Object Detection, Tracking, Re-identification and Activity Recognition for Maritime Surveillance using Thermal Vision - Stage II

FYP Feasibility Presentation

Group 07

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ENTC Electronic and Telecommunication Engineering

Motivation

Navy nabs 80 illegal Indian immigrants

Published 2 months ago on 2021/05/5

epaper.island.lk

Indians held by the Navy in the seas off Mannar. Pic courtesy Navy

By Norman Palihawadane

The Navy nabbed 80 Indians attempting to immigrate illegally into Sri Lanka in 11 boats at Mannar yesterday. They had fled India, fearing the surging of Covid-19 infections and high death toll.

Two persons engaged in illegal fishing apprehended by Navy

news.navy.lk

Navy apprehended two (02) persons for engaging in illegal fishing in Silawathura beach area, on 8th January 2020.

Continuous patrols are carried out by Navy to avert illegal fishing activities in order to preserve the marine resources in Sri Lankan territorial waters. During such an operation conducted to seize the illegal fishers a suspicious dinghy was spotted by the Navy in Silawathura beach area and it was searched. By further inquiry, it was found that they were engaging in fishing without a valid pass. Accordingly, two persons and the dinghy were apprehended. The suspects were identified as residents of Silawathura and Kalpitiya areas aged 44.

The dinghy, an outboard motor (OBM), 24 Nos of sea cucumber and 17 kg of illegally caught fish were also taken into naval custody.

The suspects together with the seized dinghy, OBM, sea cucumber, stock of illegally caught fish and fishing gears were handed over to the Fisheries Inspector-Mannar for onward action.

Sri Lanka Navy seizes over 174 kg of Kerala Cannabis in Northern seas

Mon, Jun 21, 2021, 09:13 am SL Time, ColomboPage News Desk, Sri Lanka.

June 21, Colombo: During an operation conducted in the Northern Seas off Jaffna, A Sri Lanka Navy team has seized a stock of Kerala Cannabis and dried turmeric on Sunday night.

The Navy took hold of about 174kg and 50g of Kerala cannabis and 05 kg of dried turmeric along with a dinghy and arrested two suspects, during the special operation conducted in seas off Thondamanaru, Jaffna, the Navy Media Unit said.

The Navy has increased patrols in island waters to curb wide-ranging illegal acts including the smuggling of drugs by sea routes.

Accordingly, the Northern Naval Command carried out this special operation by deploying the Inshore Patrol Craft P 177 and Z 196 and Z 215 crafts of Special Boat Squadron, which intercepted a suspicious dinghy approaching landward.

The dinghy had been loaded with about 174kg and 50g of Kerala cannabis in 05 packag turmeric and the items were taken into naval custody together with the dinghy and 02

Colombopage News Desk

The street value of the seized stock of Kerala cannabis is believed to be around Rs. 52 million.

The arrested suspects identified as residents of Point Pedro and Mullaitivu are 28 and 34 years of age.

Navy operation nabs four suspects smuggling Rs. 600 million worth 'Ice' and Hashish

Mon, Jan 4, 2021, 01:21 pm SL Time, ColomboPage News Desk, Sri Lanka.

Jan 04, Colombo: Sri Lanka Navy in a special operation carried in the sea area off Negombo on Monday (04th January 2021) arrested four suspects transporting a stock of Crystal Methamphetamine (ICE) and Hashish worth over Rs. 600 million.

The operation also led to the seizure of a multiday fishing trawler used to transfer the drugs.

The Western Naval Command intercepted a suspicious multiday fishing trawler off Negombo and apprehended the four suspects with over 100kg of Crystal Methamphetamine (ICE) and about 80kg of Hashish being transferred aboard.

- Illegal Fishing
- Drug Trafficking
- Human Smuggling
- Piracy
- Possible terrorist activities

Problem Statements

- **Unavailability of an automated thermal vision surveillance system with following features:**
  - Object Detection and Tracking
  - Vessel Re-Identification
  - Maritime Activity Detection
- **Unavailability of a public thermal vision dataset for maritime environments.**
- **Less research on Vessel Re-Identification & Maritime Activity Detection in Thermal domain.**

I corrected the text

Scope

Stage I · Stage II · Additional (Stage II)

Object Detection 100%

- 100% — Thermal Maritime Object Detection Model
- Additional — Improvements

Object Tracking 100%

- 100% — Thermal Maritime Object Tracking Model
- Additional — Improvements

Dataset 0%

- 0% — Creation & Annotated dataset

Research Paper

- 100% — Stage I BMVC
- 0% — Stage II

Activity Recognition 70%

- 100% — Online Real-Time ST Action Localization
- 0% — Maritime Action Detection
- 0% — Thermal Action Detection

Vessel Re-Identification 0%

- 0% — Viewpoint Estimation
- 0% — Vessel Re-Identification

Camera Platform 0%

- 0% — Camera Stabilization Platform

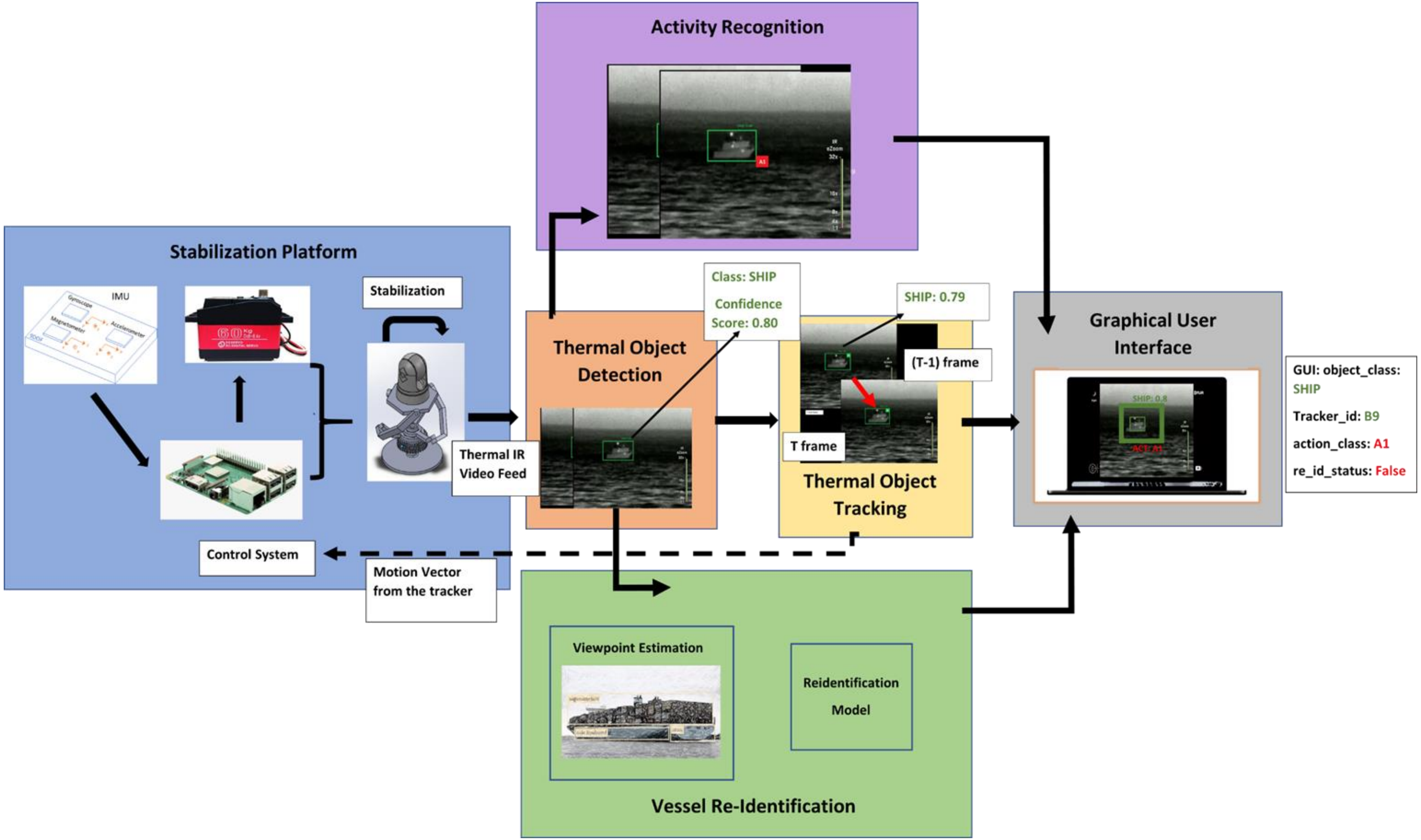
GUI 70%

- 100% — Detection & Tracking
- 0% — Re-Identification

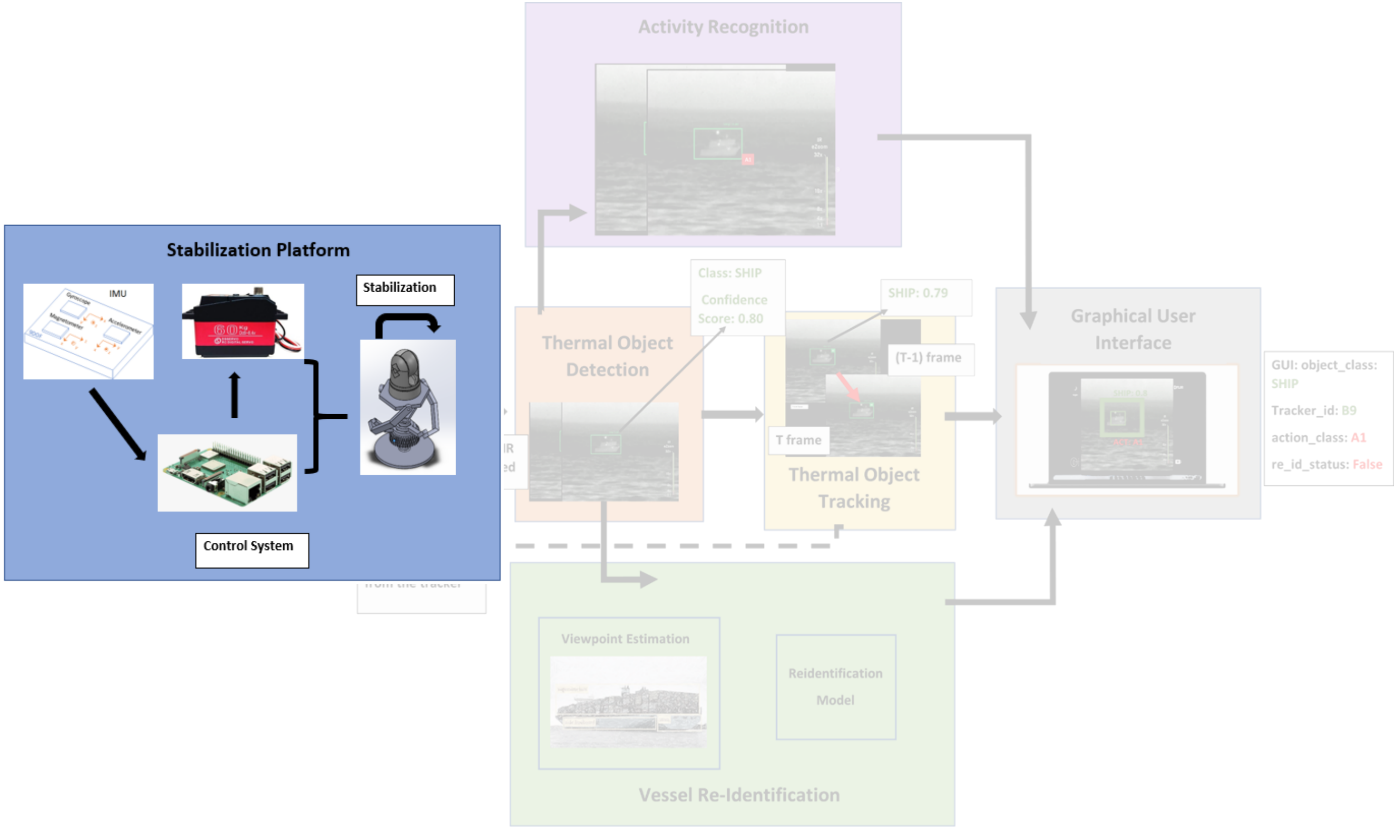
Stage II Deliverables

- Improvements in Object Detection & Tracking Model
- Re-Identify Vessels
- Camera Stabilization Platform
- Research Publication
- Activity Recognition System
- Properly Annotated Dataset
- Improvements in User-friendly Interface

Proposed Architecture for Stage II



Critically Evaluation of alternative strategies - Stabilization Platform



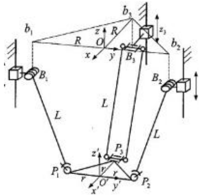
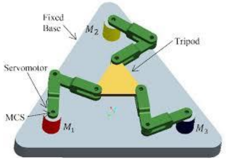
Hardware - Camera - FLIR M232 Thermal Camera

This the camera that we use to fulfill our objectives. Below are the specifications of it.

Pan Range	360
Tilt Range	+110°, -90°
Zoom	x4
Resolution	320×240
Power Consumption	15 W (typical) 18 W (max)
Video	H264 IP Video stream
Relative Humidity	95% max
Range Performance	detection of person in water up to 457m, detection of small vessel up to 1.3km
Salt mist	IEC 60945 standard
Wind resistance	161 km/h
Compliance	Maritime environment compliance

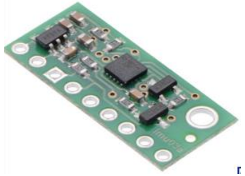
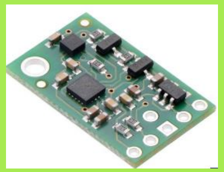
Platform Design Evaluation

These are the alternatives considered for the stabilization platform required for the product.

	 **Spherical Parallel Manipulator- 3 DoF**	 **Spatial Parallel Manipulator- 3DoF**	 **Planner Three RRR Manipulator- 3DoF**	 **Delta Robot- 3DoF**
Manipulator Type	Parallel	Parallel	Parallel	Parallel
Positioning Accuracy	High	High	High	High
Rigidity	High	High	High	Moderate
Size of Platform	Small	Moderate	Moderate- Large	Small- Large
Roll, Pitch, Yaw Movement	Roll, Pitch, Yaw Available	Pitch Only	Yaw Only	None
Mass of Load	High	High	High	Low
Speed of action	Moderate	Moderate	Moderate	High
Workspace Volume	Low	Low	Low	Low

Hardware - Inertial Measurement Unit (IMU) Sensor Comparison

IMU sensor provides the current platform orientation measurements to the microcontroller.

	 **MPU6050**	 **LSM6DS33**	 **L3GD20H**	 **MiniIMU-9 v5**
Range (°/sec) - For Gyro (g) - For Accelerometer (gauss)- For Magnetometer	Gyro Range : ±250, ±500,±1000,±2000 Accelerometer Range: ±2,±4,±8,±16	Gyro Range : ±125,±250, ±500,±1000,±2000 Accelerometer Range: ±2,±4,±8,±16	Gyro Range: ±245°/s, ±500°/s, or ±2000°/s	Gyro: ±125, ±245, ±500, ±1000,±2000 Accelerometer: ±2, ±4, ±8, or ±16 g Magnetometer: ±4, ±8, ±12, or ±16
Sensitivity	131,65.5,32.8,16.4	228.57, 114.29, 57.14,28.57,14.29	8.75 ~ 7	114.29, 57.14,14,29
ARW	0.005	0.007	0.011-0.03	-
Unit Cost $	3	11.95	8	15.95

Hardware - Motor Comparison

As per our chosen platform, three motors are needed for controlling and stabilizing the platform.

	 TD8130MG	 DSC45MG	 DS5160	 DS3230	 DS3235
Type	Digital-Metal Gear	Digital-Metal Gear	Digital-Metal Gear	Digital-Metal Gear	Digital-Metal Gear
Stall Torque	28.5 kg-cm(4.8V); 33.8kg-cm (7.2V)	35kg-cm(6.0V); 45kg-cm (8.4V)	58kgcm(6V);65kgcm (7.4V);70kg-cm(8.4)	29.5kg.cm 5V 34.5kg.cm 6.8V	32kg-cm(6.0V) 35kg-cm 7.4V
Operating Speed	0.22sec/60°(4.8V) 0.18sec/60°(7.2V)	0.12sec/60°(6.0V); 0.11sec/60°(8.4V)	0.15sec/60°(7.4V); 0.13sec/60°(8.4V)	0.2sec/60°(5V) 0.17sec/60°(6.8V)	0.12sec/60°(6.0V) 0.11 sec/60°(7.4V)
Dead Bandwidth	5μs	2μs	5μs	3μs	2-3μs
Weight	112g	75g	162g	75g	60g
Dimensions	40 x 20.5 x 40.5mm	40 × 20 × 40mm	65 x 30 x 48mm	40 x 20 x 40.5 mm	40 x 20 x 38.5 mm
Cost $	23	69	37	25	33
Specifications	Waterproofed	Waterproofed Stainless Steel Gear	Waterproofed Stainless Steel Gear	Waterproofed, Stainless Steel Gear	Waterproofed, Stainless Steel Gear

Hardware - Microcontroller Comparison

Microcontroller process sensor data and tracking system feedback to control the motors of the self stabilization platform to achieve platform stabilization and camera control.

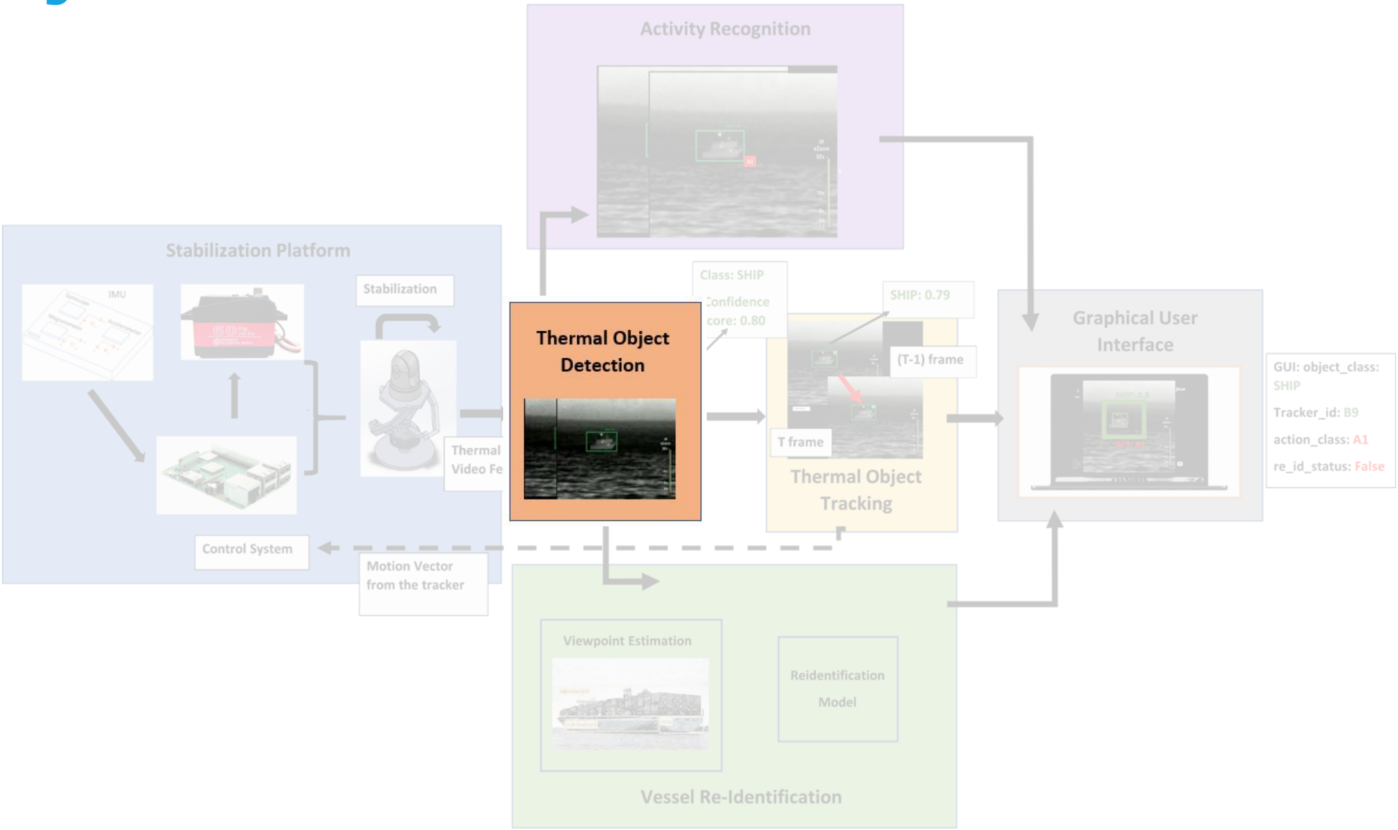
	Arduino Mega 	**STM32** 	**Raspberry-pi** 
Affordability (Financially)	Low	High	Moderate
Computational Power	Low	Moderate	High
Most Optimized Task	Logic Programming	Logic Programming	General Single Board Computer
WiFi and Bluetooth	No	No	Yes
Power Consumption	~0.5W	~0.5W	~5W

Inference Hardware

A Graphical Processing Unit is used for processing for inference in object detection, re identification,object tracking and activity detection models.

Model	**Cuda Support**	**Base /Boost**	**Memory**	**Power(W)**	**Cost**
Titan RTX	Yes	1350/1770 MHz	24GB GDDR6	280	Rs. 500,090.50
Geforce GTX 1080 Ti	Yes	1480/1582 MHz	11GB GDDR5X	250	Rs. 168029.08
Geforce GTX 1660 Ti	Yes	1365/1680 MHz	6GB GDDR6	120	Rs. 129860.02
Geforce RTX 2060	Yes	1365/1680 MHz	6GB GDDR6	160	Rs. 142024.27
Geforce GTX 1650 Ti	Yes	1485/1665 MHz	4GB GDDR5	75	Rs. 120020.20

Critically Evaluation of alternative strategies - Object Detection



Object Detection Algorithms Evaluation

After the the video feed is received, the presence of ships,boats and other objects of interest in it should be detected. A system has been developed for this in the stage 1 of the project, so this algorithm is an improvement over the the existing system.

	CenterNet [1]	**Scaled YOLO - V4** [2]
Backbone	Hourglass -104	CD53s
Stages	Single stage	Single stage
FPS	7.8	16
mAP	42.1	46.2

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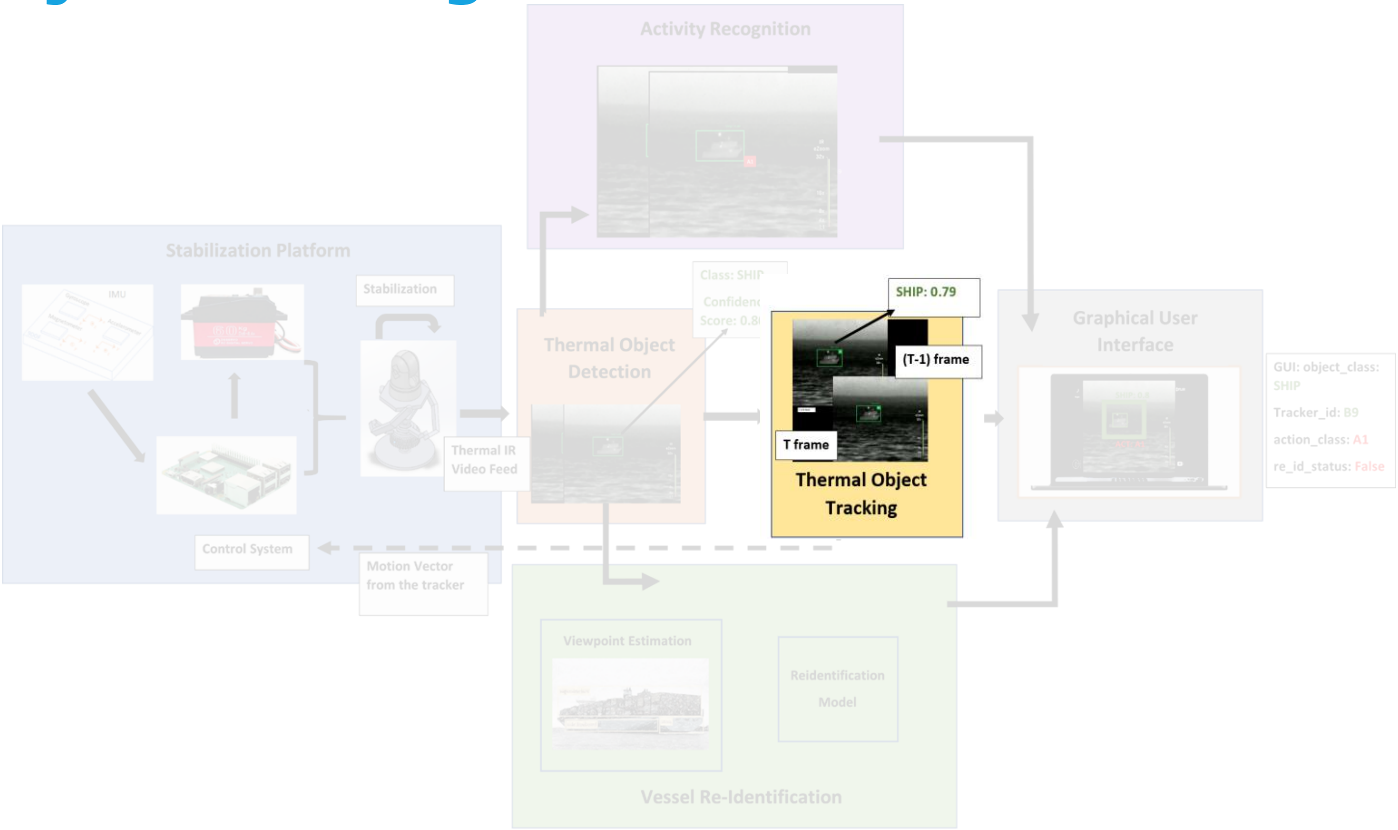
[1] Zhou, Xingyi, Dequan Wang, and Philipp Krähenbühl. "Objects as points." *arXiv preprint arXiv:1904.07850* (2019).

[2] Wang, Chien-Yao, Alexey Bochkovskiy, and Hong-Yuan Mark Liao. "Scaled-yolov4: Scaling cross stage partial network." In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 13029-13038. 2021.

Critically Evaluation of alternative strategies - Object Tracking



Object Tracking Algorithms Evaluation

Main purpose of this is to match different object instances which is detected by the detector in each frame.

	DeepSimple Online and Realtime Tracking[1]	Simple Online and Realtime Tracking[2]	Siamese Multi Object Tracking[3]
Object Detector	Faster R-CNN	Faster R-CNN	Faster R-CNN
Backbone	VGG-16	VGG-16	DLA-169
Dataset	MARS	MARS	HiEve
Online/Offline	Online	Online	Online
Runtime	40 Hz	60 Hz	-
MOTP	79.1	79.6	-
MOTA	61.4	59.8	53.2

[1] Shuai, Bing, Andrew Berneshawi, Xinyu Li, Davide Modolo, and Joseph Tighe. "SiamMOT: Siamese Multi-Object Tracking." In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 12372-12382. 2021.

[2]Bewley, Alex, Zongyuan Ge, Lionel Ott, Fabio Ramos, and Ben Upcroft. "Simple online and realtime tracking." In *2016 IEEE international conference on image processing (ICIP)*, pp. 3464-3468. IEEE, 2016.

[3]Hou, Xinyu, Yi Wang, and Lap-Pui Chau. "Vehicle tracking using deep sort with low confidence track filtering." In *2019 16th IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS)*, pp. 1-6. IEEE, 2019.

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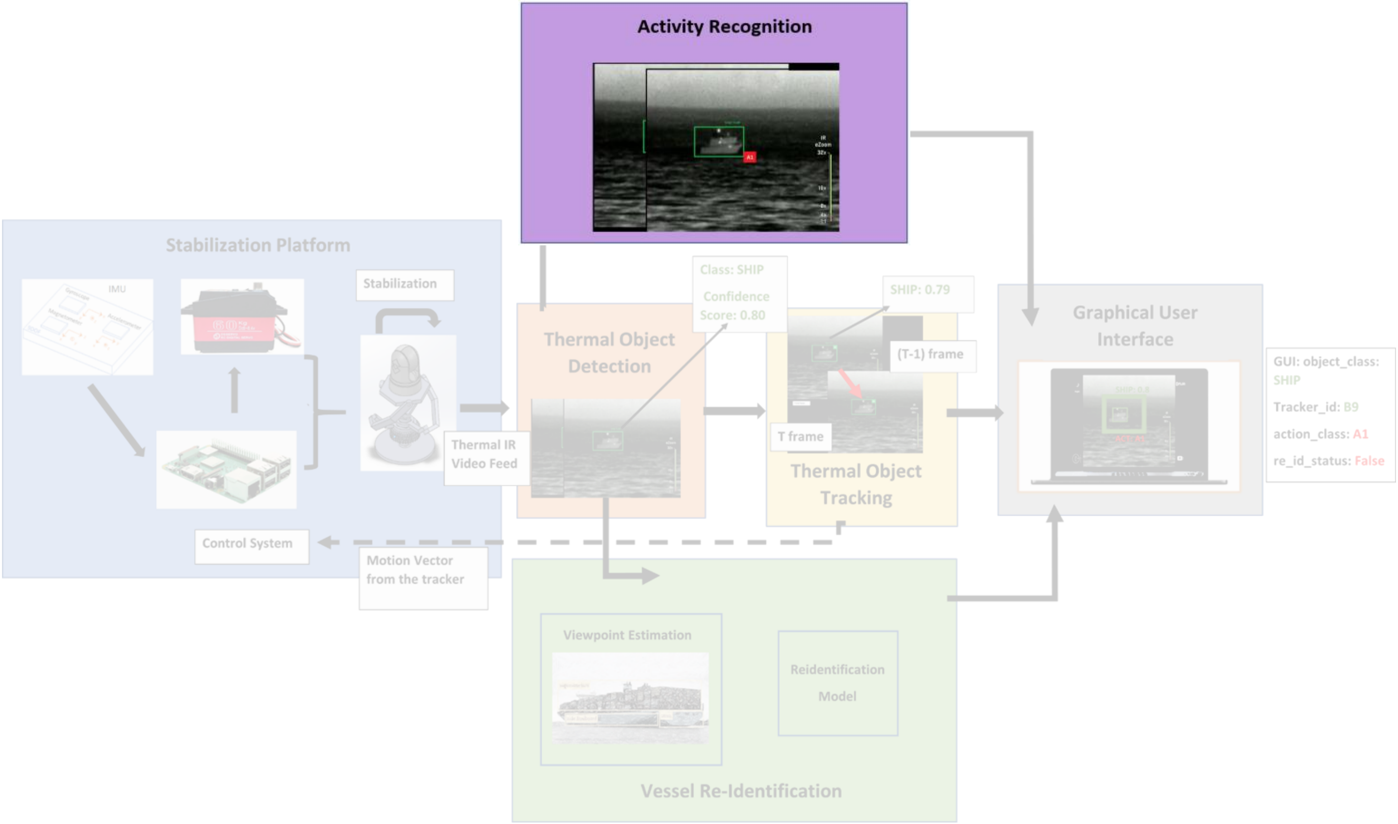
Critically Evaluation of alternative strategies - Activity Recognition



Action Recognition Architectures Evaluation

Recognizing the Action Class by combining the spatial and temporal properties of the Frame Sequence

	Gaussian Temporal Awareness Network for Action Localization[1]	Online Real-time Multiple Spatiotemporal Action Localisation and Prediction[2]	A Multi-Stream Bi-Directional Recurrent Neural Network for Fine-Grained Action Detection[3]	RED: Reinforced Encoder-Decoder Networks for Action Anticipation[4]
Spatio Temporal/Temporal	Temporal	Spatio/Temporal	Spatial/Temporal	Temporal
FPS	8	28	-	24
Stages	1	1	2	2
Backbone	Pseudo-3D	VGG-16	VGG-16	VGG-16/esNet-200
Dataset	THUMOS14	UCF101-24	MPII Cooking 2	THUMOS-14
Online/Offline	Offline	Online/Offline	offline	online
mAP Score	38.8	43.0	41.2	47.0

[1]Long, Fuchen, Ting Yao, Zhaofan Qiu, Xinmei Tian, Jiebo Luo, and Tao Mei. "Gaussian temporal awareness networks for action localization." In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 344-353. 2019.

space

[2]Singh, Gurkirt, Suman Saha, Michael Sapienza, Philip HS Torr, and Fabio Cuzzolin. "Online real-time multiple spatiotemporal action localisation and prediction." In *Proceedings of the IEEE International Conference on Computer Vision*, pp. 3637-3646. 2017.

[3]Singh, Bharat, Tim K. Marks, Michael Jones, Oncel Tuzel, and Ming Shao. "A multi-stream bi-directional recurrent neural network for fine-grained action detection." In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 1961-1970. 2016.

[4]Gao, Jiyang, Zhenheng Yang, and Ram Nevatia. "Red: Reinforced encoder-decoder networks for action anticipation." *arXiv preprint arXiv:1707.04818* (2017).

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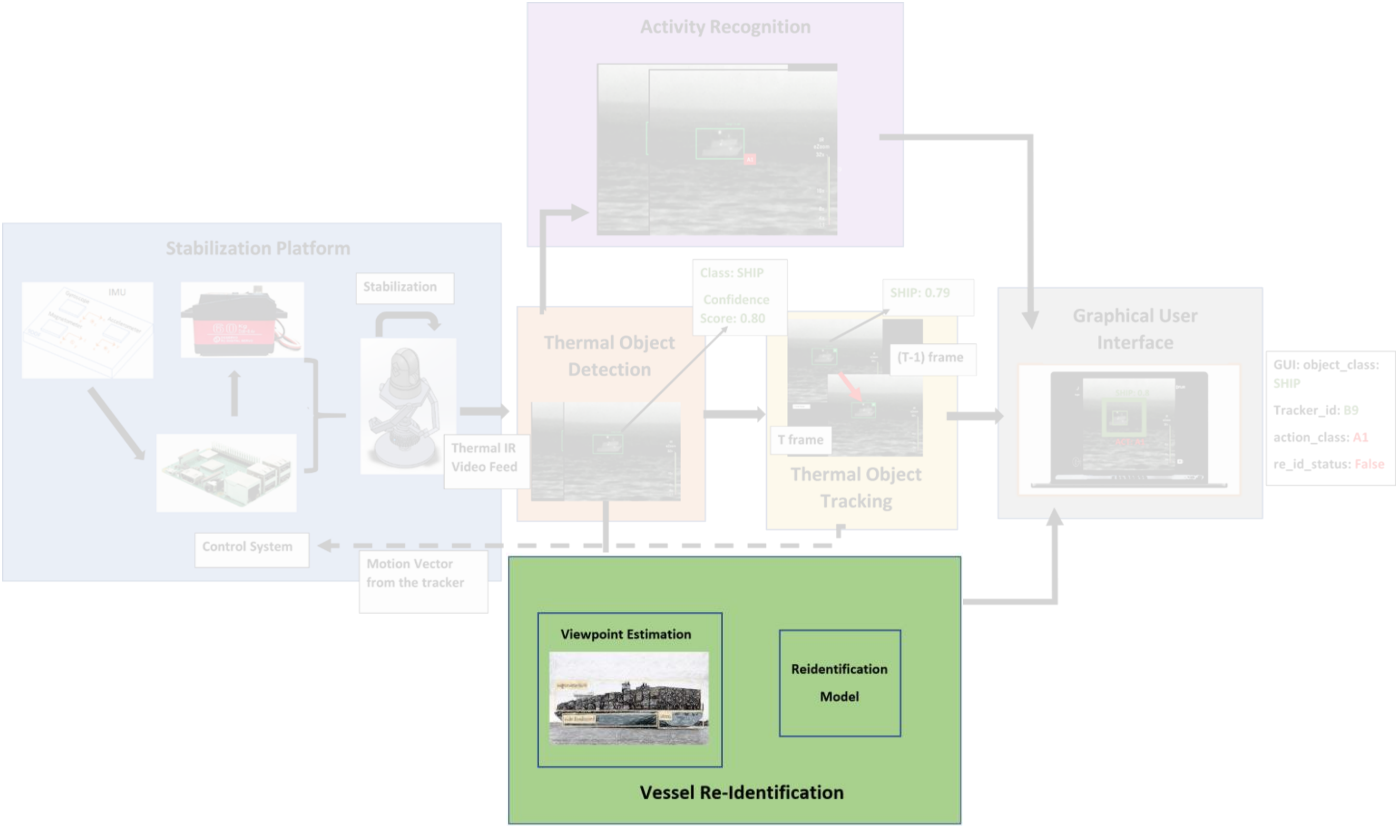
Critically Evaluation of alternative strategies - Vessel Re-Identification



Vessel Re-Identification

After an vessel is detected at the first instance the data related to it are stored. Then when the same vessel reappears at a later time, it should be re-identified as the former vessel.

	Global and Local based Discriminative Feature Learning[1]	Viewpoint- aware Metric Learning[2]	Viewpoint aware Attentive Multi View Inference[3]
Context	Vessel	Vehicle	Vehicle
New Dataset Creation	Vessel ID - 539	-	-
No. Viewpoints considered	4	3 (Ver-776 Dataset) 2 (VehicleID Dataset)	4
Evaluation	With Resnet50 - SE	ResNet50	ResNet50
Vessel ID - 539	74.9 61.4 89.6		
Veri776	-	66.34 89.78 95.99	63.12 83.25 92.40
VehicleID	-	88.12 97.29	61.32 85.92 91.84

MAP
Rank -1
Rank -5

space

[1]Qiao, Dalei, Guangzhong Liu, Feng Dong, She-Xiang Jiang, and Likun Dai. "Marine vessel re-identification: a large-scale dataset and global-and-local fusion-based discriminative feature learning." *IEEE Access* 8 (2020): 27744-27756.

[2]Chu, Ruihang, Yifan Sun, Yadong Li, Zheng Liu, Chi Zhang, and Yichen Wei. "Vehicle re-identification with viewpoint-aware metric learning." In *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pp. 8282-8291. 2019.

[3]Zhou, Yi, and Ling Shao. "Aware attentive multi-view inference for vehicle re-identification." In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 6489-6498. 2018.

Dataset Annotation Approaches

A set of images/videos obtained with the camera should be annotated with labels for training the models as required.

- Comparison of open Source platforms that can be used for annotation.

	CVAT [1]	**VoTT** [2]	**Scalable** [3]
Web platform	Available	Available but cloud storage is necessary	Not available
Supporting materials	Available	Available	Relatively less
Features	High level of features	Moderate level of features	Moderate level of features

- Approach of labelling.
  - Labelling viewpoints, parts of vessels
  - Labelling Vessel types
  - Labelling vessels uniquely for re identification

[1] https://github.com/openvinotoolkit/cvat
[2] https://github.com/microsoft/VoTT
[3] https://github.com/scalabel/scalabel

Budget for the project

Item	Unit Price($)	No: of Units	Total($)	Total(LKR)	Sponsored
FLIR M232 Thermal Camera	3499	1	3499	696301.00	Yes
Servo Motor	37	3	111	22,143.58	No
Battery		1			No
Raspberry Pi 4	55	1	55	10972.04	No
IMU Sensor	15.95	2	31.9	6363.79	No
Platform Frame Design	60.15	1	60.15	12000.00	No
GPU		1		Rs. 129860.02	Yes
Total					

Uniqueness of the End Solution

- A unique set of detection functionalities
- Ability to be used in varied visibility conditions
- Automation of ~~Surveillance~~ maritime surveillance
- Flexibility of the the camera used.
- Creation of a thermal maritime dataset

Potential Customers and Product Impact

- **Sri Lanka Navy**
  - Enables providing better security to our country.
  - Enables preventing threats to our country with more ease and efficiency.
  - Result in better national security
- **Sri Lanka Coast Guard**
- **Other Researchers**

Risk Factors - Technical Risks

Risk	How to overcome
Camera control only through proprietary software of ReyMarine	Make use of the stabilization platform for control.
Mechanical Stabilization not sufficient.	Software + mechanical stabilization
Time complexity of the process	Selection of fast models with lesser number of stages
Unavailability of a public dataset for the training process	Make use of the Dataset that we create.
Multiple object pan based tracking through platform is not feasible	Prioritizing the targets

Risk Factors - Financial Risks

Risk	How to overcome
Malfunctioning situations of the ordered component	Interacting with highly recognized vendors
Increase of cost more than the granted fund.	Self funding
HIgh delivery costs for multiple orders for components	Deep study on the component selection, Order the components at once.

Risk Factors - Health Risks

Risk	How to overcome
Non disposable product	Recycling the wastage without disposing
Poor health precautions followed by the delivery workers.	Use of proper delivery methods.
Data Collection in the Covid Period	Following proper safety precautions under the guidance of Health Bureau of Sri Lanka

Risk Factors - Sustainability Risks

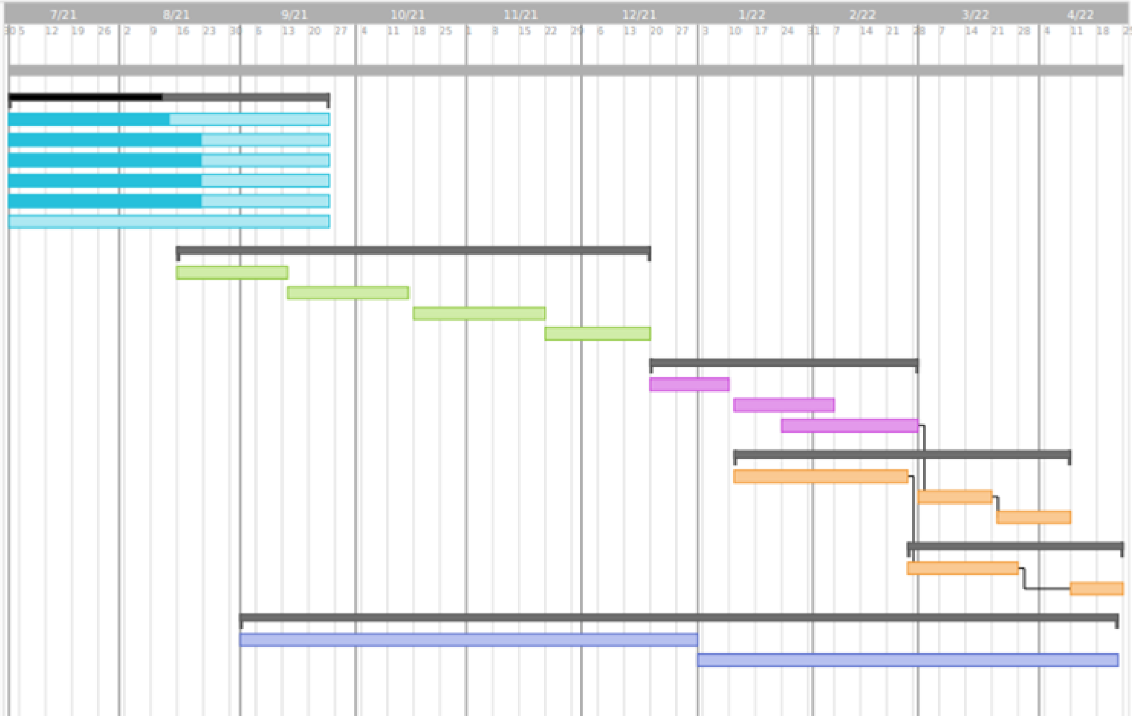
Risk	How to overcome
Corrosion of components due to saline environment	Use corrosion resistant manufacturing materials.

Main Task Delegation

Task Group	Responsible Person Name	Sub Task(s)	Tharindi	Nipun	Sathira	Kavindya
Stabilization Platform	Tharindi	Design using SW				
		Control System Design				
		Firmware Design				
		Hardware Design				
		Simulation				
		Manufacturing				
Action Recognition	Nipun	Pipeline Design				
		Evaluation of Open Datasets				
		Training for Created Dataset				
Object Detection	Sathira	Training for Created Dataset(Thermal IR)				
		Hyper Parameter Tuning for Thermal IR				
		Developments				
Object Re Identification	Kavindya	Viewpoint Estimation Model				
		Vessel Re- Identification Model				
Dataset Creation and Annotation	All	Dataset Creation				
		Dataset Annotation				
Software Design	Sathira	Re-Id Feature				

Timeline 15/06/2021 - 22/04/2022

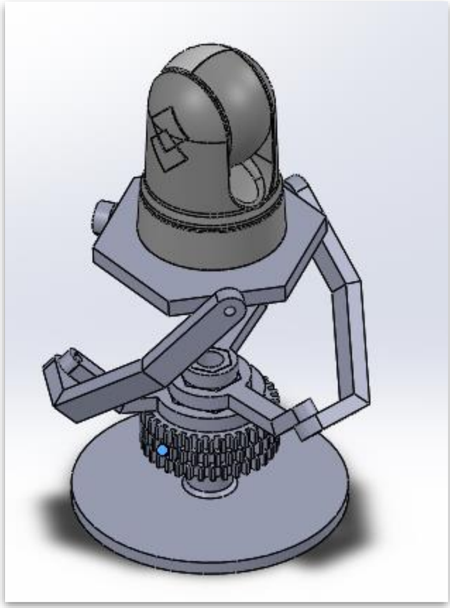
Object Detection, Tracking,...	start	end
Literature Research	**01/07/21**	**23/09/21**
Stabilization Platform	01/07	23/09
Object Detection	01/07	23/09
Object Tracking	01/07	23/09
Activity Recognition	01/07	23/09
Vessel Re-Identification	01/07	23/09
GUI	01/07	23/09
Development of Stabilization Platf...	**16/08/21**	**17/12/21**
Camera Stabilization Platform design	16/08	13/09
Camera Stabilization Platform simula...	14/09	14/10
Camera Stabilization Platform manuf...	18/10	19/11
Testing	22/11	17/12
Dataset Creation for Maritime Envi...	**20/12/21**	**28/02/22**
Dataset Annotation tools testing	20/12	07/01
Dataset Creation	11/01	04/02
Dataset Annotation	24/01	28/02
Object Detection, Tracking and Act...	**11/01/22**	**08/04/22**
Pipeline Design	11/01	24/02
Training the created Datasets for ea...	01/03	18/03
Optimizing the models	22/03	08/04
Integrating the Models	**25/02/22**	**22/04/22**
Pipeline Creation - Programming	25/02	25/03
Evaluation of the Test Dataset	11/04	22/04
Object Re-Identification	**01/09/21**	**21/04/22**
View Point Estimation	01/09	30/12
Object Re-Identification Model	31/12	21/04



Current Progress - Platform Design Using Solidworks

did you receive the thermal camera? if so, mention initial testing

→ Platform Design SW



Platform Design - In Progress

Final Expected Outcome

Tursynbek, Iliyas, Aibek Niyetkaliye, and Almas Shintemirov. "Computation of unique kinematic solutions of a spherical parallel manipulator with coaxial input shafts." In *2019 IEEE 15th International Conference on Automation Science and Engineering (CASE)*, pp. 1524-1531. IEEE, 2019.

Thanks!

Q & A