectors: 1. Light obstruction type, 2. Ionization type

This information is fed through pre-existing system for transferring it to the engine control room i.e. electrical signals. Using an Ultra High FrequencyEmitter(ranging between 300MHz to 3GHz) located near the drone base; the information can be wirelessly transmitted to the drones which act as the receivers. The Artificial Intelligence System then

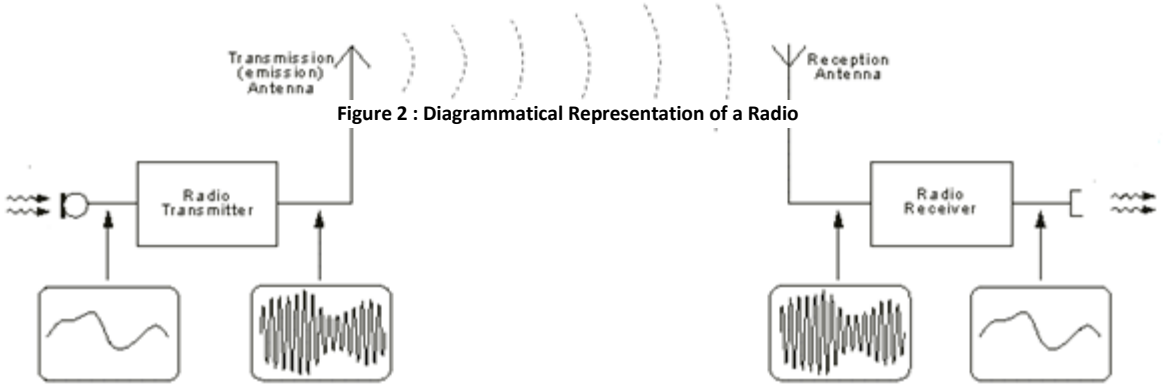


Figure 2 : Diagrammatical Representation of a Radio

decides how the drone should engage the fire.

4. Artificial Intelligence System (AIS)[5]

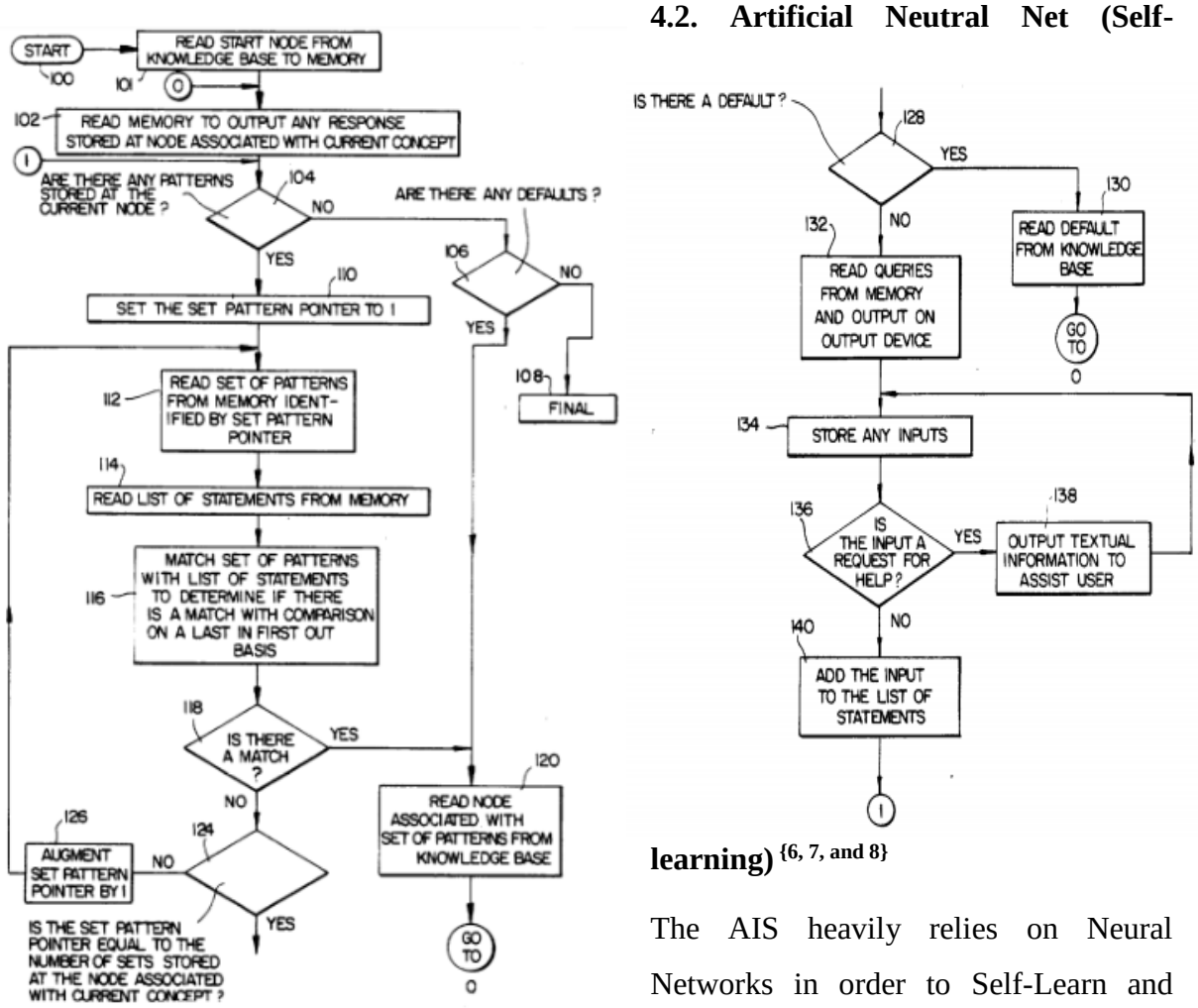
It's a system that accepts an invocation for information/action and provides an appropriate response/action, which is based upon understanding of the request, which will be a radially transmitted signal.At its very core, Artificial Intelligence refers to giving decision-making capabilities to a machine to give it autonomy. This AI system focuses on the specific goal of Natural Language Processing. It alters a machine in terms of perception and reasoning and develops intelligence.

4.1. Working

In reference with Figure 3, the AIS first establishes the central concept of the initial signal. It interacts with the user to resolve any information gaps, contradictions and ambiguities. It does so by providing inquiries which are to be answered by the user in the form of additional information. This additional information is added to the initial statement. Later, the AIS may provide responses which are in accordance to the request made and are based upon the understanding of the meaning of the input statements which are derived through

constantly providing inquires. As the initial input statement becomes more understood, the response time reduces.

Figure 3: A Flowchart depicting the working of AIS (Source: {5})



4.2. Artificial Neutral Net (Self-learning) {6, 7, and 8}

The AIS heavily relies on Neural Networks in order to Self-Learn and adapt to situations through prior experience. It's a system which is inspired by the biological neural networks; example - brains of animals. The neural net will help the AIS "learn" to perform tasks by taking into consideration day-to-day examples. For example, in image recognition, it might learn to

identify images that contain a certain type of fire by analyzing example images that have been manually labeled as "electrical fire" or "no electrical fire"andusing the results to identify fires in other images, without having prior knowledge about fires.

4.2.1. Types of Neural Networks suitable for onboard applications

4.2.1.1.Convolutional Neural Network

It is a deep, feed-forward networks, composed of one (or more) convolutional layers where the layers are fully connected. The architecture which comprises of tied weights and pooling layers allows CNNs to take advantage of the 2D structure of the data.CNNs show superior results in applications such as image and speech. These can be trained with standard backpropagation(a method used to calculate a gradient that is needed in the calculation of the weights to be used in the network). CNNs can be trained easily than other feed-forward neural networks and estimation of parameters is easier. Deep-Dreamand Robot Navigation are one of the many applications of the same.

*4.2.1.2.*Deep Belief Net

A deep belief network (DBN) is a generative model made up of multiple layers of hidden units. A DBN can be used to generatively pre-train an ANN by using the learned DBN weights as the initial DNN weights. This is particularly helpful when training data are limited, because poorly initialized weights can significantly hinder model performance.

4.3. Projection Mapping

A pre-requisite for the AIS to function is a projection map of the ship which will help the drone to perceive obstacles and the ship environment better. The complexity within the ship can be easily programmed to its spatial dimensioning and thus, allow greater flexibility for the drone in aspect of navigating and traversing. It'll help the AIS to calculate the shortest possible route for reaching the desired location and also help in rescue operation of the crew, if need be.

4.4. Blockchain Technology [16]:

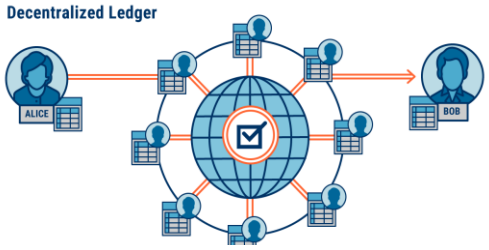


Figure 5: Depiction of the Blockchain Technology (Source: *What is Block*chain Technology*?*, a CBINSIGHTS newsletter)

"The blockchain is an incorruptible digital ledger of economic transactions that can be programmed to record, not just financial transactions but virtually everything of value."

It's like an internet with robustness, built-in. The AIS can learn about numerous number of situations by simply accessing the blocks in which this technology stores information. At the same time, this information is also available to the AIS working on ships across the globe and any new update made to the information by one, is read-able by the other. The system lives in a state of consensus and checks itself after a given interval of time. It cannot be corrupted by altering any unit of information, despite being, by definition, "public".

5.Movement

The Drone is an Octocopter which is a VTOL ("Vertical Take-Off and Landing") type. In order to move, the drone is embedded with a drone vision system which uses obstacle detection sensors to scan the surroundings, while software algorithms and SLAM technology produce the images into 3D maps allowing the flight controller to sense and avoid the object.

5.1. Obstacle Detection and Avoidance Technology

5.1.1.RFID Tags[9, 10]

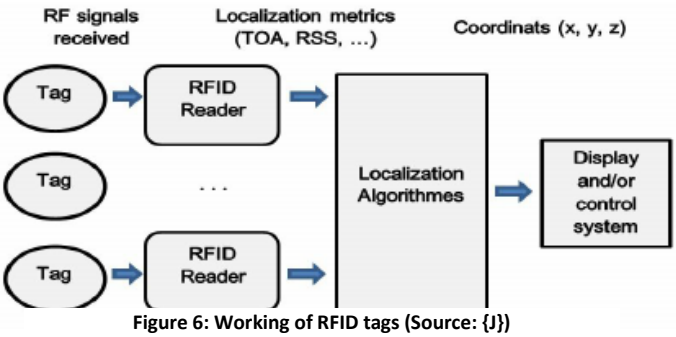


Figure 6: Working of RFID tags (Source: {J})

To accommodate for the constantly moving environment, additional Radio Frequency Identification emitters are installed onboard that operate at very vast band of frequencies (433Hz - 2.45GHz) with a readability range of 2.25 meters. These tags, being the size of a

chocolate bar, can be glued to the walls easily. The emitters can withstand a temperature of upto 200^{o}C and can absorb vibrational shocks as well. When the ship rolls or pitches, the inside environment in which the drone flies constantly change. The numerous RFID tags form a Cartesian system, that accordingly changes and the AI of the shift in the pre-programmed 3-D Map.

5.1.2. Others

Systems are fusing one or more of the following sensors to sense and avoid obstacles:

a. Vision Sensor

The Vision Sensor works by perceiving oncoming objects through the camera feed.

b. LiDAR[11]

The LiDAR measures obstacle distance to target by illuminating it with multiple laser pulses and measuring the reflected ones.

6.Real-time operations [13]

When the fire alarm goes off in a particular section, a drone is automatically deployed to the location. Upon reaching the zone, the thermal imaging camera activates for better accuracy and assesses the degree of the fire. Thermal Imaging works on the principle of measuring infra-red radiation that radiates off a body. When the number of quanta is larger, the body under observation is hotter. This perception of hotness aids in locating through temperature. The AIS checks for the required number of additional dronesto deal with the fire and transmits the request for the same. The thermal camera and other systems transmit a live video feed through a LAN Wi-Fi Network with repeaters, placed strategically to create a continuous and fast network, to the control rooms (Engine Control Room and Bridge). Initial firefighting measures, depending on the type of fire and its degree – DCP Release or Sonic Extinguisher -are immediately deployed. In case of any Humans trapped in the area, the Drone clears a pathway by extinguishing fire and leading them to the safest possible exit. While fighting fire, the Drone’s primary purpose is to completely extinguish the flames.

7. Fire Fighting

7.1. Dry Chemical Powder [4]: Dry Chemical is a powder composed of very small particles. The current system uses ABE Dry Chemical Powder –Mono-ammonium phosphate. Added to this, is the particulate material which is given a special treatment to provide proper flow capabilities, resistance to caking and provide resistance to packing. It stops combustion by interrupting the chain reaction sequenceand absorbs the heat; thus smothering the fire by blanketing it. Dry chemicals are less contaminative and extremely economical. However, for high-tension electric installation such as a transformer, excellent insulation to prevent any damage that the DCP may occur.The dry chemical powder is stored on the drone in limited quantity through a fire extinguishing grenade as compressed dry powder with compressed nitrogen as propellant; similar to the one used in DCP fire extinguishers. It is dispelled through a release mechanism which covers the entire region of the flame.The design is similar to the current industry models of Fire Ball Extinguishers by Elide. Each grenade weighs 1.3kgs. These grenades are replaceable after use and can be easily deployed to completely douse a flame in a 5 meter radius without harming any crew members in that area.

7.2. Sonic Fire Extinguisher [12]: This apparatus is also called as wave extinguisher and works by employing acoustic waves to suppress the flame. The sound waves are focused in a specific direction instead of spreading them.In reality, sound waves have the potential to control oxygen and burning material. If these two get separated, the fire dies away.The extinguisher only emits sound, making it ideal to use around equipment and personnel. The vibration separates the air from the fuel, causing a momentary lapse in the chain reaction, and then starves the flame from oxygen and hot vaporized fuel. The frequency used is between 30Hz to 60Hz which therein poses no risk to humans or machinery nearby. The principle behind the extinguisher is simple: as they are mechanical pressure waves that cause vibrations in the medium in which they travel, sound waves have the potential to manipulate both burning material and the oxygen that surrounds it. If the sound could be used to separate the two, the fire would be starved of oxygen and, accordingly, would be snuffed out. The waves move the air around them in such a way that they disrupt the rapid oxidation at the core of a fire. The process essentially separates the oxygen from the fuel source and quickly extinguishes the fire.

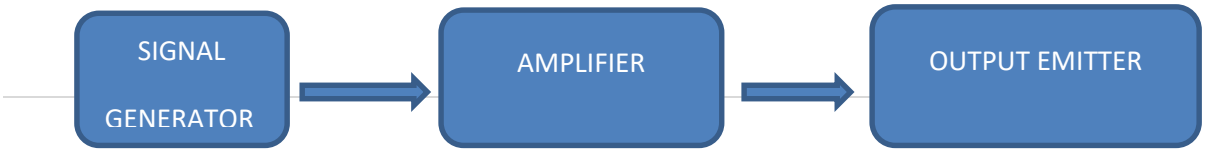


Figure 7: Route Map followed by Sonic Wave Extinguisher during operation

The AI readily transmits video feed to the control room for crew to keep track of progress. The self-learning programming paradigm also causes for auto-alignment and fighting the fire.

8. Internet of Things (IoT) [17]: It is a system of interrelated objects, animals or people, computing devices, mechanical and digital machines that are provided with unique identifiers and are capable of transferring data without requiring the interaction of human with the computer.It consists of the following components:

a. Sensors/Devices

In the first step, the data is collected from the *environment* through sensors which can be bundled together to perform separate functions.

b. Connectivity

In this step, the data is sent to the cloud (storage). This can be done by connecting the sensors to the cloud through a variety of methods including: cellular, satellite, WiFi, Bluetooth, low-power wide-area networks (LPWAN), or Ethernet.

c. Data Processing

Once the data is uploaded to the cloud, the software performs the required processes on it. It can be as complex as identifying objects on a given video.

d. User interface

The information thus acquired is made useful to the user through an interface. The vitals of a given system can be analyzed by the user through the said interface. Apart from this, the user can also perform an action to affect the system. Some actions are also performed by the interface automatically, and the output of the same is given to the user.

8.1 Smart Rescue Equipment Accessories [14]

8.1.1 **Vitality Band**

A band which monitors vitals, including pulse rate, blood pressure whichprimarily helps in monitoring the location of the crew. This band can be strapped on the biceps/forearm under the clothing and is made such that it does not hinder the working ability of the user. The device includes a motion or fall sensor and will send an alert to the control room and the nearest drone, if a fall is detected or if there is an irregular detail of a crew's vitals. The band also has distress button that can be used to send the signal manually.The drones are first to arrive at the scene and send live video feed to control room as well as assess the situation. The AI's continual assessment also recommends actions to be taken. For example, if someone has fallen and hurt their leg – the software recommends that the rescuers carry first aid and a stretcher, if possible.

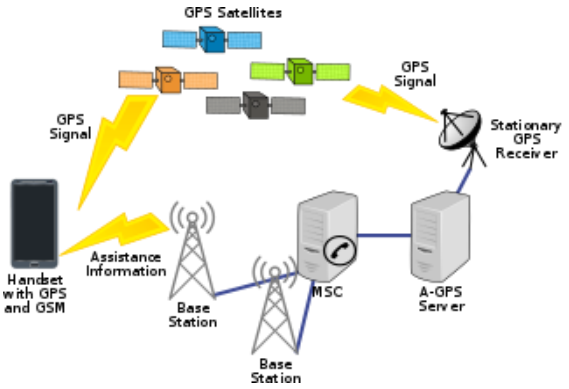


Figure 8: Working of a GPS system (Source: www.wikipedia.org)

a.Construction

Just like the drone, this transponder can be made of Carbon Fiber, making it light weight as well as heat resistant. A strap can be used to attach it to the biceps/arm of the crew.

b.Location

The device in its folds contains a micro GPS (Global Positioning System) tracking chip such as SKG09BL by SKYLAB. This chip is capable of sending and receiving GPS signals from the satellites. The output of the chip can be wirelessly fed to the Local Area Wi-Fi network of the ship and hence to the AIS.

The AIS then alerts the drones and rescue operation is conducted automatically. The device contains an SOS button which can be tapped in case of an emergency. This information is immediately transferred to the AIS which, in turn, activates the drones to reach the said location. As the drone is already equipped with a projection mapping of the ship and the input of the position tags, it provides a relatively quicker response and the AIS decides further course of action.The same method is used when the person has to be escorted to the nearest exit in case of a smoke-filled compartment, a blackout or an engulfing fire.

c.Measurement of Vitals

An optical vital sensor by ROHM can be used for measuring pulse rate, blood pressure as well as stress due to its high-speed sampling of 1024 Hz. It has a high detection accuracy and low power consumption of 0.44 mA. It uses an integrated FIFO (First in First Out) memory to reduce power consumption. It uses supply voltages if 2.5 to 3.6 volts. It also consists of an infrared sensor for sensing as to when the device is being worn. The noise to the circuitry is reduced using optical filters. Fall detection is done with the help of sensors such as gyroscopes and accelerometers which are constantly detecting crew's movements. The sensors can detect the changes in motion as well in height as they are sampled up to 100 times per second.The output of these devices can be fed along with the tracking information.

7.1.2 **Clothing Transponder**

The same transponder device can also be attached onto the clothing. In case of uneasiness or to gain the rest of the crew's attention, the transponder can be used to send out distress signal. The drones are first to respond.

In both applications of the drone, the seafarer's lives are rescued through automation and technological advancements of the drone. In case of rescue from a fire, the drones use the rescue equipment to locate the seaman trapped in the compartment and then find the safest possible escape route, whilst fighting the fire and clearing the pathway for escape.

9.Maintenance

9.1Charging[0]

The drones use wireless charging, which is a docking station on which the drone automatically sits and self-charges upon requirement.Wireless charging works on the principle of induction. The charging dock works as a primary coil that constantly traverses current. The device to be charged contains a secondary coil that is induced and thus charges it. These pads can be kept at routine places of use such as every level of the engine room, bridge, etc.

Figure 9: Wireless Drone Charging Pad (Source: Skysense-Drone Charging Pad producer)

9.2DCP Replacement

Dry Chemical Powder grenades can be automatically replaced by the drone through a self-refilling system wherein the routine code insists that empty grenade pockets are first filled up after every charging or completion of rescue, whichever is earlier. The QR Code on every grenade is scanned just before it is placed onto the deployment pocket, and its replacement date is automatically fed to the system, along with other details such as information of grenade, manufacturer and all other requirements of any Life Saving Appliance.

10.Scope

The project can be used on Manned and Unmanned Ships, with usability also inclusive of cruise liners, coastal vessels and even be extended to ports.

On Completely autonomous Unmanned Vessels, the Drones will work in tandem with the AI onboard, as extensions. The drones can also be used toaid other jobs that relate in entering enclosed spaces, working aloft, etc. by keeping the control room and OOW informed of recent developments in real-time. Through remote control, these can also help in more frequent and faster inspections of a greater area onboard.

11.Benefits

The proposal requires no major structural changes and primarily uses the ships pre-existing systems only small installations are required. Due to greater maneuverability and speed through flight, response time is significantly reduced. It also aids in watch keeping and monitoring of systems, as well as, in quickly spotting errors and issues with machinery and working through better available video surveillance.

12. CONCLUSION

The assortment of ideas when put together creates a safer, more automated format of fire-fighting and personnel caregiving which can account for every person who is at risk and also ensure they are also brought out of the risk safely. Multiple drones, and each stationed close to a command centre (Bridge, Engine Control Room, and Accommodation) or places of high fire risk, can aid in rescuing people and even extinguishing fire before the first responders show up. Through the Internet of Things, there is greater availability for surveillance of harm, better assessment of risk, in addition to the very quick response of efficient rescue systems. Here-in are discussed widely used systems that have already been developed and the possible modifications that can be brought in these developed systems for their application on-board. The life of the seafarers is paramount and hence, the technological advancement through augmentation in Fire Fighting techniques with Artificial Intelligence is indispensable to ensure safety of life followed by safety of property and environment.

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