



FEASIBILITY PRESENTATION

# Object Detection, Tracking and Suspicious Activity Recognition for Maritime Surveillance using Thermal Vision

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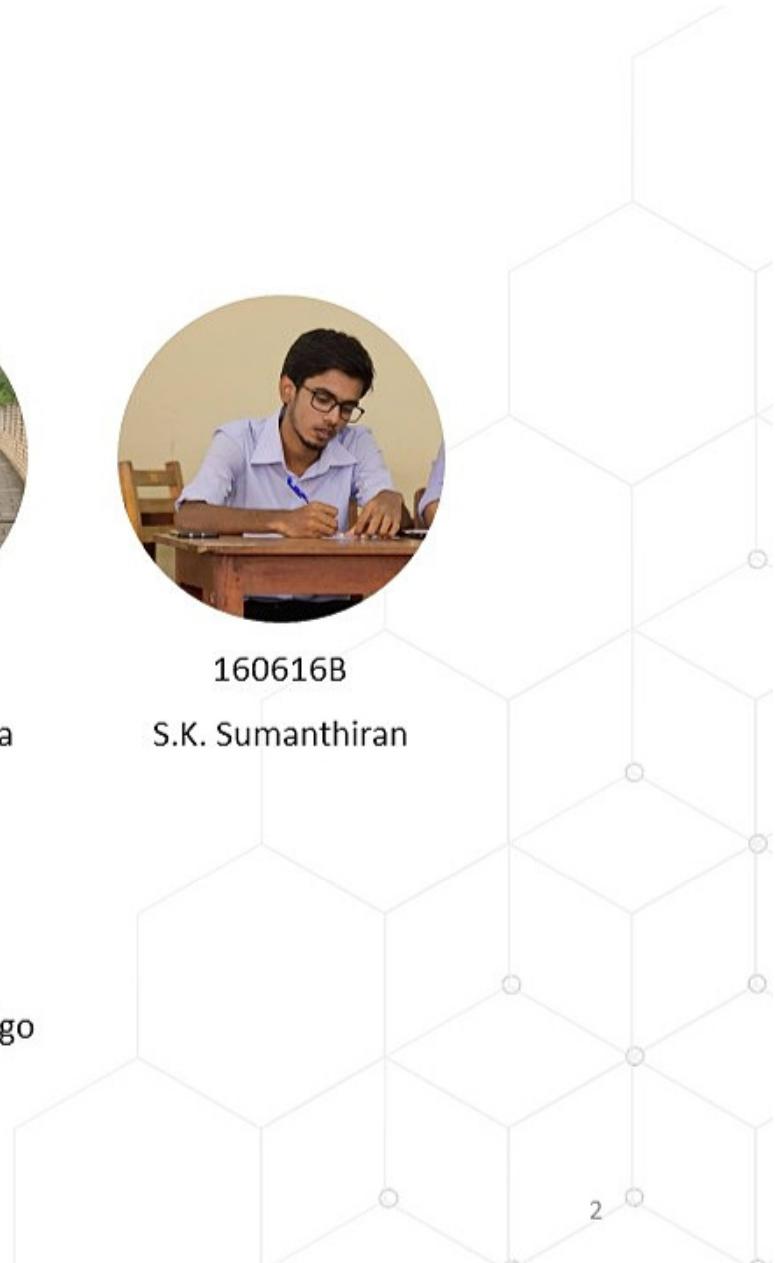
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05 Mar 2020 06:34PM

Asia

## Sri Lanka seizes record US\$33 million drugs haul at sea



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Friday, 20 March 2020 - 18:27



### Trending News

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### OVER 3KG CRYSTAL METHAMPHETAMINE (ICE) FOUND FLOATING AT SEA OFF TRINCOMALEE

Three sealed parcels of Crystal Methamphetamine, commonly known as 'Ice' found floating in seas off Trincomalee by a returning Sri Lankan midday Fishing Vessel handed over to Sri Lanka Coast Guard on 14<sup>th</sup> February 2020. The parcels contained 3.172 kg of Ice with a street value over Rs. 30 million handed over to Police Station, Tangalle for further investigations.

Sri Lanka Coast Guard is playing a vital role under close supervision of Director General – SLCG, Rear Admiral Somantha Wimalathunge in making a Sri Lanka a drug-free society, has been initiating a number of steps to prevent drug trafficking into the country via sea routes and peddling of drugs in the country. The recovery of drugs is a result of a series of awareness programmes conducted by Sri Lanka Coast Guard for fishery community on illegal drug trafficking by sea and the monitoring fishing movements in all major fishery harbours in Sri Lanka.



Event News >> Thirty (30) illegal Sri Lankan immigrants held by Navy in southern seas

### Thirty (30) illegal Sri Lankan immigrants held by Navy in southern seas

Naval personnel attached to Fast Attack Craft (FACs) belonging to the Southern Naval Command, deployed on patrol waters, intercepted a suspicious trawler plying in southern seas this morning (07<sup>th</sup> March) and held 30 suspects onboard.

Having spotted a suspicious boat movement at sea about 50 nautical miles off the Galle Lighthouse, two Fast Attack Craft directed to the location of the suspicious trawler. Accordingly, the naval personnel held 30 illegal Sri Lankan immigrants due to be handed over to the Galle Harbour Police after a medical examination and preliminary naval investigation.

The Navy urges the general public not to involve in high risk sea-borne migration to overseas countries based on false reiterates that such attempts would finally end up behind bars.

Further the Navy reminds of its strong network of intelligence and regular patrols in place to nip such illegal migration strict measures to curb such attempts.



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## Problem Statement

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- Marine surveillance is essential in border protection and eradicating illegal maritime activities.
- In the recent past, Sri Lankan seas have recorded major narcotic busts within a short period of time. Also, Indian fishermen crossing the border to Sri Lankan waters is a common news headline today.
- Are these activities always traceable and identifiable? Vessel crew can make errors due to the fatigue induced by the monotony of tasks involved in surveillance in maritime environments.
- The conventional surveillance methods are ineffective, labor intensive, and expensive due to the repetitive work involved in maritime surveillance.



## Primary Objectives

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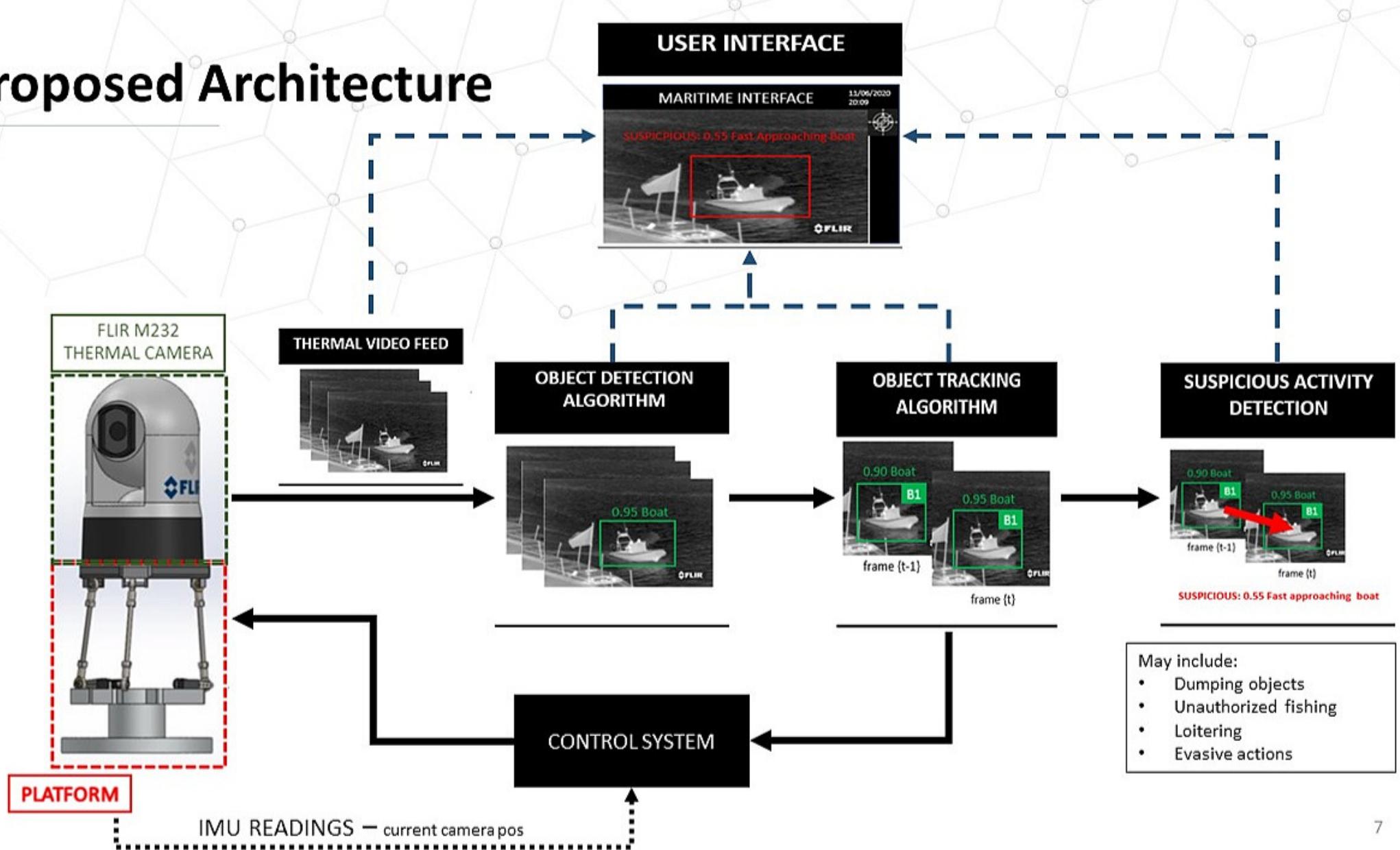
- Detect pre-defined objects using a thermal camera in seawaters.
- Detect suspicious activities occurring in any given area in the sea.
- Track and record the suspicious actor and alert the authorities.
- Create an annotated maritime thermal dataset.

## Scope

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- Develop a platform to stabilize and control the thermal camera.
- Creation of an annotated maritime thermal image dataset for object detection and activity detection
- Develop algorithms to carry out detection and bounding box estimation of dynamic targets such as boats, boat riders, swimmers and other floating objects.
- Tracking of such targets using active control of the thermal camera.
- Recognize suspicious activities using thermal imagery.
- Develop a well-documented software to monitor and control all components

# Proposed Architecture



# Evaluation of alternative methods

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- Object Detection Algorithms
- Activity Detection Algorithms
- Inference Hardware
- Platform Design
- Hardware comparison
- Control System
- Software Backend framework
- Software Frontend design framework



# Evaluation of alternatives – Object Detection Algorithms

	Faster-RCNN	SSD512	Yolo-V3	R-FCN	CornerNet	CenterNet	ConerNet-Lite (Saccade)	CornerNet-Lite (Squeeze)
Backbone	VGG-16	VGG-16	DarkNet-19	ResNet – 101	Hourglass – 104	Hourglass – 104	Hourglass – 52	Squeezed Hourglass
Single/ Double Stage	Double	Single	Single	Double	Single	Single	Single	Single
FPS	5	19	45	6	1	1	10	60
mAP	21.9	28.8	21.6	29.9	37.8	41.6	38	34

# Evaluation of alternatives – Activity Detection Algorithms

	Gaussian Temporal Awareness Networks (GTAN)	Temporal Recurrent Networks (TRN)	Reinforced Encoder-Decoder Networks (RED)	A structured Model for Action Detection	Spatio-Temporal Progressive Learning(STEP)	Online Real-time Multiple Spatio-temporal Action Localization and Prediction
Temporal/Spatio-temporal	Temporal	Temporal	Temporal	Spatio-Temporal	Spatio-Temporal	Spatio-Temporal
Backbone	Pseudo-3D	VGG-16 / ResNet-200	VGG-16 / ResNet-200	ResNet-50/Mask-RCNN	VGG-16	VGG-16
Online/Offline	Offline	Online	Online	Offline	Offline	Online
FPS	8	24	24	12	21	28
Dataset	THUMOS'14	THUMOS'14	THUMOS'14	UCF101	UCF101	UCF101
mAP score	38.8	47.2	45.3	77.9	75.0	43.0

## Evaluation of alternatives – Inference Hardware

	Titan RTX	GeForce GTX 1080 Ti	GeForce GTX 1660 Ti	GeForce RTX 2060	GeForce GTX 1650 Ti	Radeon RX 590
Cuda Support	Yes	Yes	Yes	Yes	Yes	No
RAM (GB)	24	11	6	6	4	8
Memory Bandwidth (GB/s)	672	484	192	336	128	256
Power (W)	280	250	120	160	75	175
Price (Rs.)	Rs. 500,000	Rs. 160,000	Rs. 56,000	Rs. 65,000	Rs. 30,000	Rs. 36,000

# Evaluation of alternatives - Platform Design

				
<b>Stability of Platform</b>	Moderate	High	Moderate	Moderate
<b>Positioning Accuracy</b>	Low	High	High	High
<b>Force-to-Weight ratio</b>	Low	High	High	High
<b>Rigidity (off-axis)</b>	Low	High	Moderate	Moderate
<b>Size of Platform</b>	Small - Medium	Large	Small - Medium	Small - Large
<b>Cost</b>	Low	High	Moderate	Moderate
<b>Mass of Load</b>	Low/Moderate	High	Moderate	Low
<b>Speed of action</b>	Moderate	Moderate	High	High
<b>Workspace Volume</b>	Moderate	Small	Small	Small

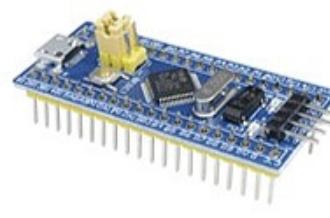
# Evaluation of alternatives – Hardware – Servo Motors

					
<b>Gear Material</b>	Metal	Metal	Metal	Metal	Metal
<b>Stall Torque</b>	9.4 kgf.cm (4.8 V) 11 kgf.cm (6 V)	14kgf.cm (4.8V) 15.5kgf.cm (6V)	14kgf.cm (4.8V) 16kgf.cm (6V)	15.3 kg·cm 212 oz·in	18kgf.cm(6V), 20kgf.cm(7.2V)
<b>Operating Speed</b>	0.17 s/60° (4.8 V) 0.14 s/60° (6 V)	0.18 s/60° (4.8V) 0.16 s/60° (6V)	0.18 s/60° (4.8V) 0.14 s/60° (6V)	59 RPM 0.169sec/60°	0.14 s/60° (6V) 0.16 s/60° (7.2V)
<b>Operating Voltage</b>	4.8V – 7.2V	4.8V – 7.2V	4.8V – 6.0V	9V - 12V	4.8V – 7.2V
<b>Dead Bandwidth</b>	5µs	5µs	5µs	2µs	3µs
<b>Weight</b>	55g	56g	48g	55g	60g
<b>Dimensions (mm)</b>	40.7 x 19.7 x 42.9	40.8 x 20.1 x 38	41 x 20 x 36	50x 26 x 37.5	40 x 20 x 40.5
<b>Cost (\$)</b>	3	19	22	47	12

# Evaluation of alternatives – Hardware – Gyroscope

				
Special Features	<ul style="list-style-type: none"> <li>6 or 9-axis Motion Fusion data in rotation matrix, quaternion, Euler Angle, or raw data format</li> <li>3-Axis accelerometer with a programmable full-scale range of <math>\pm 2g</math>, <math>\pm 4g</math>, <math>\pm 8g</math> and <math>\pm 16g</math></li> </ul>	<ul style="list-style-type: none"> <li>“Always on” experience with low power consumption for both accelerometer and gyroscope</li> </ul>	<ul style="list-style-type: none"> <li>3 axis silicon monolithic Hall-effect magnetic sensor with magnetic concentrator</li> <li>Digitally programmable low-pass Gyroscope filter</li> <li>Includes gyroscope, accelerometer and magnetometer</li> </ul>	<ul style="list-style-type: none"> <li>Pololu MinIMU-9 v2 packs a L3GD20 3-axis gyro, a LSM303DLHC 3-axis accelerometer and 3-axis magnetometer.</li> <li>I<sup>2</sup>C interface accesses nine independent rotation, acceleration, and magnetic measurements to calculate the sensor’s absolute orientation</li> </ul>
Sensitivity	131, 65.5, 32.8, 16.4	228.57, 114.29, 57.14, 28.57, 14.29	131, 65.5, 32.8, 16.4	114.29, 57.14, 14.29
ARW	0.005	0.007	0.01	0.03
Non-Linearity	0.2	0.5	0.1	0.2
Unit Price	3	8	7	15.95

# Evaluation of alternatives – Hardware – Microcontroller

			
Affordability (Financially)	High	High	Moderate
Computational Power	Low	Moderate	High
Most Optimized Task	Logic Programming	Logic Programming	General Single Board Computer
WiFi and Bluetooth	No	No	Yes
Power Consumption	~ 0.5 W	~ 0.5 W	~ 5 W

# Evaluation of alternatives – Control System

Joint-Space Controller	Cartesian Space Controller
Attempts to null the joint parameter error by commanding a torque signal to servo-drive	Attempts to null the cartesian coordinate error by commanding a torque signal to servo-drive
Dynamic equations are complicated	Dynamic equations are less complicated
Need 6, 1-DoF sensors to measure the joint parameters at each joint ( $d$ or $\theta$ )	Need 6-DoF sensor to measure the position and the orientation of the platform

# Evaluation of alternatives – Backend Development

 Flask		 Phoenix Framework		
<ul style="list-style-type: none"><li>• Python based</li><li>• Very flexible</li><li>• More lightweight than Django, great for smaller projects</li><li>• Great documentation</li><li>• Offers the ability to build prototypes quickly</li></ul>	<ul style="list-style-type: none"><li>• Python Based</li><li>• Highly customizable</li><li>• No need to reinvent the wheel, encourages rapid development</li><li>• Very scalable</li><li>• Extensive community and documentation</li></ul>	<ul style="list-style-type: none"><li>• Elixir Based</li><li>• Very fast</li><li>• Fault tolerant</li><li>• Built in database options</li><li>• Well designed</li><li>• Great documentation and active community</li></ul>	<ul style="list-style-type: none"><li>• Java Based</li><li>• Create stand-alone Spring applications</li><li>• Highly scalable</li><li>• Great documentation</li><li>• Built for large scale applications that use a cloud approach</li><li>• Extensive ecosystem</li></ul>	<ul style="list-style-type: none"><li>• Node.js Based</li><li>• Great routing API</li><li>• Minimalistic and unopinionated</li><li>• Setup is easy and it's straightforward to learn</li><li>• Large number of plugins available for use</li></ul>

# Evaluation of alternatives – Frontend Development

 React	 ANGULAR	 ANGULARJS by Google	 jQuery <small>write less, do more.</small>
<ul style="list-style-type: none"><li>• Maintained by Facebook</li><li>• The community is constantly evolving</li><li>• Virtual DOM</li><li>• High performance</li><li>• Suitable for applications with high traffic</li><li>• Often updated</li></ul>	<ul style="list-style-type: none"><li>• Strong community</li><li>• 2-way data binding</li><li>• Simple single page app</li><li>• Shadow DOM</li><li>• Typescript</li></ul>	<ul style="list-style-type: none"><li>• JavaScript friendly compared to Angular</li><li>• 2-way data binding</li><li>• Fast development</li><li>• Highly testable applications</li></ul>	<ul style="list-style-type: none"><li>• Beginner friendly</li><li>• Compatible with all browsers</li><li>• Ease of use</li><li>• A lot of plugins</li><li>• Big community</li></ul>

# Deliverables

## Functioning Activity Detection algorithm

- Identifying at least 3-classes of pre-defined suspicious activities.
- With competitive mAP score.
- Using thermal image sequences.

## Camera mounting platform with

- Stabilization.
- Active control for object tracking

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Functioning Object Detection algorithm

- For objects related to maritime environment such as boats, swimmers etc.
- Competitive mAP score on predicted bounding boxes
- Using thermal images.

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Annotated maritime dataset

- Capable of use for object detection and activity detection in maritime environment.
- Either a locally obtained thermal dataset or already published maritime thermal dataset.
- Publication in a well-known forum.

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Well documented software

- User-friendly

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# Uniqueness



Automation of real-time threat detection at sea during both day and night.



Alerting relevant authorities upon detection of suspicious activities



Deep learning-based activity detection on marine objects using thermal images



Minimizes human intervention in watching for suspicious activities.



## Potential Customers

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## Risk Factors – Technical Risks

Risk	How to mitigate
Inability to use the pan and tilt abilities of the camera.	Controlling the orientation of camera using the designed platform.
Stabilization of platform will not be possible to achieve entirely from Gyro-PID based controller.	Use digital video stabilization techniques to stabilize the video feed alongside with the mechanical stabilizer.
Documented motor and servo parameters being different from actual values of the motors obtained.	Perform physical testing of the motors obtained and adjust the control loop parameters
Workspace volume of the platform not sufficient	Creating and simulating multiple platform designs with different dimensions and different DOFs (6 –DOF and 3-DOF)
Unable to run the currently selected pipeline in real time.	Use smaller, faster algorithms, and use other techniques to improve the accuracy of the model

## Risk Factors – Financial Risks

Risk	How to mitigate
Reordering cost for failing components.	Order with a buffer margin at first
Cost limit for the project exceeding the university stipend.	Self funding
Delivery cost of different vendors	Selecting a vendor based on the price of the component and customer feedback.

## Risk Factors – Sustainability Risks

Risk	How to mitigate
Dataset collection on Sri Lankan sea with sufficient level of suspicious activities may take longer time	Do all the tasks based on available datasets obtained in foreign seas
Components may not arrive on time and depreciated components	Order components early and check whether they are in good quality

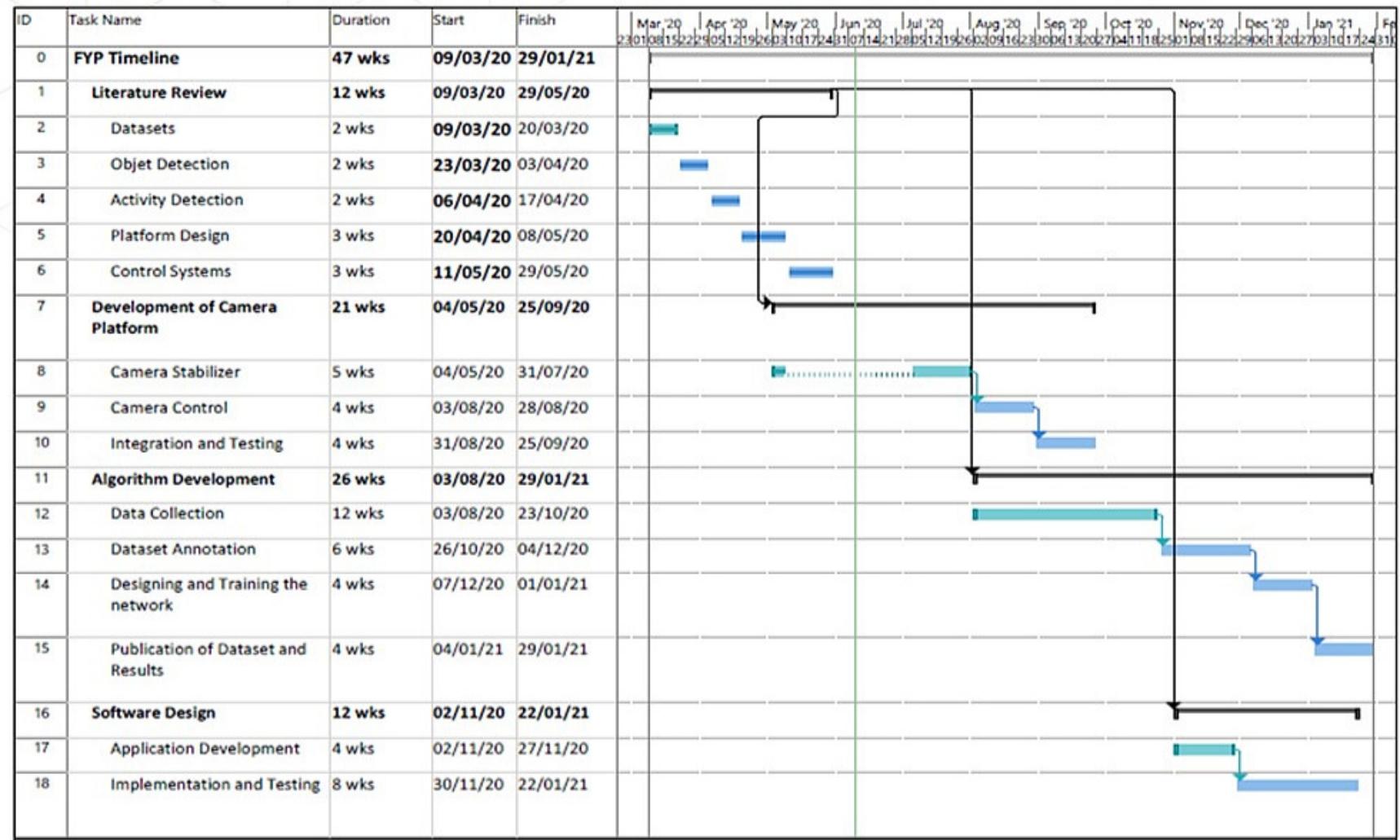
## Risk Factors – Health Risks

Risk	How to mitigate
Received packages from overseas may not have adhered to the safety measures from the vendors	Sanitization of the packages and selecting the vendors more carefully
Getting firsthand experience on how the suspicious activities are detected by SL Navy, how the movements and vibrations of vessels may affect the quality of our algorithms not possible due to the current context.	Contact personnel from SL Navy through a Zoom meeting and get their input when the situation is better

## Budget

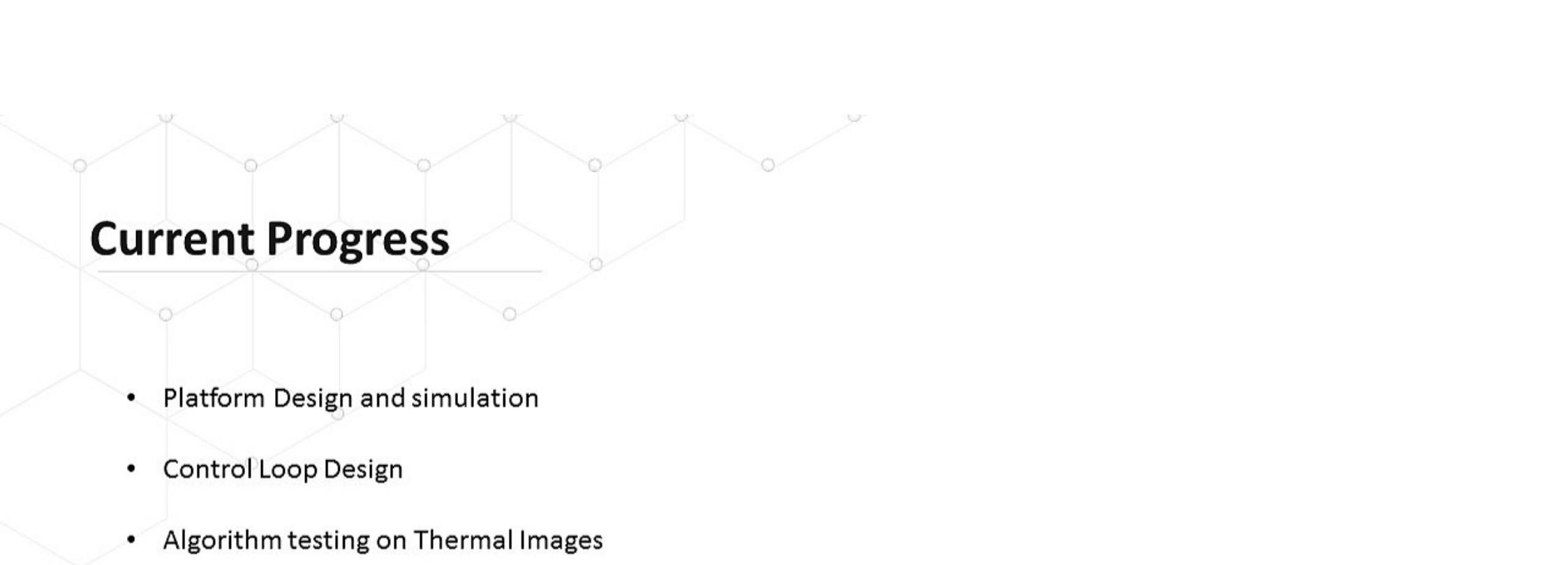
Item	Unit Price (\$)	No of Units	Total (\$)	Total (LKR) (1USD = LKR185)	Sponsored
FLIR M232 Thermal Camera	3499	1	3499	645791.54	Yes
DS3218 Servo	11.20	8	89.6	16576	No
Connecting Rods (4 per set)	9	4	36	6660	No
2s1p 5200mAh LiPo Battery	40	1	40	7382.58	No
Mini IMU 9 - Pololu	16	2	32	5920	No
Raspberry Pi 3	40	1	40	7382.58	No
Base and top platforms Laser Cut (approx.)				5,000	
GPU	300	1	300	55,500	Yes
<b>Total Budget = LKR 750,212.7 ( Non-Sponsored = LKR 48921.16)</b>					

# Timeline



# Task Delegation

Task Group	Responsible Person	Tasks	Delegation			
			Kalana	Sakuna	Sachira	Shechem
Object Detection and Activity Detection	Shechem	Data Preprocessing		✓	✓	✓
		Data Annotation	✓	✓	✓	✓
		Algorithm Development and Training	✓	✓	✓	✓
		Object Tracking	✓		✓	✓
Platform and Control System Design	Sachira	Platform Design	✓		✓	
		Simulation	✓		✓	
		Prototyping	✓	✓	✓	✓
		Control System and Programming	✓	✓		✓
Integration	Kalana	Integration of Hardware and Software	✓	✓		✓
Software Development	Sakuna	Backend Development		✓		✓
		Frontend Development		✓	✓	

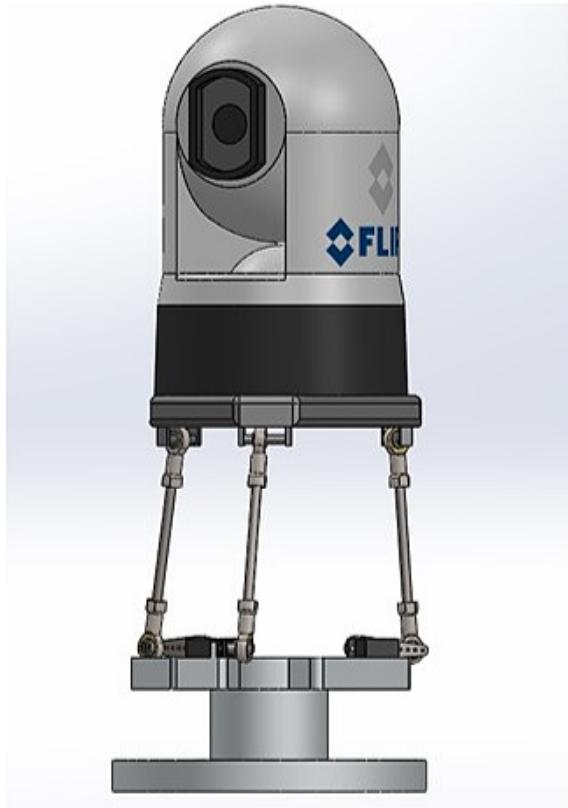


## Current Progress

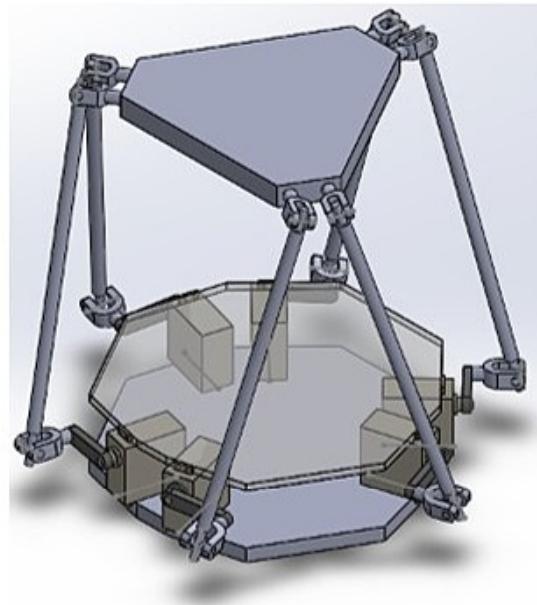
- Platform Design and simulation
- Control Loop Design
- Algorithm testing on Thermal Images
- Alternative dataset search

# Platform Design and Simulation

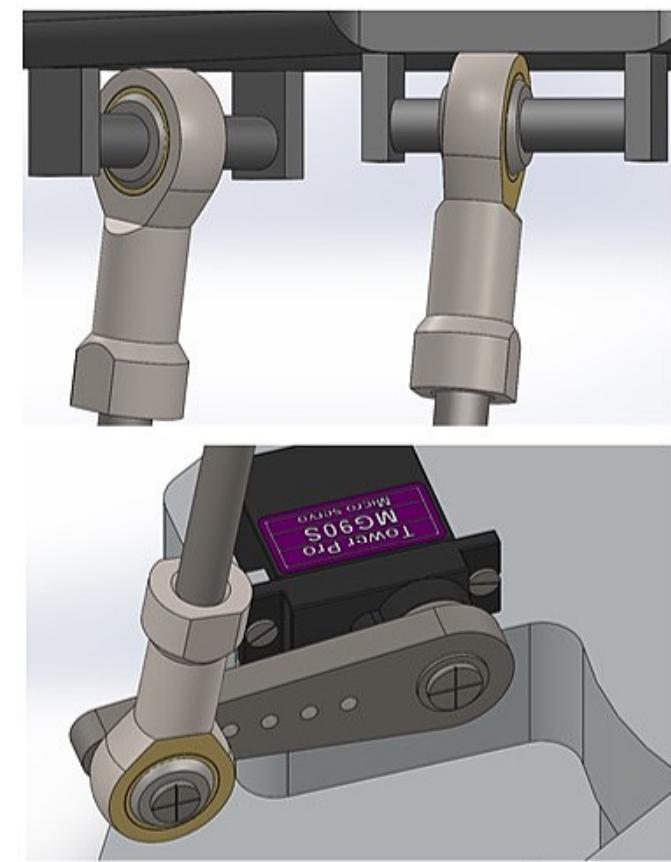
3-DOF STEWART PLATFORM



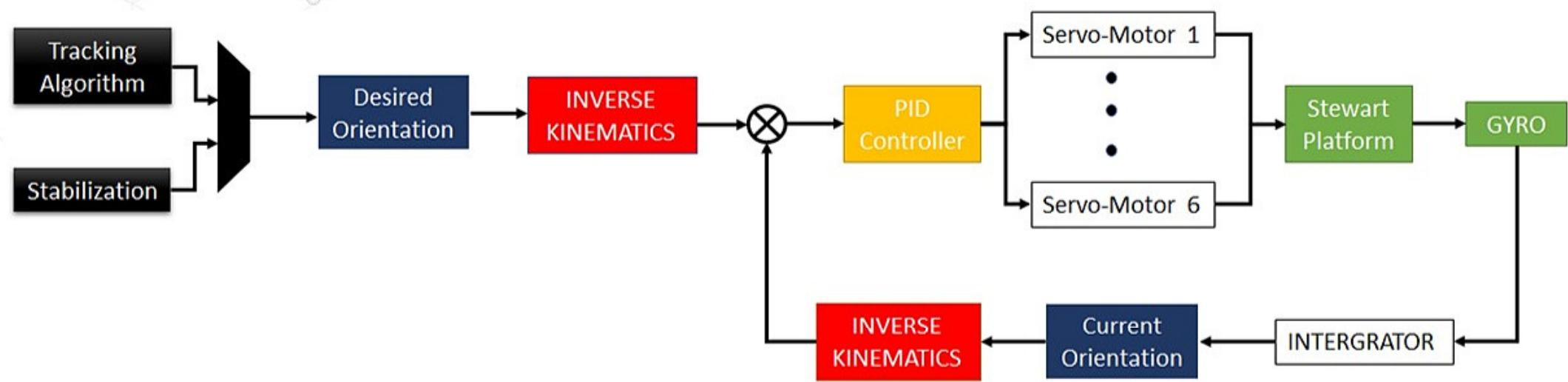
6-DOF STEWART PLATFORM



Universal Joints design and  
Servo Arm design



# Current Progress – Control System Design



# Current Progress – Algorithm testing on thermal images\*

Property	Faster-RCNN	Yolo-V3	R-FCN	CenterNet	ConerNet-Lite (Saccade)	CornerNet-Lite (Squeeze)
FPS	5	45	6	1	10	60
mAP %	65	85	78	88	65	81

\*Algorithms are trained on FLIR Self Driving Thermal Image Dataset



# Current Progress – Alternative Datasets

Datasets	Link	Images/ Video type	Description	Suitability
<b>Singapore Maritime Dataset</b>	<a href="https://sites.google.com/site/dilipprasad/home/singapore-maritime-dataset">https://sites.google.com/site/dilipprasad/home/singapore-maritime-dataset</a>	Near IR videos	Near Infra-red (NIR) videos which is also captured using another Canon 70D camera with hot mirror removed and Mid-Opt BP800 Near-IR Bandpass filter.	Both the videos and the annotations files are provided Not captured from a thermal camera (hence the quality of the images may be not of the thermal cameras) No Suspicious activities included
<b>IPATCH</b>	<a href="http://ftp.pets.rdg.ac.uk/pub/PETS2016/MidHighLevelChallengeData/IPATCH/">http://ftp.pets.rdg.ac.uk/pub/PETS2016/MidHighLevelChallengeData/IPATCH/</a>	Both R and Thermal	Contains a set of fourteen multi camera recordings (visible, thermal) collected off the coast of Brest, France  (Mainly the images are provided. For two thermal cameras, a summary video is provided per directory)	Dataset consists the following scenarios: -> boat detection and boat tracking -> Abnormal events such as boat speeding up , boat loitering , Group formation/separation -> Threat events: attack to the vessel  Thermal images extracted from the video clips are all captured in daytime (Potential bias ) No object-level annotations are provided Quality of the thermal frames extracted are not of good quality

## References

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- Szufnarowski, F. (2013). Stewart platform with fixed rotary actuators: a low cost design study. *Advances in medical Robotics*, (4).
- Bang, H., & Lee, Y. S. (2018). Implementation of a ball and plate control system using sliding mode control. *IEEE Access*, 6, 32401-32408.



**Thank you.**

