SUMMER INTERNSHIP REPORT

On

OBJECT TRACKING USING IMAGING TECHNIQUES -AN IN DEPTH ANALYSIS

PROOF AND EXPERIMENTAL ESTABLISHMENT (PXE) DEFENCE RESEARCH & DEVELOPMENT ORGANISATION (DRDO) CHANDIPUR, BALASORE 756025

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ABSRACT

Defense innovation plays a pivotal role in ensuring national security and asserting technological leadership on the global stage. The development of strategic systems requires interdisciplinary expertise and a collaborative environment that enables the rapid transformation of innovative ideas into practical defense solutions.

During our summer internship at the Proof and Experimental Establishment (PXE), DRDO, we had the opportunity to explore real-world defense applications involving advanced image processing techniques. Our project focused on implementing and analyzing three core computer vision methods: Kanade-Lucas-Tomasi (KLT) feature tracking, Optical Flow, and Background Subtraction.
Using MATLAB, we applied these techniques to track moving objects in real-time video sequences. Background subtraction allowed us to isolate motion by separating dynamic elements from static scenes. Optical flow provided pixel-level motion estimation, capturing subtle movements across frames. The KLT algorithm enabled robust tracking of distinct feature points, maintaining object identity even under partial occlusion or motion blur.

Through this work, we gained practical insights into motion detection, trajectory analysis, and feature tracking—skills critical for defense applications such as surveillance, missile tracking, and autonomous targeting systems. This hands-on experience deepened our understanding of imaging technologies and reinforced the importance of indigenous research in strengthening national defense capabilities.

These projects significantly expanded our technical knowledge in signal processing, circuit design, and human-machine interaction, while also highlighting the importance of indigenous defense technologies.. The internship has enriched our practical skills and strengthened our resolve to contribute to India’s vision of technological self-reliance and innovation in defense systems.

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ABOUT DRDO

The Defence Research and Development Organisation (DRDO) is India’s premier agency for research and development in defense technologies. Established in 1958 under the Ministry of Defence, DRDO was formed by merging the Defence Science Organisation with some existing technical development establishments. Headquartered in New Delhi, it has grown into a network of more than 50 laboratories working in diverse fields such as aeronautics, armaments, electronics, combat vehicles, engineering systems, instrumentation, missiles, advanced computing, and naval systems.

DRDO’s primary objective is to make India self-reliant in defense technologies and systems. It aims to design, develop, and produce cutting-edge weapons and equipment to support the Indian armed forces. Over the decades, it has played a critical role in strengthening India’s defense capabilities by delivering indigenous solutions like the Agni and Prithvi missile series, Tejas Light Combat Aircraft, Arjun Main Battle Tank, PINAKA multi-barrel rocket launcher, and Akash surface-to-air missile system.

The organization is divided into several clusters based on its areas of specialization, such as the Missile and Strategic Systems (MSS) cluster, ACE cluster, and Naval Systems & Materials (NS&M).
These clusters ensure focused research and efficient project execution. DRDO also collaborates extensively with academic institutions, public sector undertakings, and private industry to foster innovation and
technology transfer.

Some of the major contributions of DRDO is in the area of missile technology. Under the Integrated Guided Missile Development Programme (IGMDP), DRDO achieved remarkable progress in creating a family of strategic and tactical missiles. In addition, the organization is involved in developing technologies for cyber security, artificial intelligence, and electronic warfare.

In recent years, DRDO has also contributed significantly to civilian applications, especially during national emergencies. During the COVID-19 pandemic, DRDO developed ventilators, sanitization chambers, and PPE kits to support the healthcare sector.

In conclusion, DRDO stands as a pillar of India’s defense preparedness and technological advancement.Through its dedicated efforts and continuous innovation, DRDO not only enhances the country's strategic strength but also supports the vision of “Atmanirbhar Bharat” (Self-reliant India) in the field of defense and
beyond.

ABOUT PXE

PXE, a premier DRDO lab, is located at Chandipur, Odisha, 15 km from Balasore on the coast of the Bay of Bengal.

Vision:

To transform into a world-class dynamic test and evaluation centre for armament stores.

Mission:

Test, evaluation, and proof of various armament stores.

● PXE is one of the oldest DRDO establishments ,initially setup in 1895 by a government order.
● The first firing took place on 7 November 1895, with Captain R.T. Moore as the first Proof Officer.
● The lab was brought under the DRDO in 1958, leading to major modernization and global recognition.

●PXE specializes in testing guns ,mortars ,rockets ,tank guns, naval weapons, and related ammunition.
● It also evaluates armour systems ,including tank armour ,ICVs ,proximity fuzes, and more.
● Technologies developed include S-band and X-band radars and gun mounts for MBT Arjun.
● Chandipur'screscent-shapedcoastprovidesanaturalandsafeenvironmentforprojectiletrials.

The Proof and Experimental Establishment (PXE) was strategically established at Chandipur, Balasore, Odisha, for a combination of unique geographical, logistical, and scientific advantages.

1. Receding Sea Water – Over 3 km During Low Tide
● **Chandipur beach is unique**: During low tide, the Bay of Bengal recedes by more than 3 km, exposing a wide stretch of hard-packed sand.
● This natural feature enables easy recovery of projectiles like artillery shells, bombs, rockets, and missile components without deploying divers or marine recovery units
. ● **Why recovery matters:**
After any firing test, it is critical to retrieve the fired ammunition/projectile to:
- Examine for structural deformities, cracks, or thermal damage
- Perform failure analysis
- Check ballistic integrity

● **Hard seabed**: The exposed seabed during low tide offers a flat and firm surface ideal for impact
studies and projectile retrieval with minimal sinking or scattering

2. Crescent-Shaped Coastline (~5 km long)

- The curved or crescent (half-moon) shaped coast provides a natural bay-like environment.
- This geography helps in:
    - Naturally bounding the flight path of test projectiles, preventing them from veering too far off due to crosswinds or misfires
    - Reducing wave turbulence, making the waters calmer during low tide, which aids in safe projectile recovery.
    - Serving as a semi-enclosed testing range, with minimal need for artificial barriers or containment areas.
- The ~5 km curvature makes tracking radars, cameras, and sensors easier to deploy in an arc for comprehensive telemetry.

3. Uninhabited Coastal Belt

- The area around PXE and Integrated Test Range (ITR) is sparsely populated, reducing risk to civilians and making it ideal for live-fire testing.

4. Long Stretch of Open Land and Water

- Provides a natural firing range for different artillery systems and allows for multiple trajectories
(high-angle, flat, etc.).
- Facilitates sea-based missile testing without needing a ship-based launch.

5. Security and Surveillance

- Coastal location allows easy airspace and maritime zone control.
- DRDO can temporarily block access to certain coastal and air zones during testing.

6. Proximity to Other Defence Installations

- Located near ITR (Integrated Test Range), Wheeler Island (now Abdul Kalam Island)—all major missile and rocket testing activities of India happen here.
- Logistical synergy for missile programs like Agni, Akash, BrahMos, etc.

DRDO PRODUCTS

1. MBT Arjun:

The Arjun Main Battle Tank (MBT) is India's indigenously developed third-generation main battle tank, designed by the Defence Research and Development Organisation (DRDO). It is one of the most advanced armored fighting vehicles in the Indian Army's inventory.

a. Overview of Arjun MBT

- **Name:** Arjun MBT
- **Developer:** DRDO, India
- **Manufacturer:** Heavy Vehicles Factory (HVF), Avadi, Chennai
- **Entered Service:** 2004 (Arjun Mk I), followed by Mk II variant in the 2010s

b. Key Specifications

Feature	ArjunMkI	Arjun Mk II
Main Gun	120 mm rifled gun	Same, with better firepower
Armor	Kanchan composite	Improved Kanchan + ERA
Engine and Weight	armor 1,400 hp MTU diesel engine ~58.5 tons	Same ~68.6 tons
Speed	~70 km/h (on road)	Slightly lower due to added weight
Crew	4 (commander, gunner, loader, driver)	Same
Fire Control	Computerized with thermal imaging and laser range finder	Improved with automatic target tracking and night fighting capability

c. Special Features

- **Indigenous Armor: "Kanchan"** composite armor is highly effective against APFSDS and HEAT and rounds
- . **Advanced Fire Control System:** Enables firing on the move and under low visibility.
- **NBC Protection:** Nuclear, biological, and chemical protection systems for the crew.
- **Hydropneumatic Suspension:** Provides a smooth ride across rough terrain.
- **Auxiliary Power Unit:** Powers the electronics without the main engine.

d. Comparison of the Arjun Mk II with other major MBTs

Feature	Arjun Mk II	T-90 Bhishma	M1A2 Abrams SEPV3	T-14 Armata	Type 99 A	Leopard 2A7+
Origin	India	India/ Russia	USA	Russia	China	Germany
Weight	~68.6 tons	~46.5 tons	~66.6 tons	~55 tons	~54 tons	~66.5 tons
Crew	4	3	4	3	3	4
Main Gun	120 mm rifled	125 mm smoothbore	120 mm smoothbore	125 mm smoothbore(auto)	125 mm smoothbore	120 mm smoothbore
Armour	Kanchan+ ERA	Composite + ERA	Chobham + DU layers	Malachit ERA + capsule	Modular composite + ERA	Advanced composite + modular armor
Engine	1,400 hp diesel	1,000 hp diesel	1,500 hp gas turbine	1,500 hp diesel	1,500 hp diesel	1,500 hp diesel
Power /Weight Ratio	~20.4hp/t	~21.5hp/t	~22.5hp/t	~27.2hp/t	~27.7hp/t	~22.5hp/t
Top Speed	~58km/h	~60km/h	~67km/h	~80km/h	~80km/h	~72km/h
Range	~500km	~550km	~425km	~500+km	~600km	~450km
Fire Control	Advanced, with auto target tracking	Good (Russian tech)	Highly advanced, integrated sensors	AI-assisted system	Modern FCS	Superior digital FCS
Night Vision/ Thermal	Yes	Yes	Yes	Yes	Yes	Yes

Protection System	Explosive Reactive +Kanchan + laser warning	Shtora +ERA	Trophy APS (in newer versions)	Afghanit APS	ERA + Laser detection	Active/Passive system

2. Pinaka MBRL System:

The Pinaka Rocket System is a multiple barrel rocket launcher (MBRL) developed by India's DRDO. It is named after the bow of Lord Shiva and is a vital component of India's artillery modernization.

Key Features of the Pinaka Rocket System:

a. Purpose & Role

- Designed to replace the older Russian BM-21 Grad systems.
- Provides quick and high-volume saturation fire against enemy targets at long ranges
.
- Used for area denial, suppression of enemy artillery, and destruction of concentrated troop formations.

b. Versions

- **Pinaka Mk-I:**
  - Range: ~40 km
  - Warhead: High-explosive, incendiary, anti-tank, anti-personnel types
- **Pinaka Mk-II:**
  - Range: ~60–75 km
  - Improved guidance and accuracy (uses inertial navigation with GPS)
- **Pinaka Mk-III / Guided Extended Range (under development):**
  - **Range: ~90+ km**
  - **Enhanced precision and longer reach**

c. Launcher System

- Mounted on Tatra 8x8 trucks for mobility.
- Each launcher has 12 tubes, and a battery consists of 6 launchers
.
- Fully automatic reloading, laying, and firing system.
- Fires a full salvo of 12 rockets in 44 seconds.

d. Guidance (for Mk-II and beyond)

- Integrated navigation systems.
- Mid-course correction for improved

e. Indigenization & Production

- Developed by DRDO; produced by Tata Powe rSED, Larsen & Toubro(L&T),and BEM.
- Export potential to friendly nations.

f. Operational Use

- Successfully used in the Kargil War(1999).
- Deployed along India's western borders with Pakistan and LAC with China.

g**. Comparison of major Multiple Barrel Rocket Launcher (MBRL) systems including India's Pinaka Mk-II, USA's HIMARS and M270 MLRS, and Russia's BM-30 Smerch:**

Feature	**Pinaka Mk-II**	**BM-30 Smerch**	**HIMARS**	**M270 MLRS**
Origin	India	Russia	USA	USA
Range	Up to 75 km	Up to 90–120 km	70–300+ km	70–300+ km
Rockets/ Launcher	12	12	6	12
Guidance	GPS + Inertial	Inertial/GLONASS	GPS + Inertial	GPS + Inertial
Mobility	Wheeled (Tatra)	Wheeled (MAZ)	Wheeled (FMTV)	Tracked (Bradley)
Notable Feature	Indigenous & rapid	Heavy warheads	Precision, mobility	Heavy tracked launcher

3.**ATAGS (Advanced Towed Artillery Gun System):**

a. Developed by:

DRDO (specifically by **Armament Research & Development Establishment (ARDE)** in collaboration with PXE, and manufactured with partners like **Bharat Forge (Kalyani Group)** and **TATA Advanced Systems).**

b. Overview

ATAGS is an **indigenous 155 mm, 52-calibre towed artillery gun system** developed under India's "Make in India" initiative. It aims to modernize the Indian Army's artillery regiments with a powerful, long-range, and fully automated

c. Key Features and Capabilities

Feature	Details
Caliber	155 mm
Barrel Length	52 Calibre (i.e., 52 x bore diameter)
Range	Over 48 km with extended range projectiles (record achieved: 48.074 km)
Rate of Fire	5 rounds per minute (sustained), burst mode: 3 rounds in 30 seconds
Ammunition Compatibility Weight	NATO standard 155 mm ammunition ~18 tons
Automation	Fully automated loading and laying system
Crew Required Mobility	6–8 personnel Towed by high-mobility vehicle (8x8 truck)
Fire Control System	Electro-mechanical, with advanced ballistic computer & GPS support
Recoil System	Advanced retractable hydro-pneumatic recoil

d. Notable Achievements

- World Record: Longest range achieved in its class (over 48 km with HE-BB ammunition).
- Successfully tested in Sikkim and Pokhran under extreme temperatures and terrain.
- Developed by a consortium approach: DRDO (ARDE, PXE), Bharat Forge, Tata Advanced Systems.

e. Advantages Over Older Systems

- Greater range and accuracy than Bofors FH-77B.
- Fully automated features reduce crew fatigue and increase speed.
- Modular design allows easy maintenance and upgrades.
- Contributes to strategic autonomy in defense production.

System	Country	Caliber	Barrel Length	Max Range	Remarks
ATAGS	India	155 mm	52 cal	~48 km	Indigenous, advanced FCS
M777 (Ultra Light)	USA/UK/India	155 mm	39 cal	~30 km	Lightweight, air-portable
Caesar	France	155 mm	52 cal	~42 km	Wheeled self-propelled
K9 Vajra-T	South Korea/India	155 mm	52 cal	~40 km	Tracked self-propelled

g. ATAGS vs Bofors FH-77B Comparison Table
Bofors FH-77B: the 155 mm howitzer that India imported from Sweden in the 1980s.

Feature	**ATAGS** (India)	**Bofors FH-77B** (Sweden)
Caliber	155 mm	155 mm
Barrel Length	52 Calibres	39 Calibres
Max Range	~48 km (with Extended Range Base Bleed)	~24–30km(with standard ERFB-BB rounds)
Rate of Fire	5 rounds/min (sustained); 3 round burst in 30 sec	3 rounds in 15seconds burst; sustained 2rds/min
Automation	Fully automated loading and laying	Semi-automaticloading
Weight	~18tons	~11.5tons
Crew Required	6–8 personnel	6–8 personnel

Recoil System	Advanced Electro Hydraulic Recoil System	Hydro-pneumatic recoil
Mobility	Towed by 8x8 high mobility truck (TATA or Bharat Forge)	Towed by trucks (originally by Scania trucks)
Fire Control System	Digital, Electro Mechanical with GPS and INS guidance	Manual sights and analog FCS
Ammunition Compatibility	NATO 155 mm standard rounds	NATO 155 mm standard rounds
Indigenous Content	~80–90% (designed and built in India)	Completely imported from Sweden
Operational Since	Under induction since 2023 (in trials earlier)	Inducted in Indian Army in 1986–87

Conclusion

While **Bofors FH-77B** served India extremely well (especially during the **Kargil War**),the significant **technological leap forward**,providing:

- Longer range
- Greater fire power
- Bette raccuracy
- Indigenous capability

ATAGS is not just a replacement, but a **next-generation artillery system** suited for modern battlefield requirements.

ABOUT CAMERA

A camera is a device that captures images or videos by recording light through a lens. It typically consists of a sensor (like a digital sensor or film) that captures the light, and a lens that focuses the image. Cameras can be used for a wide range of purposes, from photography to video recording, and come in various forms, such as smartphones, DSLRs, and mirrorless models. The quality of the captured image depends on factors like resolution, lens quality, and sensor size.

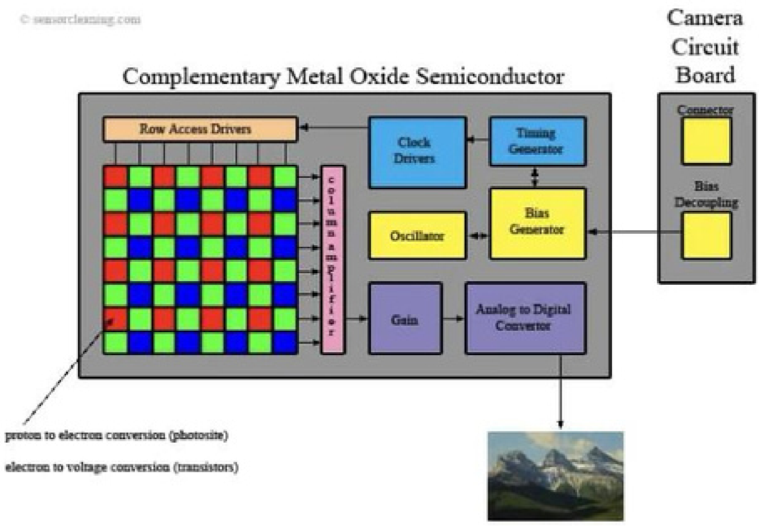
Fig: DSLR
Camera

ABOUT SENSORS

A sensor camera uses image sensors to capture visual data. It detects light through lenses, converts it into electronic signals, and creates images or videos for monitoring or analysis.They are two type of image sensors used in digital cameras imaging devices . 1- Complementary Metal Oxide Semiconductor (CMOS) 2- Charged Couple Device (CCD)

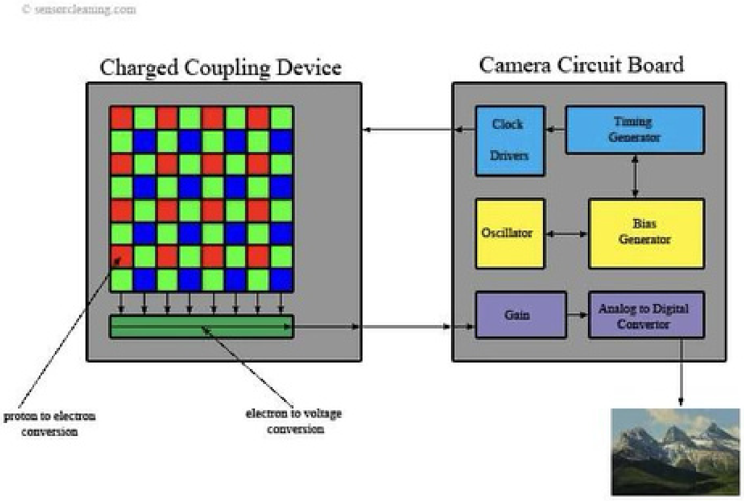
CMOS- A CMOS sensor camera uses a Complementary Metal-Oxide-Semiconductor sensor

to capture



images. It's energy-efficient, fast, and commonly found in smartphones, webcams, and digital cameras. CMOS sensors convert light into electrical signals, enabling digital image processing.

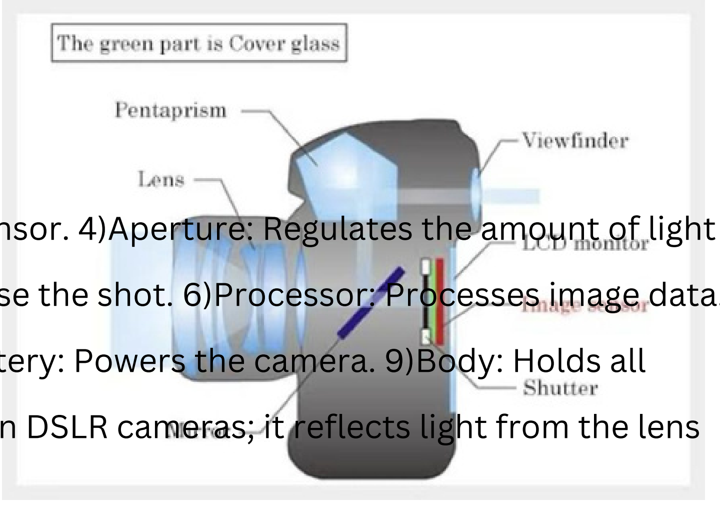
CCD - A CCD sensor camera uses a Charge-Coupled Device to capture images. Here's a simple explanation. CCD sensor camera. Converts light into electrical signals using a special chip. Known for high image quality, low noise, and accurate color reproduction. Commonly used in professional photography, astronomy,



and medical imaging. Generally consumes more power and is more expensive than CMOS cameras.

CAMERA COMPONENTS

The main components of a camera : 1)Lens: Focuses light onto the sensor. 2)Image Sensor: Captures the image (e.g., CMOS, CCD).



3)Shutter: Controls how long light hits the sensor. 4)Aperture: Regulates the amount of light entering.. 5)Viewfinder/Screen: Helps compose the shot. 6)Processor: Processes image data. 7)Storage: Saves photos (e.g., SD card). 8)Battery: Powers the camera. 9)Body: Holds all components together. 10)Pentaprism: Used in DSLR cameras; it reflects light from the lens to the optical viewfinder, allowing
you to see exactly what the lens sees in real-time (optical view).
11) LCD Mirror - Found on digital cameras displays digital preview from the camera sensor

,allowing live
view,playback, and menu access.

CAMERA USES IN DRDO

DSLR: The Nikon D5 is a professional-grade DSLR camera known for its speed, durability, and low-light performance.

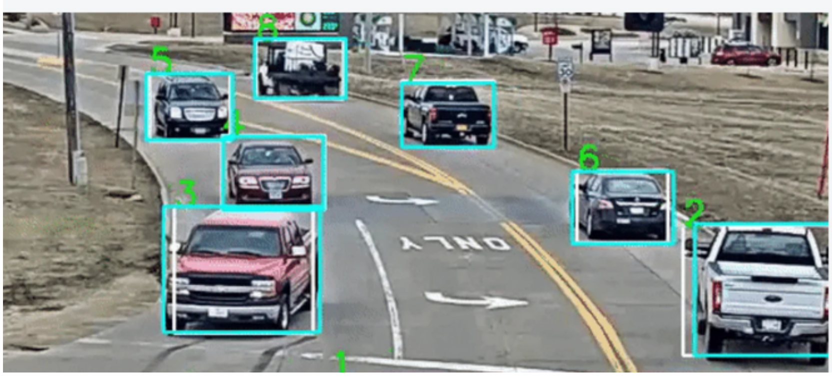
Key features include:

- 20.8 MP full-frame sensor EXPEED 5image processor
- 12 fps continuous shooting
- 4K UHD video recording.
- 153-point autofocus system.
- Dual XQD or CF card slots

PHOTRON FASTCAM SA5: The Photron FASTCAM SA5 is a high-speed camera offering: Ideal for applications in materials research, ballistics, aerospace, PIV, combustion, fluid dynamics, and cavitation.

1. Resolution & Frame Rate: Captures 7,000 fps at 1,024 × 1,000 pixels; up to 775,000 fps at reduced resolution. 2. Sensor: 12-bit monochrome (36-bit RGB color) CMOS with 20 µm pixels. Exposure Time: Minimum 369 ns for 1,000,000 fps models. 3. Memory Options: 8GB, 16GB, 32GB, or 64GB. Control Interface: Includes a remote keypad with a 5-inch LCD screen for standalone operation. 4. Software: Comes with Photron FASTCAM Viewer (PFV) and Software Development Kit (SDK) for integration.

Object Tracking Using Imaging Technique :



Introduction

Object tracking using imaging techniques is a fundamental problem in the field of computer vision and image processing. It involves detecting, localizing, and following the trajectory of objects as they move through a sequence of video frames. The objective is not just to recognize what an object is, but to continuously monitor its movement and interactions with the environment.

Object Tracking?

In dynamic environments, real-time information about object motion is essential for decision-making. Object tracking provides this dynamic understanding, which enables machines to perceive their surroundings and respond accordingly. This capability is crucial for:

- Security and Surveillance: Identifying suspicious activity, monitoring restricted zones, or tracking individuals in public spaces.
- Autonomous Systems: Helping self-driving cars detect and respond to pedestrians, other vehicles, and road conditions.
- Human-Computer Interaction: Recognizing gestures, facial expressions, and body movements for interactive systems.
- Robotics: Allowing robots to navigate, manipulate objects, and perform tasks in unstructured environments.

Core Challenges in Object Tracking:

Despite being a well-studied problem, object tracking remains challenging due to several factors:

- **Occlusion:** Objects may be partially or fully hidden by other objects.
- **Lighting Variations**: Shadows or changes in brightness can confuse tracking algorithms.
- **Scale and Orientation Changes**: Objects may appear larger, smaller, or rotated as they move.
- **Background Clutter:** Dynamic or textured backgrounds can make object separation difficult.
- **Real-Time Constraints:** Applications like autonomous driving or security require processing at high speed.

Role of Imaging Techniques

To address these challenges, a combination of imaging techniques is used, including:

- Background Subtraction: Isolates moving objects from static scenes.
- Optical Flow: Estimates the motion of each pixel across frames.
- Feature-Based Methods (e.g., KLT): Tracks key feature points like corners or edges

These techniques help simplify the scene, extract relevant features, and maintain object identities over time. By leveraging imaging and mathematical models, object tracking transforms raw visual data into actionable insights.

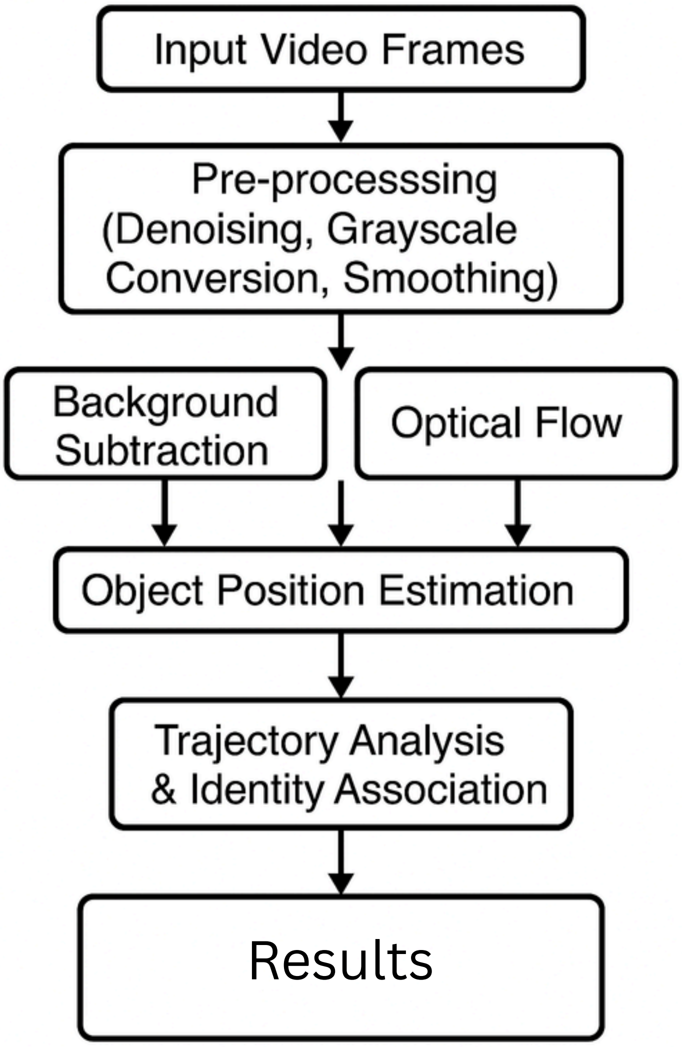
Relevance and Importance

With the advent of AI, IoT, and edge computing, object tracking has expanded from research labs into real-world applications such as:

- Smart traffic systems
- Industrial automation
- Augmented and virtual reality (AR/VR)
- Sports performance analytics
- Wildlife monitoring

As visual sensors become cheaper and more ubiquitous, the demand for efficient and robust tracking systems continues to grow. The integration of classical algorithms with modern deep learning methods further enhances tracking accuracy and adaptability.

Flowchart of Object Tracking Method



Methodology:

- The process begins with the acquisition of input video frames, captured from camera

- The video frames undergo pre-processing to enhance quality and reduce computational complexity. This involves denoising to eliminate random noise, converting frames to grayscale to simplify processing, and applying smoothing filters to stabilize pixel intensity variations.

- Following pre-processing, the pipeline branches into multiple tracking approaches, including:

  Background Subtraction: Detects foreground motion by comparing each frame static reference background.
  Optical Flow: Estimates pixel-wise motion vectors to track object movement.

The data from these tracking methods is integrated in the Object Position Estimation stage, where spatial and motion information is used to accurately localize objects in each frame.

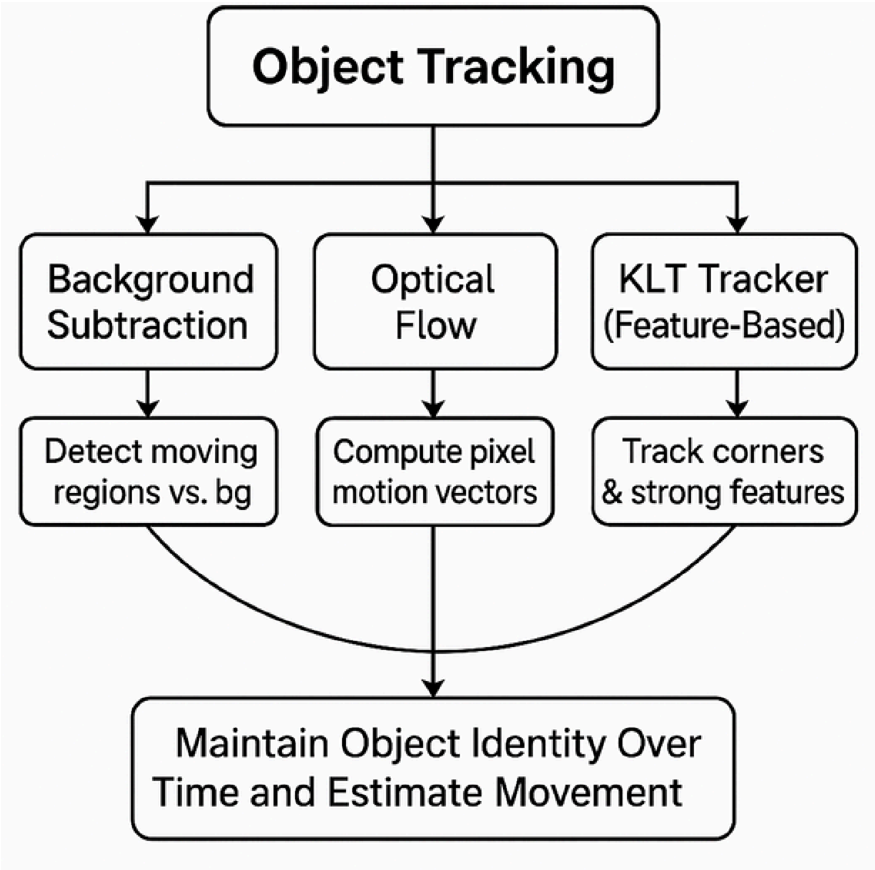
- Next, **Trajectory Analysis & Identity Association** ensures that objects are consistently identified and tracked across frames, enabling the construction of motion paths and persistent identity tracking.

- The final (currently placeholder) step would typically involve visualization or export of tracked trajectories, allowing further analysis or integration into higher-level systems such as behavior recognition or anomaly detection.

- Result:

The implemented pipeline successfully tracks moving objects with high accuracy across video sequences, even in varying conditions. The results demonstrate reliable object localization and trajectory continuity, validating the effectiveness of the tracking system.

Functionality Mapping of Techniques

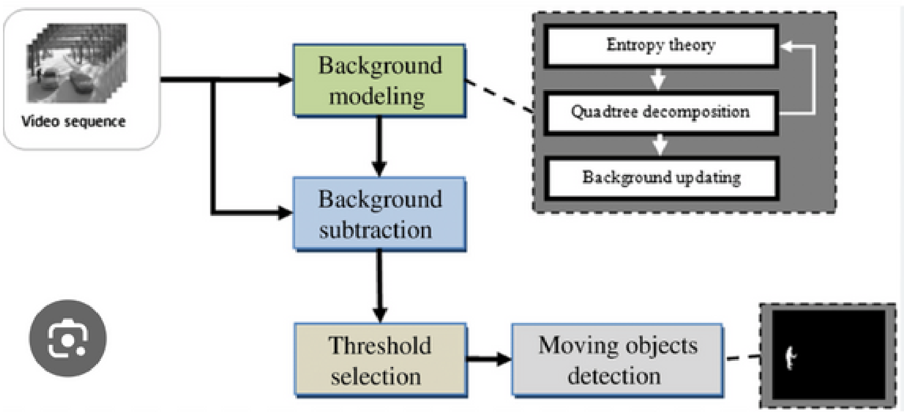


Assessment 1:

Background Subtraction:

Background Subtraction (BS) is a widely used technique in computer vision for detecting moving objects in video sequences. It separates foreground elements (moving objects) from the static background. This method is crucial in areas such as surveillance, traffic monitoring, and human-computer interaction.

Objective:
To detect moving objects from a static camera video using background subtraction and analyze the output shown derived from the provided video.



1. **Video Input:** A sequence of frames from a video feed is used as input.
2. **Background Modeling:** A static background is modeled using multiple frames. Advanced steps include entropy-based analysis, quadtree decomposition, and regular background updating to adapt to gradual scene changes.
3. **Background Subtraction:** The current frame is compared with the background model to extract moving (foreground) objects.
4. **Threshold Selection:** A threshold is applied to refine the difference image and reduce noise.
5. **Object Detection:** The result is a binary output highlighting moving objects.

Conclusion:
This method effectively detects motion in video sequences and is widely used in surveillance, traffic, and defense systems.

Methodology (Implemented in MATLAB)

1. Load Video:

```matlab
videoReader = VideoReader('2288346-hd_1920_1080_25fps (1).mp4');
```

2. Read First Frame as Background:

```matlab
background = readFrame(videoReader);
background = rgb2gray(background);
```

3. Apply Filter to Background:

```matlab
h = fspecial('average', [3 3]);
backgroundFiltered = imfilter(background, h);
```

4. Process Each Frame:

```matlab
while hasFrame(videoReader)
    currentFrame = readFrame(videoReader);
    grayFrame = rgb2gray(currentFrame);
    frameFiltered = imfilter(grayFrame, h);
    diffFrame = abs(double(backgroundFiltered) - double(frameFiltered));
    bw = diffFrame > threshold; % e.g., 30
    ...
end
```

5. Morphological Operations:

```matlab
bw = imopen(bw, strel('disk', 3));
bw = imclose(bw, strel('disk', 5));
```

Results

Case 1: Moving Background with Static Object (Camera in Motion)

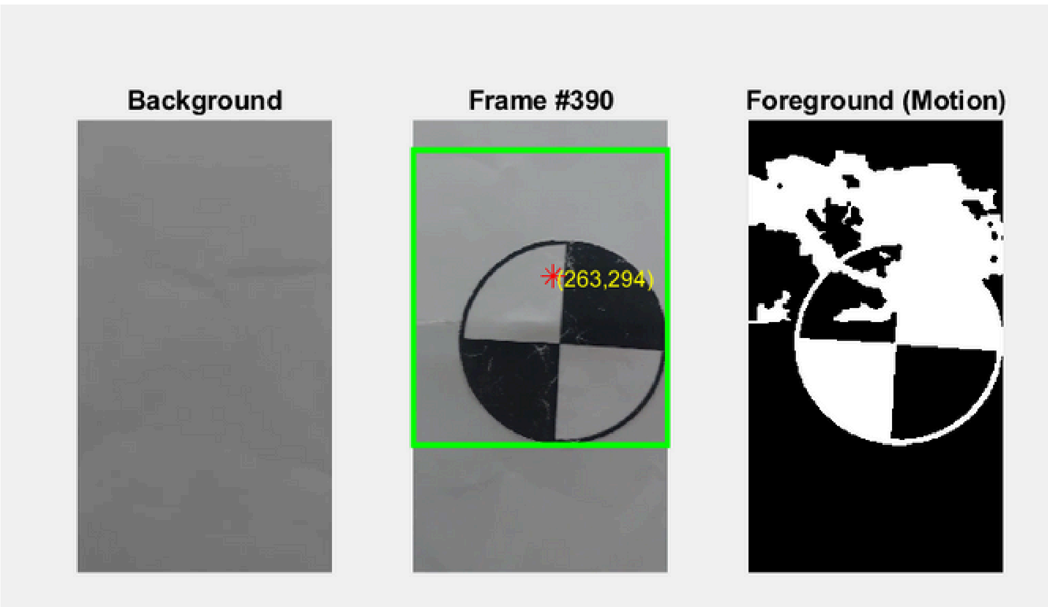
Description:
This scenario involves the use of a mobile or moving camera, such as one mounted on a handheld device or a drone, while the object of interest remains stationary within the scene. As the camera moves, the background appears to shift in each frame due to changes in perspective, lighting, or angle. This introduces significant complexity for traditional background subtraction techniques, which generally assume a static background captured from a fixed viewpoint.

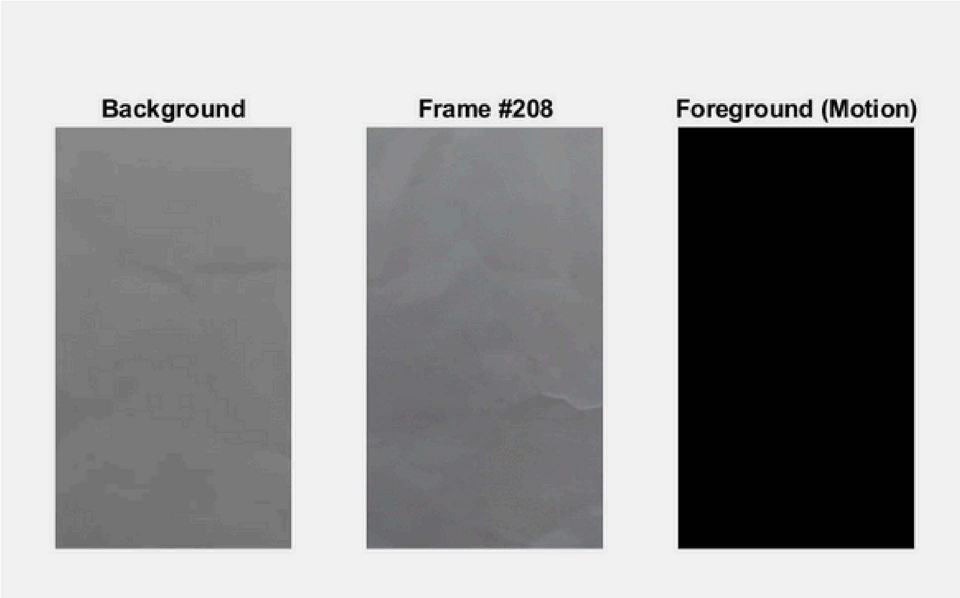
In such dynamic conditions, directly comparing each frame with a fixed background model often leads to incorrect results, as the entire frame appears to be in motion—even though the actual object has not moved. This can cause false detections or the failure to isolate the target object.

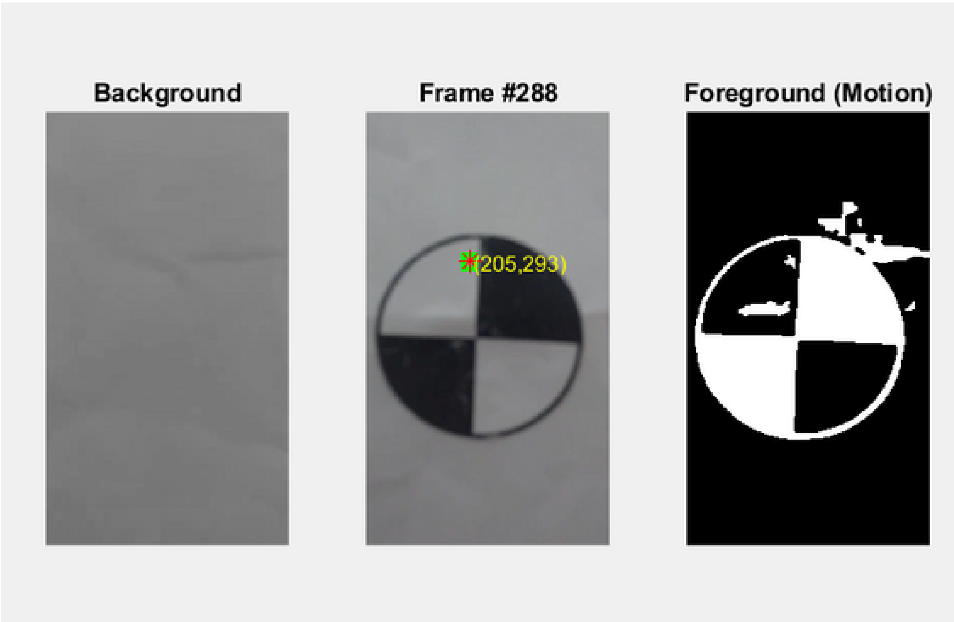
To address this, advanced computer vision methods are required:

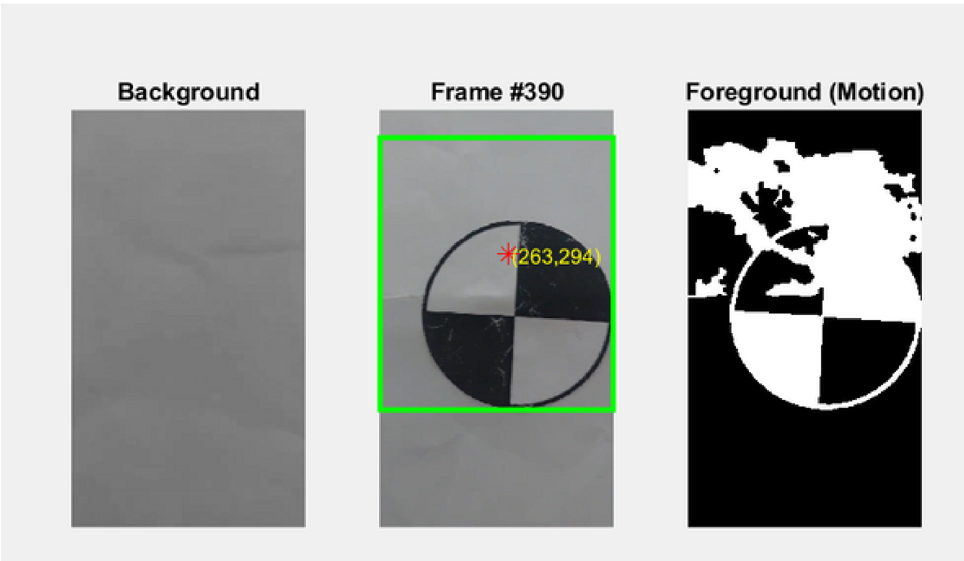
- **Frame Alignment:** Aligns successive frames using geometric transformations to simulate a stationary camera view.
- **Homography Estimation:** Calculates a transformation matrix that maps one frame to another, compensating for camera rotation or translation.
- **Feature Matching:** Detects and matches key points (like corners or edges) between frames to estimate the motion of the camera and stabilize the background.

By applying these techniques, the scene can be motion-compensated, allowing background subtraction to function more reliably.




Background
Frame #208
Foreground (Motion)


Background
Frame #288
(205,293)
Foreground (Motion)


Background
Frame #390
(263,294)
Foreground (Motion)

1. Frame #208: No Motion Detected

- **Background and Frame** are nearly identical.
- **Foreground (Motion)** is completely black → **No movement detected**.
- This confirms the system correctly identifies when there is **no object motion**.

Conclusion: Background subtraction works accurately when there's no object in motion.

2. Frame #288: Object Appears

- A black-and-white circular object enters the scene.
- Detected centroid at **(205, 293)** shown with a green asterisk.
- Foreground (right image) clearly highlights the circle and some noise at the top.

Conclusion: The object is successfully detected and localized. Minor noise is present but does not affect main detection.

3. Frame #390: Object Shifts Right

- The object has moved to the right; new centroid: **(263, 294)** marked with a red asterisk.
- Green bounding box captures the motion region.
- Foreground image shows **clear object isolation**, with some upper-area noise.

Conclusion: The system tracks the object's position change accurately using centroid and bounding box.

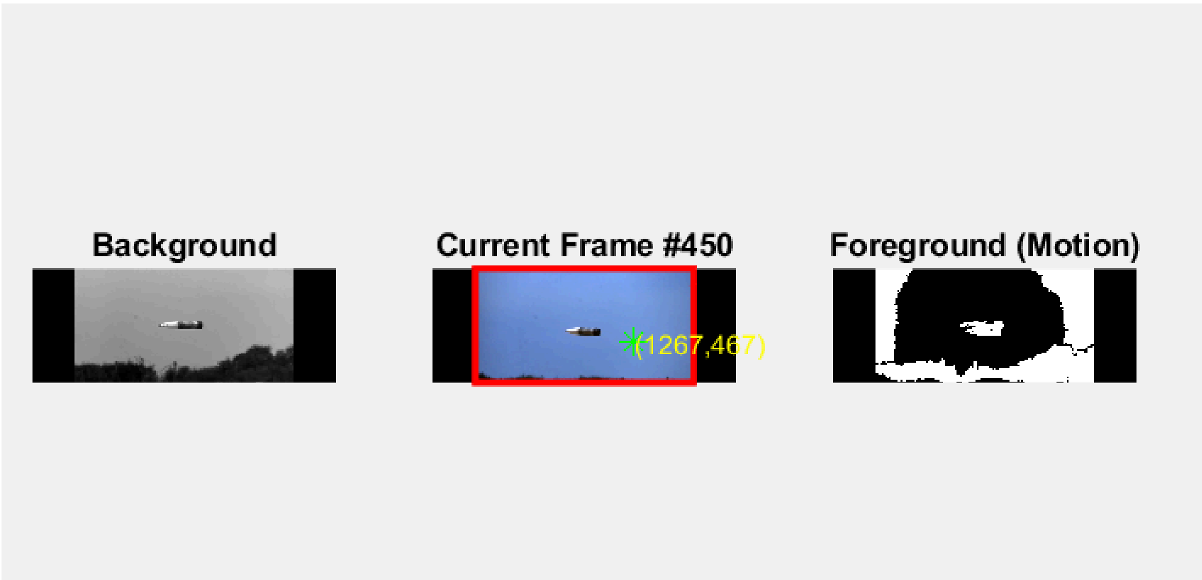
Case 2: Background with Moving Object

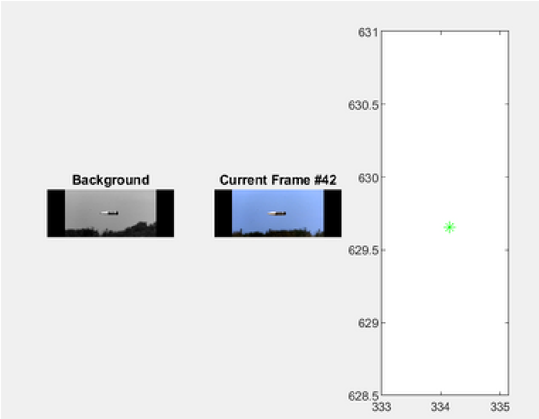
Description:

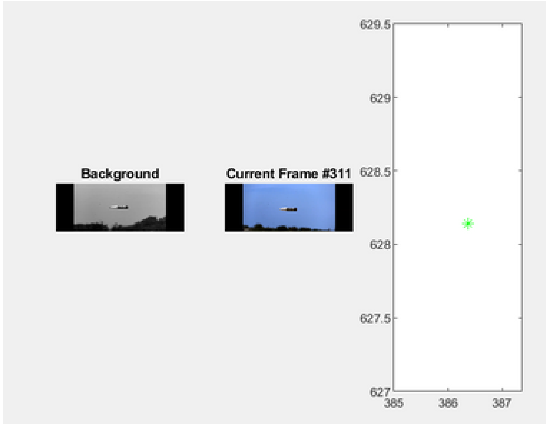
This case features a fixed camera setup, where the background remains constant over time, and the object of interest (such as a missile, vehicle, or person) moves within the scene. Since the camera does not move, any change detected across frames is most likely due to the motion of objects, making this scenario ideal for background subtraction techniques.

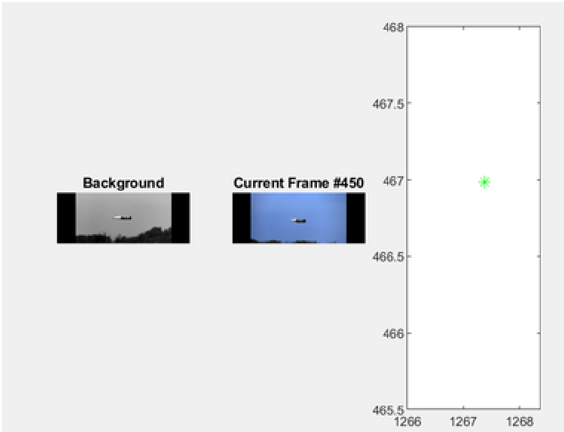
In this approach, a reference background model—usually created from one or more initial frames—is used to compare with each incoming frame. Pixel-wise differences between the current frame and the background highlight the moving regions, effectively isolating the object from the static scene.

This method is highly efficient and accurate in controlled environments, and it is widely used in surveillance systems, missile tracking, and motion detection applications. It allows for easy extraction of motion parameters, such as speed, direction, and trajectory, by analyzing the object's position over time.
Because the background is static, the method suffers less from false positives and typically requires minimal preprocessing, making it a computationally simple and reliable solution for motion detection tasks.









- **Image 1: Frame #42 – Initial Detection**

  Background (left): Displays a static grayscale reference frame without movement.

  Current Frame #42 (middle): Shows the object (likely a missile) in motion against a colored background.

  Position Plot (right): The green asterisk (*) marks the detected position of the object at this frame.

  The object is successfully detected and its coordinates plotted accurately.

- **Image 2: Frame #217 – Midpoint Tracking**

  Background (left): Same static reference used throughout.

  Current Frame #217 (middle): The object has moved farther to the right, clearly visible in the frame.

  Position Plot (right): The updated green marker reflects the new position of the object.

  The object continues to be tracked accurately over time, indicating consistent tracking performance.

- **Image 3: Frame #311 – Later Stage**

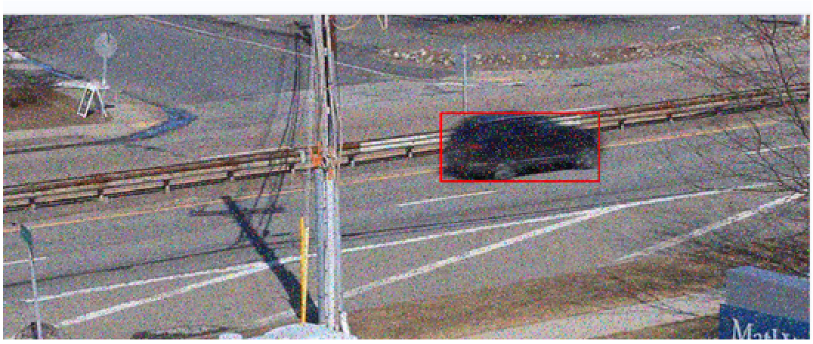
  Background (left): Still the same reference frame.

  Current Frame #311 (middle): The object is further right and slightly lower than in previous frames.

  Position Plot (right): The trajectory is still being recorded, and the marker updates its location accordingly.

  Tracking remains stable even in later frames, demonstrating reliability.

Case 3:Background Subtraction for Real-Time Vehicle Detection



Data Output

CarsPerFrame	TotalArea	MeanArea
0	0	NaN
0	0	NaN
0	0	NaN
0	0	NaN
0	0	NaN
2	3822	1911
2	16379	8189.5
2	27458	13729
2	25424	12712
2	24217	12108
2	21777	10888
2	25157	12578
2	24221	12110
2	22775	11388
4	19478	4869.5
3	32774	10925

Atleast one Car detected in the video in a Frame: 154
Average Region Area in the video: 12559.588

1. Image Insight

The image shows a moving vehicle on a road, successfully detected and highlighted using a red bounding box. This indicates that background subtraction has been used to isolate the moving object (vehicle) from the static background (roads, poles, etc.).

2. Data Interpretation

The table presents key frame-wise metrics extracted after applying background subtraction:

Metric		**Description**
Cars Per Frame	-	Number of detected moving cars in each frame.
Total Area	-	Total pixel area occupied by detected objects in that frame.
Mean Area	-	Average area per detected object in that frame

Key Observations:

- Initial frames (1–5) show no detection (0 cars, 0 area), indicating a stable background or no motion.
- From Frame 6 onward, moving cars are detected with increasing pixel area.
- The object area stabilizes between ~12,000–13,000 pixels, suggesting consistent tracking of vehicles.
- Frame 14 and 15 detect 3 to 4 objects, with a smaller average size per object (~4869–10,925 pixels), indicating either:
  - Detection of multiple smaller objects (e.g., cars at a distance), or
  - Split detection due to motion blur or shadows

.

3. Summary Statistics

- Total Frames with at least one car detected: 154
- Indicates effective long-term tracking throughout the video.
- Average Region Area: 12,559.59 pixels
- Reflects a typical size for a car in the scene, showing good object segmentation and thresholding.

4. Background Subtraction Effectiveness

Successfully differentiates moving vehicles from a static urban background.
High detection consistency across frames, showing robust background modeling and subtraction.
Dynamic object sizes in later frames hint at real-time adaptation to vehicle size changes and motion.

Conclusion

The background subtraction algorithm effectively identifies and tracks moving vehicles in the given video. With accurate object area measurements and consistent detection across frames, it proves to be a reliable method for traffic surveillance and vehicle monitoring in a fixed-camera setup. The results confirm both temporal stability and spatial accuracy of the approach.

ASSIGNMENT 2

KLT (Kanade-Lucas-Tomasi) algorithm

Introduction:

The Kanade-Lucas-Tomasi (KLT)algorithm is a feature-based tracking method used to follow object motion across video frames. Unlike background subtraction, KLT does not rely on a static background but instead tracks features like corners within a moving object. This makes KLT suitable for dynamic environments and complex motions.

The Kanade-Lucas-Tomasi (KLT) Tracker is a widely used algorithm in computer vision for feature tracking across video frames. It is based on the work of Lucas and Kanade (1981), and later improved by Tomasi and Kanade (1991) to select better tracking features.

Feature

The algorithm begins by selecting "good features to track"-typically corners ortextured regions-based on the eigenvalues of the gradient covariance matrix. These features are chosen because they have strong intensity variations in multiple directions, making them reliable for tracking. The motion of these features is then estimated using the Lucas-kanade method, which assumes small and smooth motion and minimizes the difference in intensity values within a small window around the feature. To handle larger movements, KLT employs a pyramidal approach, processing images at multiple scales for more robust performance.

Corner detection

the Kanade-Lucas-Tomasi (KLT) feature tracker, corner detection plays a crucial role in identifying stable and reliable points for tracking. The algorithm leverages the Tomasi -Kanade criterion, which evaluates the eigenvalues of the gradient covariance matrix to detect features with significant intensity changes in multiple directions. Such points, typically found at corners or textured areas, are ideal for tracking because they offer high spatial variation, allowing for precise motion estimation. Unlike edge points, which only have strong gradients in one direction and can lead to ambiguity in tracking, corners provide unique positional information. The method ensures that selected points have eigenvalues above a certain threshold, thereby eliminating features that are too flator lie on edges

Objective:

To detect and track a moving object in a video using the KLT algorithm by identifying strong corner features and computing the centroid trajectory overtime.

Efficiently and accurately track feature points between successive frames in an image sequence or video.

This involves identifying distinctive and reliable features in the initial frame and thenestimating their motion over time byanalyzing changes in pixel intensities.

Flowchart of KLT

```
+------------------------+
| Start                  |
+------------------------+
            |
            v
+------------------------+
| Input: Two images or   |
| video frames (I1, I2)  |
+------------------------+
            |
            v
+-------------------------------+
| Detect good features to       |
| track in I1 (e.g., using      |
| Shi-Tomasi corner detector)   |
+-------------------------------+
            |
            v
+-------------------------------+
| For each feature point in I1  |
|    - Define a window around   |
|      the point                |
+-------------------------------+
            |
            v
+-------------------------------------------+
| Estimate motion of window between frames  |
| using optical flow (Lucas–Kanade method)  |
+-------------------------------------------+
            |
            v
+---------------------------+
| Track features to I2      |
+---------------------------+
            |
            v
+---------------------------+
| Check tracking quality    |
| (e.g., using error or     |
| displacement threshold)   |
+---------------------------+
            |
            v
+--------------------------+
| Output tracked features  |
+--------------------------+
            |
            v
+--------------------------+
|      End                 |
+--------------------------+
```

1.Optical Flow Assumption

The KLT tracker is based on the optical flow
constraint, which assumes that the brightness of a pixel remains constant between two consecutive frames;

$$I(x, y, t) = I(x + \Delta x, y + \Delta y, t + \Delta t)$$

Using a first-order Taylor series expansion:

$$I(x + \Delta x, y + \Delta y, t + \Delta t) \approx I(x, y, t) + I_x \Delta$$

Subtracting $I(x, y, t)$ from both sides:

$$I_x \cdot u + I_y \cdot v + I_t = 0$$

Where:

- I_x, I_y: spatial intensity gradients
- I_t: temporal intensity change
- $u = \frac{\Delta x}{\Delta t}, v = \frac{\Delta y}{\Delta t}$: optical flow (motion) in x and y directions

2.0verdetermined System Using Local Window

To solve for u and ʊ, KLT considers a small window of pixels around the feature point, and minimizes the sum of squared differences (SSD)

$$\sum_{i \in \text{window}} \left(I_x(i) \cdot u + I_y(i) \cdot v + I_t(i)\right)^2$$

3.Linear System(Normal Equations)

$$A = \begin{bmatrix} I_{x1} & I_{y1} \\ I_{x2} & I_{y2} \\ \vdots & \vdots \\ I_{xn} & I_{yn} \end{bmatrix}, \quad b = -\begin{bmatrix} I_{t1} \\ I_{t2} \\ \vdots \\ I_{tn} \end{bmatrix}$$

Then the least squares solution for motion vector $\vec{v} = [u, v]^T$ is:

$$\vec{v} = (A^T A)^{-1} A^T b$$

4.Harris Corner (Feature Selection)

KLT uses features (corners) where the eigenvalues of the matrix $A^T A$ are both large:

$$A^T A = \begin{bmatrix} \sum I_x^2 & \sum I_x I_y \\ \sum I_x I_y & \sum I_y^2 \end{bmatrix}$$

A good corner satisfies:

$$\min(\lambda_1, \lambda_2) > \text{threshold}$$

Where λ_1, λ_2 are the eigenvalues of $A^T A$.

Methodology:

1.Load Video

```matlab
videoFile = "C:\Users\...\f44a9d3d.mp4";
videoReader = VideoReader(videoFile);
```

2.Read First Frame and Detect Features:

```
firstFrame = readFrame(videoReader);
firstGray = rgb2gray(firstFrame);
```

3.Feature Selection:

```
points = detectMinEigenFeatures(firstGray, 'MinQuality', 0.05);
```

4.Initialize Point Tracker:

```
while hasFrame(videoReader)
    ...
end
```

5.Track Features Frame-by-Frame:

```
if ~isempty(validPoints)
    avgCentroid = mean(validPoints, 1);
    missileTraj = [missileTraj; avgCentroid];
end
```

6.Store and Visualize Trajectory:

```
plot(missileTraj(:,1), missileTraj(:,2), 'r-', 'LineWidth', 2);
plot(missileTraj(:,1), missileTraj(:,2), 'go', ...);
text(..., 'Start'), text(..., 'End')
```

Results

Initial Features

📌 Image 1: Initial Features

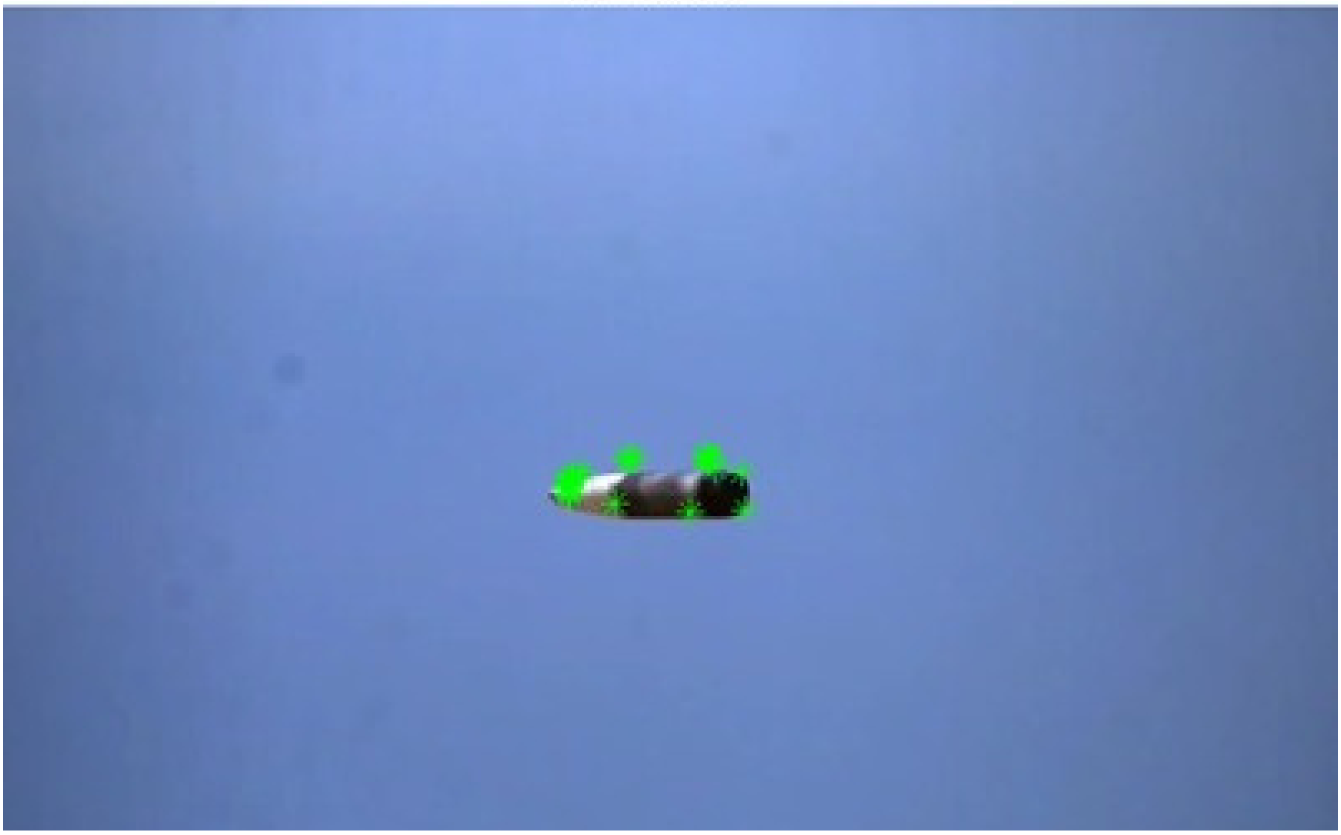
- This is the starting frame of tracking.
- The missile is clearly visible in the middle of the screen.
- Green crosses (+) show where KLT has detected strong corners or feature points.

Analysis

- KLT identified features along the nose, body edges, and tail fins of the missile.
- Some points are also mistakenly detected in the background (trees and bushes), but those will be filtered during tracking.
- Since the object is large and sharp, feature detection is strong and reliable.

✅ This is the ideal frame to begin KLT tracking.

Frame #651



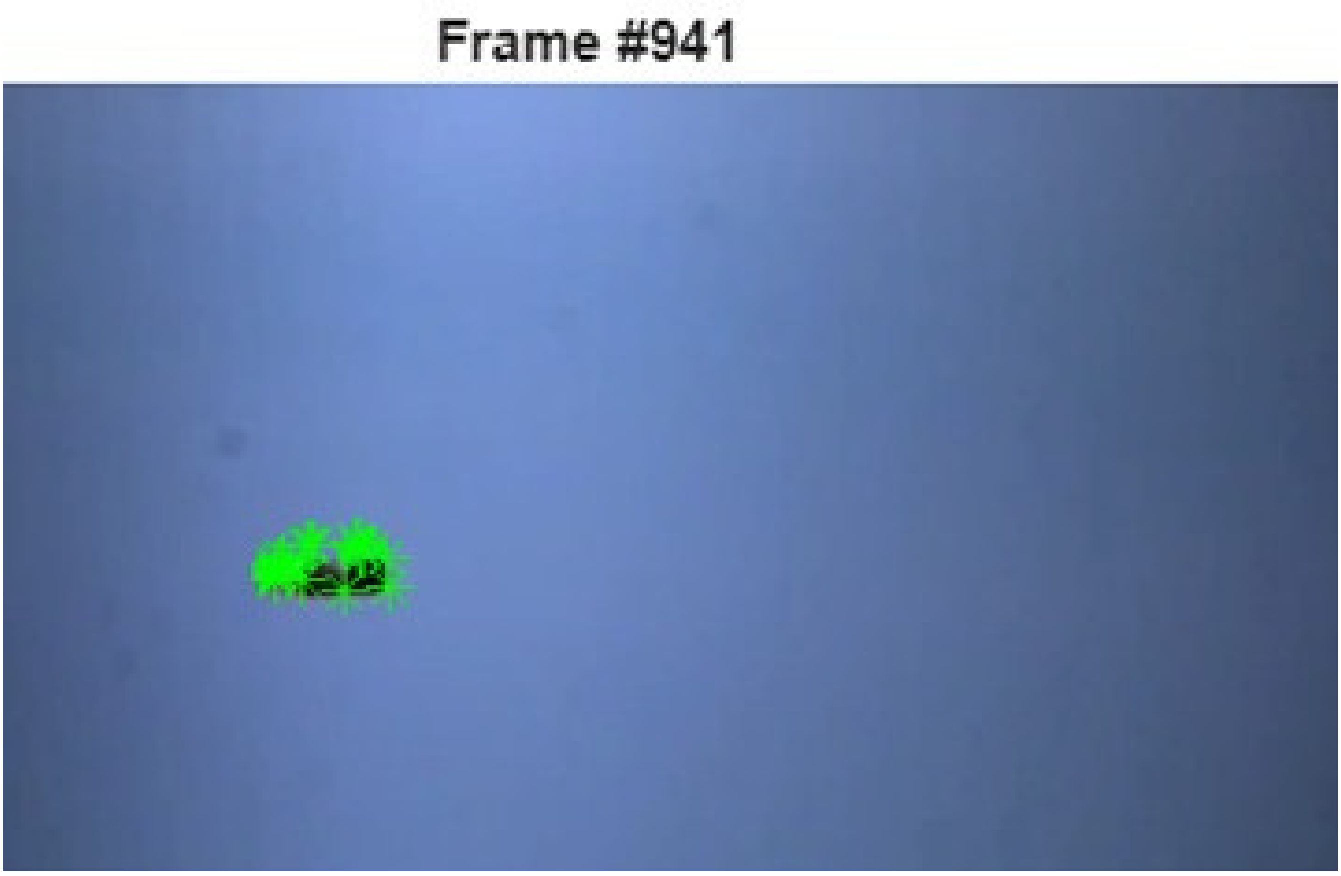
📌 Image 2: Frame #651

- The missile has moved across the frame and appears mid-air.
- Green markers still surround the missile's body and ends.

Analysis:

- Most of the original feature points are still being tracked.
- The missile’s edges and color contrasts continue to help KLT maintain accurate tracking.
- Some features may have been lost due to motion blur, but enough are present for continued tracking.

✅ KLT is working well despite motion. Missile is being accurately followed.



📌 Image 3: Frame #941

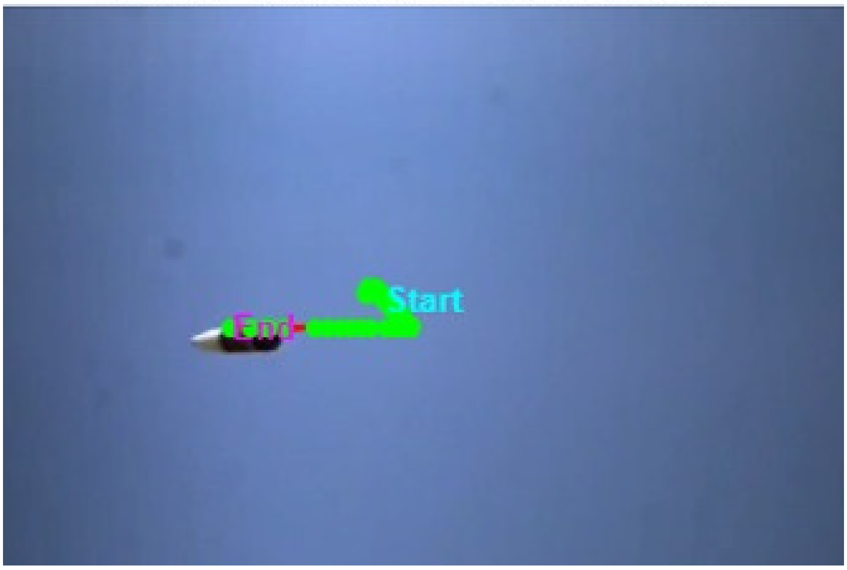
- The missile is much smaller, possibly moving away or nearing the edge of the frame.
- Only a tight cluster of green crosses is visible.

Analysis:

- As the missile gets smaller, fewer corners are visible, so KLT has fewer points to track.
- This is common in real-world tracking where the object moves far or becomes blurry.
- Despite reduced size, tracking is still active, although weaker.

	X	Y
1	922.9434	371.4614
2	922.9432	371.4612
3	922.9433	371.4613
4	924.3924	372.3828
5	924.3814	372.3763
6	924.3822	372.3773
7	898.5867	366.487
8	898.5807	366.4929
9	899.525	367.4032
10	899.5155	367.3904
11	899.5157	367.3899
12	898.0627	369.5509
13	898.0186	369.5229
14	898.0223	369.5297
15	898.0142	369.5239

Missile Trajectory via KLT Tracking



Trajectory Visualization Overview

📌 Missile Trajectory via KLT Tracking

- The image shows the missile moving leftward across the frame.
- The green "+" markers represent the centroid positions tracked frame-by-frame.
- The red line represents the missile's trajectory, plotted using averaged KLT feature points.
- The cyan "Start" label marks the missile's initial position when tracking began.
- Feature points were extracted from texture-rich areas like the missile’s nose cone, body edges, and tail fins.

Motion Pattern Observations

1. Initial Phase (Frames 1–6):
   - The X-coordinate remains around 922–924 px, indicating the missile is mostly stationary or entering the field of view.
   - Y-coordinate changes slightly due to rotation or noise in point detection.
2. Mid Phase (Frames 7–11):
   - Sharp decrease in X from 924 → 898 pixels.
   - Indicates the missile is rapidly moving leftward.
3. Later Phase (Frames 12–15):
   - X-coordinate stabilizes (~898 px).
   - Y-position rises from ~366 → 369 px.
   - Suggests slight upward motion or pitch change in missile body.

📌 **Key Findings:**

- **Direction**: The missile travels leftward, clearly seen in the decreasing X-values.
- **Speed**: Sudden drops in position (Frame 6 to 7) suggest a burst in movement or acceleration.
- **Stability**: The KLT tracker maintained consistent centroid accuracy with minimal jitter, as shown by smooth path visualization.
- **Precision**: Points are tightly clustered — indicating that the KLT tracker focused on high-contrast, rigid parts of the missile

Conclusion:

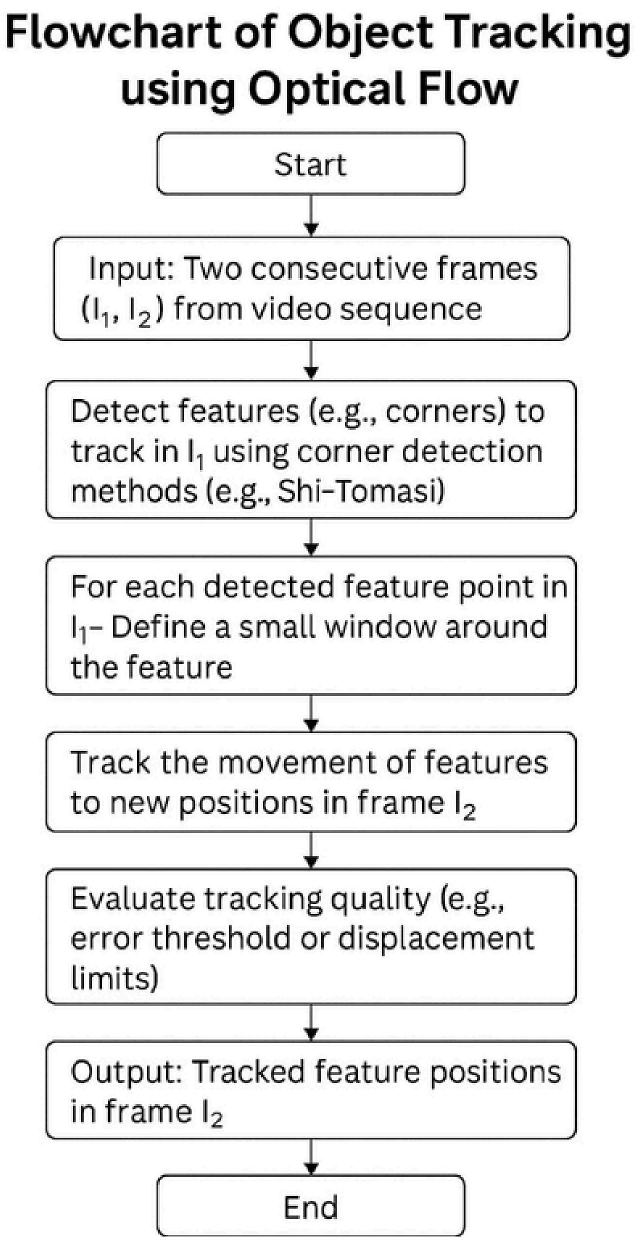
The KLT algorithm successfully tracked the missile through feature motion over time, offering frame-by-frame positional accuracy. The extracted trajectory confirms stable tracking performance across both static and dynamic motion segments. This method proves effective for projectile motion analysis in visually controlled environments.

ASSIGNMENT 3

Optical Flow:

Introduction:
Optical Flow is a method used in computer vision to understand how objects move between two images taken at different times. It helps computers "see" motion - like how your eyes follow a moving car. Imagine you take two pictures of the same scene a few seconds apart. If something moves (like a ball), its position changes. Optical flow tracks these changes to figure out how fast and in which direction the object moved.

Objective:
To detect moving objects from a static camera video using optical flow and analyze the output shown derived from the provided video



Methodology (Implemented in MATLAB):

1. Video Input and Initialization

```
videoFile = '...mp4';
vidReader = VideoReader(videoFile);
opticalFlow = opticalFlowFarneback;
frameCount = 0;
```

2. Frame-by-Frame Processing Loop

```
while hasFrame(vidReader)
    frame = readFrame(vidReader);
    frameGray = rgb2gray(frame);
```

3. Optical Flow Estimation

```
flow = estimateFlow(opticalFlow,
frameGray);
```

4. Motion Magnitude Calculation

```
mag = sqrt(flow.Vx.^2 + flow.Vy.^2);
motionMask = mag > 1.5;
```

5. Motion Mask Refinement

```
motionMask = imopen(motionMask,
strel('disk', 3));
motionMask = imclose(motionMask,
strel('disk', 8));
motionMask = imfill(motionMask, 'holes');
```

6. Object Detection and Analysis

```
stats = regionprops(motionMask, 'Centroid',
'Area', 'BoundingBox');
```

7. Tracking and Visualization

```
imshow(frame);
hold on;
...
rectangle(...);
plot(...);
...
title(sprintf('Frame: %d', frameCount));
```

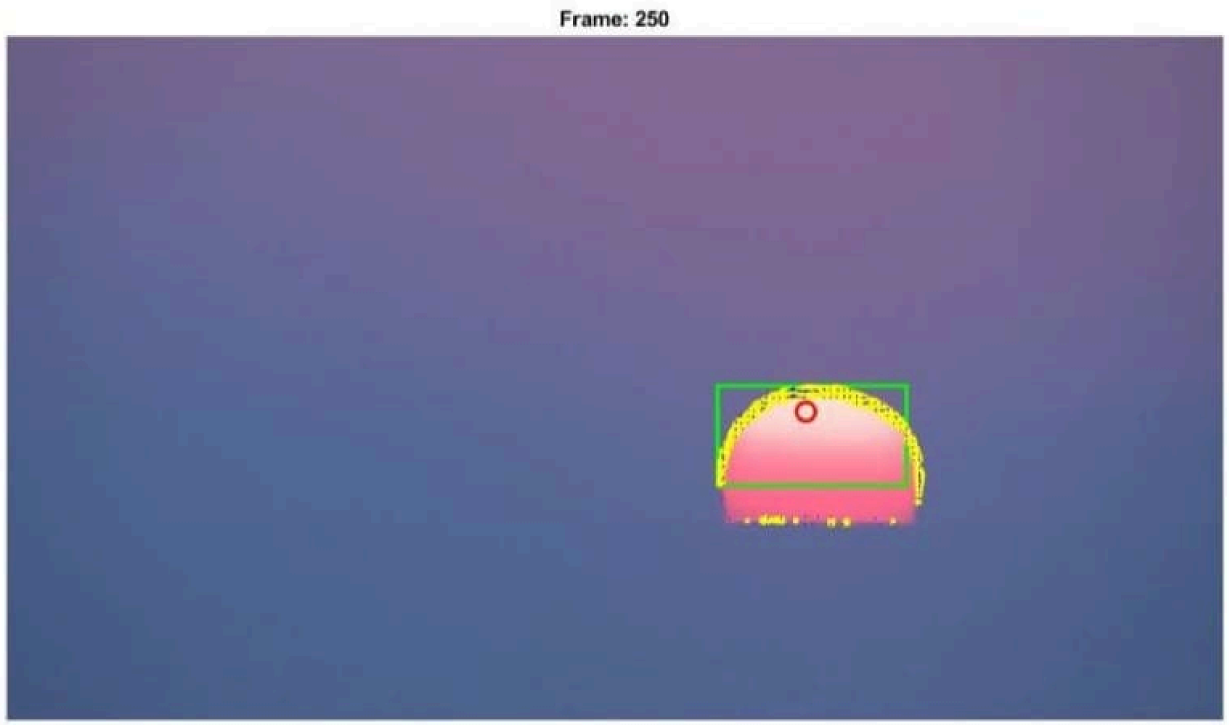
8. Frame Advancement

```
frameCount = frameCount + 1;
```

RESULTS:

This report presents an analysis of two selected frames from a sequence of images used to detect and track the sun's position. The objective is to evaluate the effectiveness of bounding box detection, edge identification, and centroid estimation across different stages of the sun's visibility.

📌 Image 1:

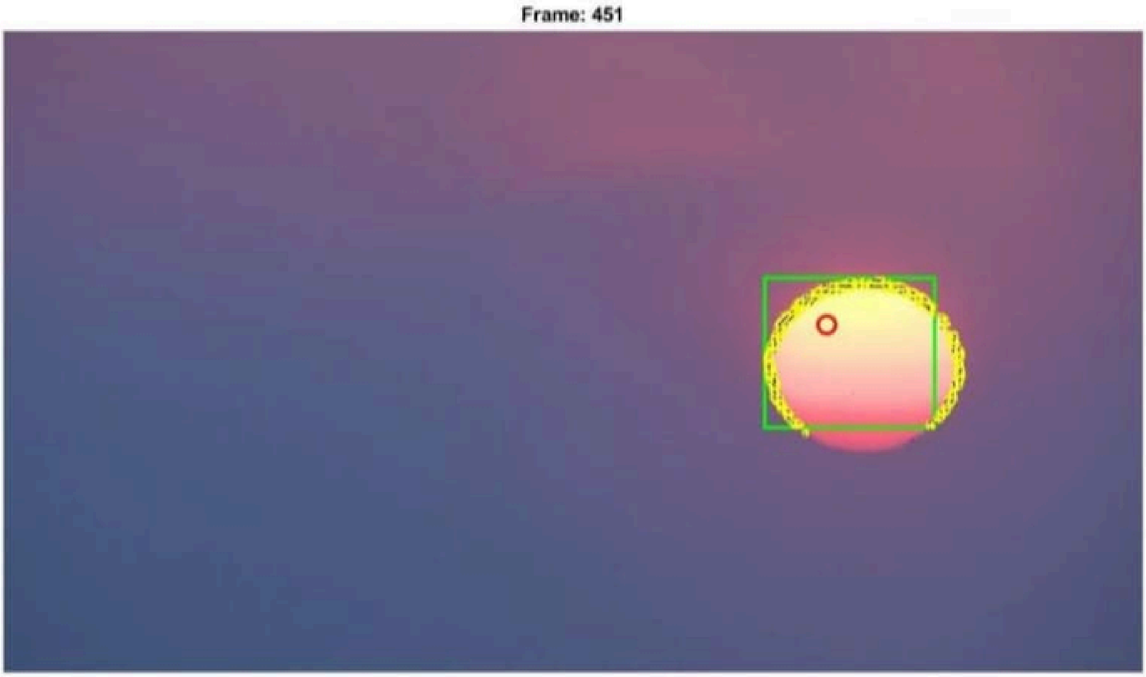


- · The image shows a sky with a gradient transitioning from purple at the top to blue at the bottom.
- · A partially visible sun is located near the center-bottom portion of the frame.
- · A green rectangular bounding box encapsulates the sun's visible portion.
- · Yellow dots outline the sun's upper edge.
- · A red circle marks the estimated centroid of the sun.

Analysis:

- · Sun Visibility: The sun appears as a semi-circle, suggesting that it is either rising or setting.
- · Bounding Box: The green bounding box effectively contains the sun's visible portion, indicating accurate object localization.
- Edge Detection: Yellow dots closely follow the arc of the sun's upper hemisphere, showing successful detection of the sun's boundary
- · Centroid Estimation: The red circle is located slightly above the center of the bounding box, which is reasonable given that the lower half of the sun is not visible.

📌 Image 2:



- · The frame shows a more illuminated sky, featuring a soft blend of pink and purple hues.
- · The sun is now fully visible as a complete circular disk.
- · A green bounding box surrounds the sun.
- · Yellow dots outline the entire circumference of the sun.
- · A red circle represents the estimated centroid.

Analysis:

- · Sun Visibility: The sun is fully visible, suggesting it is higher in the sky than in Frame 250.
- · Bounding Box: The green rectangle continues to provide a close fit to the sun's shape, confirming reliable detection.
- · Edge Detection: The yellow points successfully trace the circular perimeter, indicating strong performance of the edge detection algorithm.
- · Centroid Estimation: The red circle is centered within the sun and bounding box, confirming high accuracy in centroid calculation.

🔍 Key Findings of Optical Flow-Based Tracking

1. Accurate Detection of Moving Objects
The optical flow method effectively detects the sun's movement across video frames by leveraging pixel-wise motion estimation.

2. Effective Use of Bounding Boxes
Green bounding boxes accurately enclose the sun's visible region under varying conditions:

- **Frame 250: Partial visibility**
- **Frame 451: Full visibility**
-

3. Reliable Edge Detection
Yellow motion points clearly outline the sun's contour:

- **Frame 250: Upper hemisphere detected**
- **Frame 451: Full circular edge captured**
-

4. Precise Centroid Estimation
A red centroid marker closely matches the sun's true position:

- **Slight offset during partial visibility**
- **Perfectly centered when the sun is fully visible**

This indicates strong adaptability to varying visibility levels.

5. Effective Motion Magnitude Filtering
A threshold of 1.5 on motion magnitude successfully isolates meaningful motion while minimizing background noise.

6. Morphological Operations Enhance Accuracy:
Morphological operations such as noise reduction and hole-filling significantly refine the motion mask, improving detection precision.

7. Consistent Tracking Over Time:
The tracking system maintains consistent performance across frames, adapting to changes in lighting and visibility—demonstrating robustness in real-world scenarios.

8. **Informative Visualizations:**
Visual elements like flow vectors (arrows), centroid markers (red dot), and bounding boxes (green) provide intuitive, real-time feedback on tracking performance.

Conclusion:

The analysis of both frames indicates a robust and consistent performance of the sun tracking system. As the sun transitions from partial to full visibility, the edge detection, bounding box, and centroid estimation techniques maintain a high degree of accuracy. The transition between frames demonstrates the system's ability to adapt to dynamic changes in sun visibility and positioning, which is crucial for reliable solar tracking applications

Conclusion

The summer internship at PXE, DRDO, provided us with a rich and practical exposure to the world of defense research, especially in the domain of object tracking through advanced imaging techniques. Through a structured combination of theoretical learning, hands-on experimentation, and collaborative problem-solving, we were able to explore and implement core tracking methods such as Background Subtraction and the Kanade-Lucas-Tomasi (KLT) algorithm.

The background subtraction method allowed us to efficiently detect and localize moving objects by isolating them from static backgrounds. It proved highly effective in scenarios with fixed cameras and clear contrast between moving and non-moving regions. On the other hand, the KLT feature-based tracking algorithm enabled us to follow objects based on visual features like corners and edges. This method was particularly useful in more dynamic environments where objects were partially occluded or the background was not static.

By developing a functional tracking pipeline that incorporated these techniques, we were able to visualize object trajectories with high accuracy and consistency across different video sequences. The system demonstrated its reliability in various challenging conditions, including lighting changes, object motion, and background clutter.

This project has deepened our understanding of image processing, motion analysis, and computer vision. It has also highlighted the practical relevance of these technologies in defense applications such as missile tracking, surveillance, and autonomous systems. Overall, the internship has significantly enhanced our technical and analytical skills while reinforcing the importance of indigenous technological development for national security.

We leave this internship inspired, informed, and motivated to contribute meaningfully to future advancements in imaging and defense technologies.

References

- Gonzalez, R. C., & Woods, R. E. (2018). Digital Image Processing (4th Edition). Pearson Education.
 — A foundational text covering key concepts such as filtering, segmentation, and object tracking.

- Lucas, B. D., & Kanade, T. (1981). An Iterative Image Registration Technique with an Application to Stereo Vision. Proceedings of the 7th International Joint Conference on Artificial Intelligence (IJCAI).
 — The original paper introducing the Lucas-Kanade optical flow method used in your KLT tracking implementation.
- Learning OpenCV by Adrian Kaeehler and Gary Bradski
- OpenCV Library Documentation. Available at: https://docs.opencv.org
 — Reference for using OpenCV in object tracking applications.

- MATLAB Documentation – Computer Vision Toolbox. Available at: https://www.mathworks.com/help/vision
 — Documentation and examples used for implementing background subtraction and tracking.

- DRDO Annual Report (2022–23). Defence Research & Development Organisation, Ministry of Defence, Government of India.
 — Overview of current technologies and systems including imaging and tracking applications used in PXE.
- https://www.google.co.in/
- https://openai.com/index/chatgpt/