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Experimental Study on the Application of UAV Drone to Prevent Maritime Pirates Attacks

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ABSTRACT: In this paper, we present a concept of an application of UAV drones as a possible low-cost device to avoid pirate attacks. Recent UAV drone can be operated in the range of more than 2km and transmit very clear images. Pirates will be approaching using a small boat and they will be climbing up along the sidewall of the ship. We tried several experiments in our laboratory to check how the drone can be applied to interfere the pirate approaching and climbing. We present a conceptual structure of an anti-piracy drone system and fabricated a part of device including a thermo camera sensor and a net launcher to stall the boat. The results showed this method seems effective considering the cost, although the operator must be trained to control the drone properly.

1 INTRODUCTION

The number of incidents of maritime piracy is decreasing recently through various efforts under international cooperation. In Japan, Ministry of Defense requested 3,200 million JPY in FY2017 national budget for preventive activities off the coast of Somalia pirates. A very important sea lane from Japan to Europe through Suez Canal must pass along this area. Japanese Maritime Self Defense Force dispatches a fleet to protect Japanese ships. This works effective, however, it's much better if the commercial ship can protect themselves to minimize the naval escort.

In this research, we firstly surveyed the piracy trend mainly from the viewpoint of Japanese, based on IMB reports from 2003 to 2016. Secondly, we surveyed the existing anti-piracy measures and checked if the measure has some demerits.

Based on the surveys above, we found that more effective way should be developed and an application of a UAV drone seems an effective way which is handy and low cost because it needs no extra facilities on the ship. Pirates attack often occurs in the night with a small fishing boat, so the drone should have a thermo camera to detect human beings or an outboard engine in the dark. To check whether the thermo camera can work well attached to a drone, we assembled a test system which consists of Raspberry Pi and a cheap thermo camera. We used DJI S1000 as our test drone. Its payload is around 10kgf and the flight duration time is around 20 minutes.

Using this system, we did some experiments to develop our new concept of anti-piracy measure using the drone system.

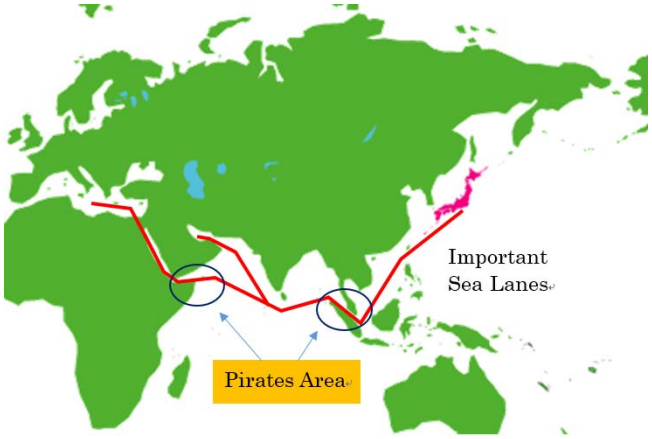

Figure 1. Important sea lanes for Japanese shipping.

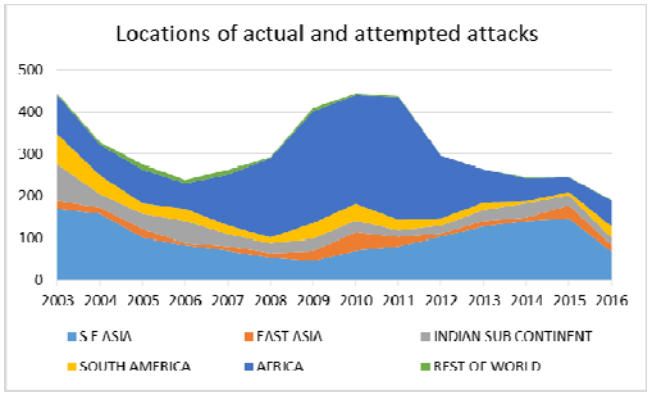

Figure 2. Locations of actual and attempted attacks in the major area of the world.

2 SURVEY OF PIRACY TREND

2.1 *Importance of piracy prevention in Japan*

Around 99.6% of trade amount in terms of weight depends on marine transport in Japan. For example, in 2010, around 1800 Japanese merchant ships passed through Gulf of Aden because Suez Canal connects Europe and Asia. Among these 1800 ships, 35% is container ships, 32% PCC, 12% chemical tanker and 11% LNG vessels. Also, around 20% of Japanese car exports goes through this area. So the safety of this area is very important.

Malacca Straits or off the coast of Indonesia is also a very important sea lane for Japanese shipping companies. However, the number of reported attacks increases recently in this area. Figure 1 shows two major areas where pirates' attacks were reported for last 15 years.

2.2 *IMB annual piracy report survey*

According to the ICC International Maritime Bureau's report on Piracy and Armed Robbery against Ships from 2003 to 2016, we can see several trend in piracy incidents in the world. Figure 2 shows the numbers of actual and attempted attacks with respect to regions. Africa and South East Asia are dominant. Figure 3 shows the total number of the attacks. The total attacks are decreasing, however it shows there occurs around 200 incidents in spite of international cooperation and effort to prevent piracy. From 2008 to 2012, we can see a mountain like curve in the graph. In this period, over half of the incidents are in Africa especially in famous Somalia.

There are more than 88 countries where victim ships are controlled or managed for those 10 years from 2007 to 2016. The sum of the total victim ships is 3089. Figure 4 shows the top 10 countries. Japan ranked at five and the total is 153, which means almost 15 ships were attacked a year in average. Also, as for Japan, the number of attacks decreased almost half in 2013, 2014. However in 2015, 2016, the attacks were recovered. Figure 5 shows Japanese national budget for anti-piracy measures from 2011 to 2016. As shown in the figure, the budget amount is almost doubled in fiscal year 2012-2014 and halved in 2015-2016. We cannot say with certainty that there are apparent causal relation between the number of attacks and the budget, however, it is interesting to note that the incidents were reduced to half after the budget was doubled and the incidents were doubled after the budget was reduced to half. This implies that if Japanese government wants to keep some effective anti-piracy measures then we need to spend enough money every year unless we cannot develop less expensive but effective measures.

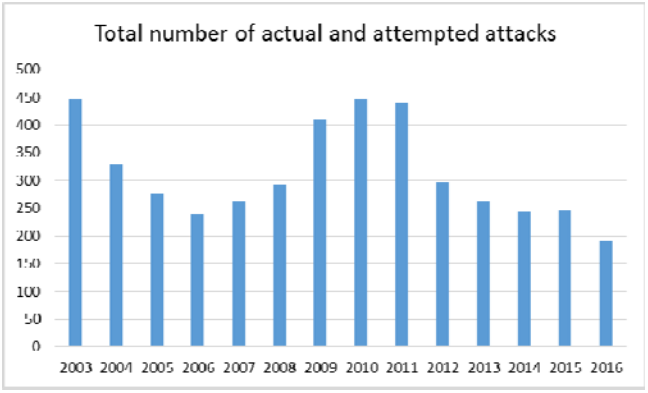

Figure 3. Total number of actual and attempted attacks from 2003 to 2016.

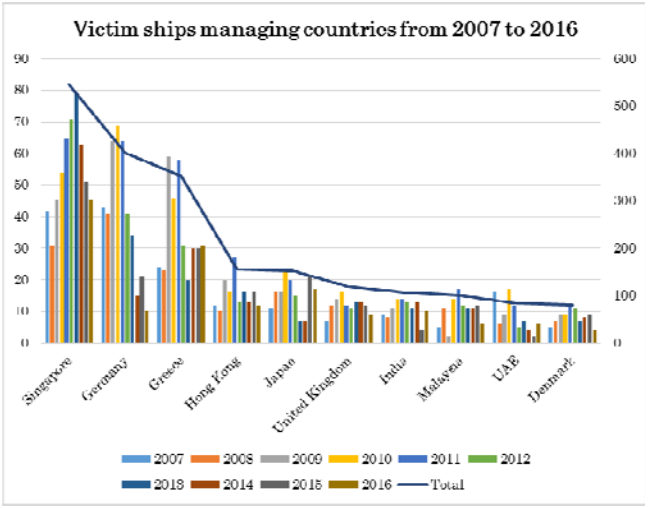

Figure 4. Top 10 countries where victim ships are managed.

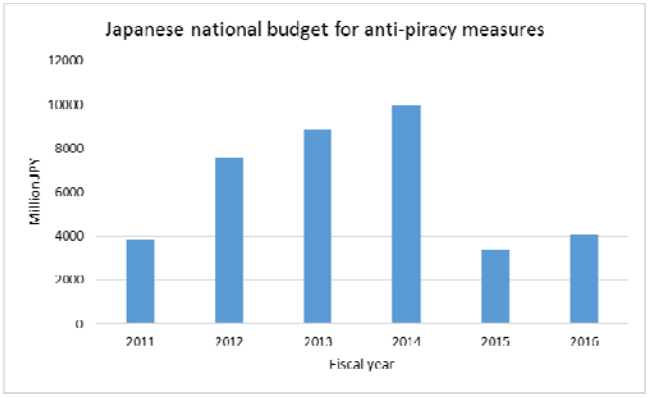

Figure 5. National budget for anti-piracy measures in Japan.

Table 1 shows comparison of types of attacks from 2003 to 2016. It is surprising that although the total number of attacks seems decreasing, more than 75% of the attacks was the boarded attacks since 2013. This implies that preventing pirates from boarding is very important. In many cases, they come by a small boat, so stopping the boat will be the first step.

2.3 *Non-lethal anti-piracy measures*

There are several anti-piracy measures. Here we'd like to survey those existing measures briefly.

1 Water cannon
Water Cannon is extensively used on merchant ships. This delivers powerful stream of water to prevent pirates from climbing up the side wall. This can be controlled remotely from a safe place in the ship. However, it needs extra pumps and hoses as well as a control system if the nozzle direction is remotely operated.

2 Electric fence
Electric fence surrounds the ship and prevents pirates from climbing. The system can be folded when not in use. However, the extension or folding the fence seems a messy work.

3 Long range acoustic device
LARD is a sonic weapon and produces high pitched noise that is intolerable level of a human being. However, if the pirates wear earplugs we are not sure it works properly.

4 Laser device
The laser device uses strong laser beam to be temporarily blinding the pirate who is climbing up the wall. However, the control of rectilinear beam is sometimes not an easy task.

5 Slippery foam
Slippery foam is used to make the deck or sides of a ship slippery to keep pirates from climbing. This chemical foam should be selected not to affect marine environment.

6 Anti-piracy curtain
Anti-piracy curtain consists of a series of hoses which are dangled on the side wall of the ship hull. High pressured sea water is passed through the nozzles, which makes the hoses dance in unpredictable motion. However, dangling many hoses from the hull wall is a messy work.

7 Razor wire canister
This device uses big canisters with sharp razor wires. This becomes a barrier between the pirates and the ship to prevent them from climbing. However, some pirates may be able to climb up through the void space between two canisters.

8 Liquid deterrent system
This method uses liquid which stinks and burns to prevent pirates from climbing up the hull wall. This method seems effective but how to shower the liquid over the pirates is a problem to consider.

Table 1. Comparison of types of attacks and boarded rate.

	Actual Attacks		Attempted Attacks			Boarded
	Boarded	Hijacked	Fired upon	Attempted	Total	Rate
2003	311	19	20	93	443	70
2004	228	11	13	77	329	69
2005	182	23	19	52	276	66
2006	162	14	7	56	239	68
2007	169	18	14	62	263	64
2008	151	49	46	47	293	52
2009	155	49	121	85	410	38
2010	196	53	107	89	445	44
2011	176	45	113	105	439	40
2012	174	28	28	67	297	59
2013	202	12	22	28	264	77
2014	183	21	13	28	245	75
2015	203	15	1	27	246	83
2016	150	7	12	22	191	79

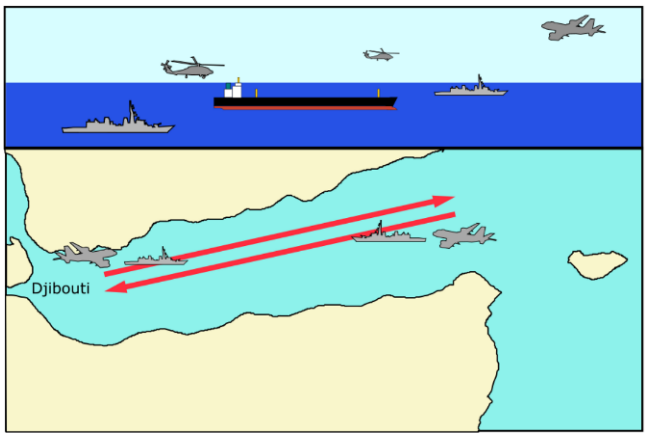

Figure 6. Conceptual sketch of Somali anti-piracy activity by Japanese Maritime Defense Force.

These methods are effective and still important but the problem here is that all these methods are to deal with the situation after the pirates reach the ship. We believe we need to develop an anti-piracy measure which not only prevent pirates to climb the wall but also keep pirates away from approaching the ship.

3 PROPOSAL OF A NEW ANTI-PIRACY MEASURE

3.1 *Japanese self-defense force anti-piracy activity*

In 2009, Japan announced sending naval task force to stop piracy off the coast of Somalia for international cooperation. This activity started in 2010.

This anti-piracy measure consists of some maritime patrol aircrafts like P3C, helicopters and the destroyers. Figure 6 shows a conceptual schematics of an example of Somali anti-piracy activities by Japanese Defense Force.

Here, several merchant ships are escorted by the fleet along about 900km on the sea lane of Gulf of Aden. Needless to say, this measure is very effective and as shown in Figure 4, the number of incidents dramatically decreased. However, there are some disputes and worries in this measure due to Japanese social background.

Japanese non-aggressive constitution contains the article 9 which means Japanese military forces can only be used for defensive purposes. It says Japanese military forces never use their force to solve any international issues. It is obvious that this activity is based on an international cooperation without any vicious intention, however dispatching a military force outside of Japanese regional area includes legally vague problems. So this activity has been controversial in Japan and has risks that the Japanese government will face some legal problems if Japanese maritime defense force happens to hurt someone.

This sensitive issue is beyond our profession, but challenging to develop a new effective measure to replace dispatching the military force is our responsibility as engineers. We believe each merchant ship should have a measure to protect herself with minimized damage to human beings.

3.2 *A new concept using UAV drones*

Our concept is using UAV drones. Just bringing in drones does not need any extra facilities like water pumps, electric fences etc. We need no extra space to keep them. When we want to change a ship we just bring the system into the ship. Portability and flexibility are one advantage of this concept.

There are basically three phases in our concept as explained below.

- Phase 1 – Finding & Warning
  When a ship is in the area of frequent pirate attacks, it's important to monitor the radar to find any boat approaching to the ship. If the unidentified boat comes into a certain range (e.g. 10km), we send a drone to the boat to find what kind of people are on the boat. If they are not apparently fisher men and suspicious looking, we warn them using a speaker attached to the drone that we found you and not come nearer any more otherwise you will be harmed. We call this phase as finding & warning phase as shown in Figure 7.
- Phase 2 – Stalling
  If the boat ignores the warning and still approaching the ship, the phase moves to the next stage. In this phase, we can launch nets or ropes from the drone to the bow of the boat. The screw propeller of the boat will inhale the nets or ropes, which stalls the engine of the boat. We call this phase as stalling phase as shown in Figure 8.
- Phase 3 – Obstruction
  If the stalling phase fails to stop the boat and the pirates reach to the side wall of the ship, the phase moves to the final stage. In this phase, we have to obstruct their climbing up the side wall. It is possible to load some fire arms on the drone. However, to find a non-lethal way is one of the important purposes of this research. There are several non-lethal ways like LARD or strong laser device but they need strong power, which is not suitable for a drone because payload of the drone is limited. So we decided to select a liquid or powder deterrent system to attach to the drone.

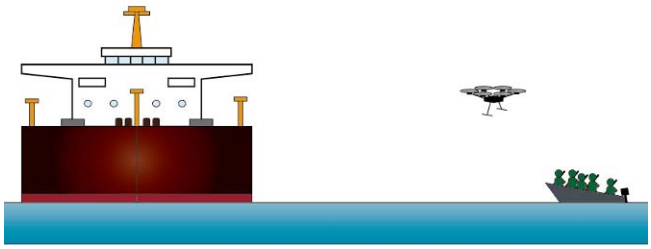

Figure 7. Finding & Warning phase.

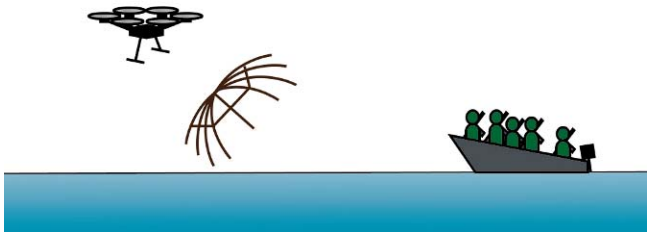

Figure 8. Stalling phase.

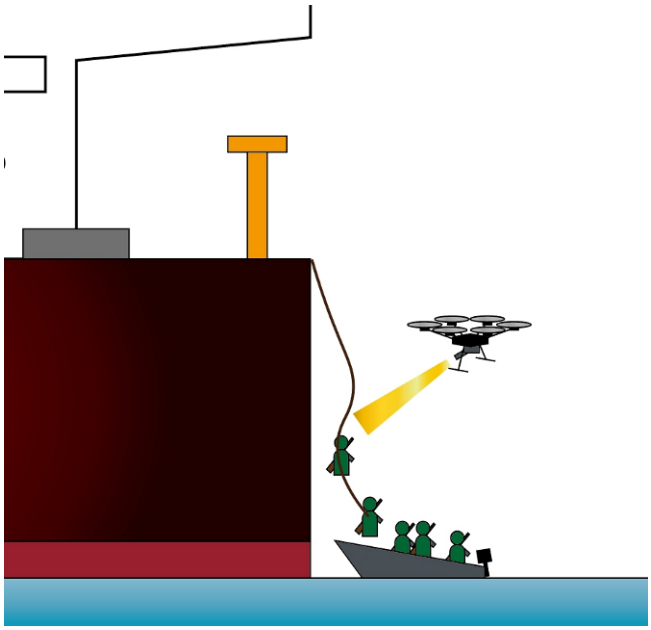

Figure 9. Obstruction phase.

The maximum speed of a drone is around 40kt, which is faster than a boat. A possible concern is the maximum flight time which is around 20 minutes. We need to develop a drone which can fly longer.

4 A CONCEPTUAL DESIGN OF THE SYSTEM

4.1 *System Components*

Figure 10 shows the drone DJI S1000 for our experiments. Its payload is 10kgf. The video transmission range is less than 3km. This range is short because Radio act limits the transmission power

in Japan. As this limit is not applied to the sea outside of Japanese area, we can amplify the power to broaden the transmission range when it is used in the real situation.

Figure 10. DJI S1000 for our experiments

Figure 11 shows the structure of our design. The minimum system consists of a camera unit, a speaker unit, a wireless communication unit and an anti-piracy unit. The camera unit includes a normal camera and a thermo camera. The wireless communication unit has a video transmitter and a remote control module. The anti-piracy unit has a net launcher and a liquid or powder spray unit.

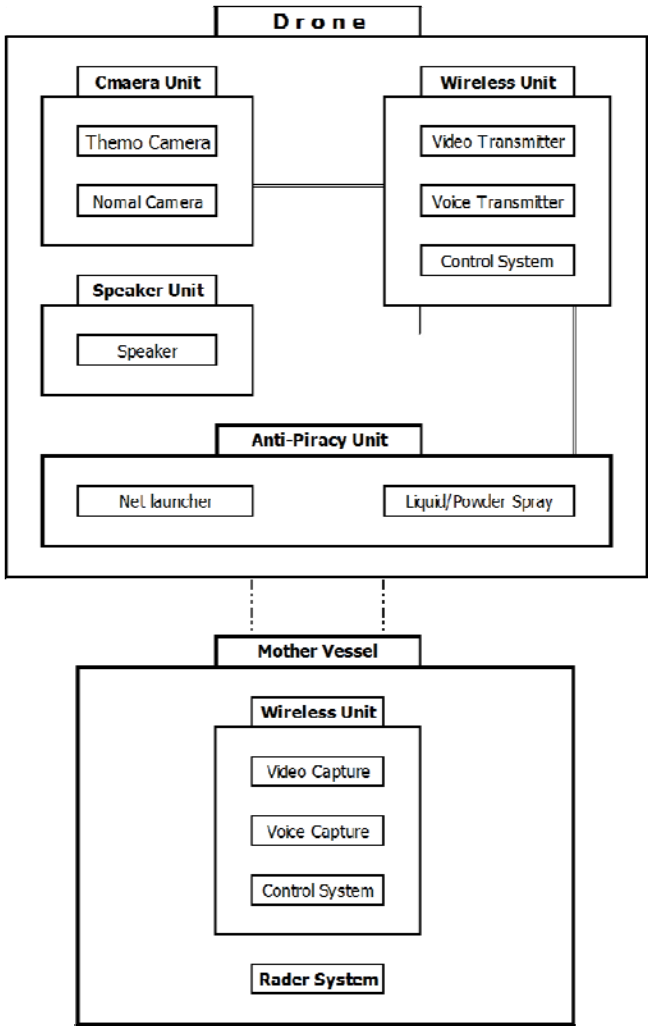

Figure 11. System components

4.2 *Thermo camera system*

A thermo camera system is very important for our system. Attacks of pirates often occur during the night and normal cameras cannot be used unless a lighting device is not equipped. From the viewpoint of avoiding a pirate shooting down the drone by fire arms, it's better for us not to equip a lighting device because it also helps his shooting it. On the other hand, a thermo camera can detect the engine of the boat as well as a body of a human being without any lighting devices.

There is a drone which has a thermo camera whose price is around 2 million JPY. It is too expensive for us. So we made a cheaper system for our experiments using a small computer "raspberry pi" and a FLIR thermo camera. The raspberry pi's HDMI connects to LIGHTBRIDGE data communication device and we can monitor both the console of raspberry pi and the thermo camera image as well as the status of the drone like GPS or height as shown in Figure 12. We are planning the program of the anti-piracy unit is to set on this raspberry pi computer module. So we checked in this experiment that we can monitor the raspberry pi console through LIGHTBRIDGE module.

Figure 13 and 14 show the experimental result of taking thermo image in the dark. As shown in these pictures we can take a clear thermo image through this system. In this experiment, our thermo camera range is around only 15m, because the thermo camera including raspberry pi in this experiment is very cheap as less than 50,000 JPY. In the real operation, we need to use more high spec camera to make the capture range longer. This is one of our important future works.

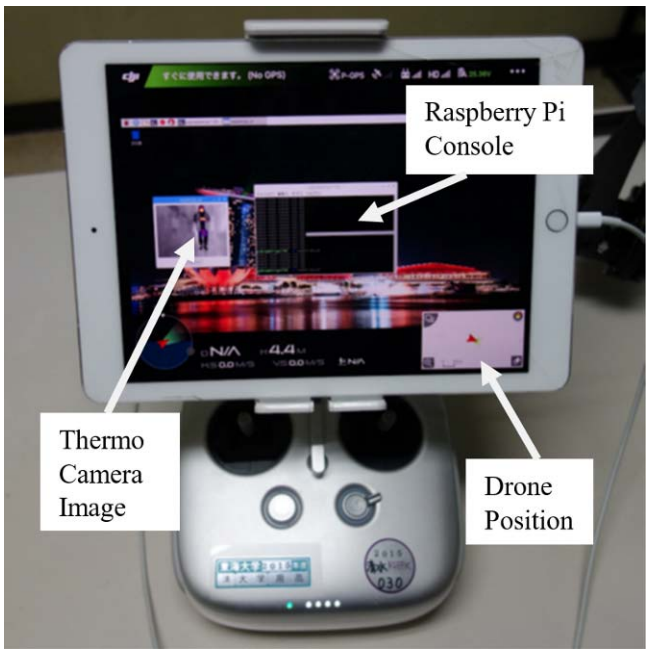

Figure 12. Monitor system of cameras and drone status.

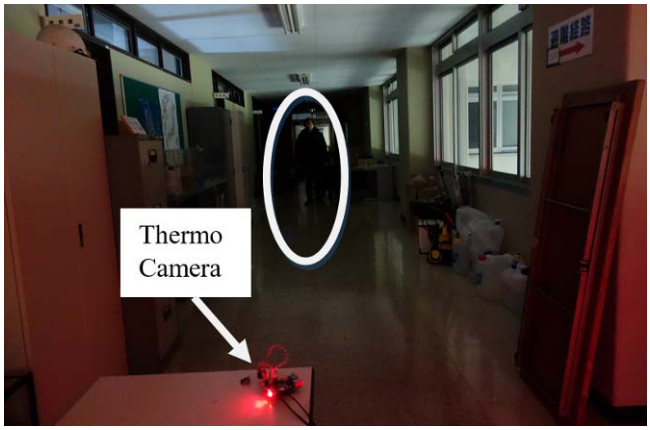

Figure 13. Experiments of a thermo camera.

Figure 14. Thermo camera image transmitted by the drone.

4.3 *Net launcher and liquid/powder spray system*

Our anti-piracy unit consists of a net launcher and a liquid/powder spray system. A net launcher has a servo motor controlled hook which holds a net. We used the controller's extra switch to open the hook remotely. We confirmed that a net falls down from the drone remotely. However, it seemed difficult to control the position of the net on the sea when the drone flies high. The driver of the drone must be trained to put the net properly in front of the approaching boat.

As for the liquid or powder spray system, we tried a basic test using a small box which has a lid on its bottom. The lid can be opened using a servo motor. When we open the lid, pepper powder fall down from the box. The drone must be positioned above the head of a climbing pirate to put the liquid or powder onto him. We are investigating this matter further the place where is the best to deter a pirate from climbing as well as the timing when is the best.

5 CONCLUSIONS

In this paper, we surveyed recent trend in piracy incidents from IMB reports, especially from the viewpoint of a Japanese. The total number of incidents are decreasing reflecting the various activities on anti-piracy international cooperation, especially in Africa including Somalia. However, in East Asia, especially in Indonesia, the number of pirate attacks are increasing. Considering national budget for anti-piracy measure in Japan, there were an interesting relation between the budget and the number of incidents. In 2015 and 2016, the budget has been cut and the attacked piracy incidents for Japanese managed ships increased. Japanese anti-piracy measure is sending a feet of Japanese Maritime Self Defense Force including destroyers, P3Cs and helicopters. This is effective but more low-cost measures should be investigated.

We proposed a concept using a drone as a non-lethal measure. This method doesn't need any constructive fabrication to the ship and the total system is very portable and flexible. We successfully tested a thermo camera system as an important sensor to find a pirate boat. Also we tested a net launch and liquid/powder spray system. As the operator must practice to manipulate a drone system, we found it very effective as a new anti-piracy measure.

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