9th of January
Creation of team - and groups for communication

Meeting Time: 22th of January
Background Subtraction - an overview | ScienceDirect Topics
https://www.sciencedirect.com/topics/computer-science/background-subtraction

Karel : Background subtraction in real appl : Challenges current models and future direction

Stephen:
4.3 Background subtraction
- Conducted background research on methods, history

Tanmaya:
Read quite a few papers from the survey to get a feel of the topic.
Traditional and recent approaches in background modeling for foreground detection.
https://www.sciencedirect.com/science/article/pii/S1574013714000033
-

Karel:
- Read on Background Subtraction Survey: https://arxiv.org/abs/1901.03577

Trevor:
Assigned to do neural network research.

Issue or Blockers:
-

Next Meeting: 11:00 AM Next Wednesday

Meeting time: 5th of February

Stephen:

- Continued doing background research

Tanmaya:

Read initial papers to finalize application we wanted to work on.

-

Karel:

- Applications of backSub is mostly the initial step to many other CV problems such as tracking, segmentation, etc.
- challenges: lighting changes, dynamic environments (occlusion,the thigns we talked about in class), camera quality, and the need for real-time performance.

Trevor:

- Found potential resources for project part 1:
  https://doi.org/10.1109/IWSSIP.2016.7502717
  https://doi.org/10.1016/j.neunet.2019.04.024

Issue or Blockers:

-

Next Meeting: 11:00 AM Next Wednesday

Meeting time: 19th of February

Stephen:

- Wrote a rough draft for the project proposal, more research

Tanmaya:

Studied different methods for background subtraction - trying to figure out the math.

-

Karel:

- Write the introduction and background for the project proposal.

Trevor:

- Documented current deep learning methods as performed by various researchers.

Issue or Blockers:

-

Next Meeting: 11:00 AM Next Wednesday

Meeting time: 5th of March

Issue or Blockers:

- MIDTERM so we'll meet again next week

Next Meeting: Wednesday after the midterm*

Meeting time: 12th of March

Stephen:

- Attending meeting with Omar regarding topic selection, tried to get GMG running but had difficulty and couldn't

Tanmaya:

Experimented with shadows and freezing backgrounds. Detecting ball and figuring out how to detect when white stripe was facing the camera.

-

Karel:

- Pushed initial code for comparing background subtraction methods: MOG2, MOG, KNN, and GMG. the video and code is uploaded on GH.
- https://github.com/karel-harjono/BallDetection

Trevor:

- Was sick this week, but found a basic CV2 example of background subtraction https://docs.opencv.org/3.4/d1/dc5/tutorial_background_subtraction.html

Issue or Blockers:

-

Next Meeting: Wednesday after the midterm*

Meeting time: 19th of March

Stephen:

- Began working on report parts

Tanmaya:

Experimented with adding players.
Worked on report and presentation.

-

Karel:

- Updated the code to use HSV filter to filter the ball from the rest of the background subtracted mask.
- Tested Morphological method for reducing the noise from the MOG2 result.
- Tried to test multiple params combinations for the MOG2 method. The final code is pushed to GH under main.ipynb

Trevor:

- Had issues running Jupyter on machine. Conflicting versions of python led to inability to run teammate's code.

Issue or Blockers:

-

Next Meeting: Wednesday after the midterm*

Meeting time: 26th of March

Stephen:

- Worked on report, found new sources

Tanmaya:

Experimented with removing video adds and same jersey audience
Worked on report and presentation

-

Karel:

- The ball foreground detection is performing better by finding the contour then filtering based on the area. Pushed the code to GH.
- Now the ball mask can subtract everything except the ball.
- Found that with morph_dilate, use a longer vertical component to see better movement_mask result.

Trevor:

- Added to report and presentation. Went over with team what each person would cover.

Issue or Blockers:

-

Detailed discussions / chats

09/01/2025, 15:21 - Karel created this group
09/01/2025, 15:21 - Karel added you
09/01/2025, 15:21 - Karel changed the group name from "Karel" to "Computer Vision Project"
09/01/2025, 15:21 - Trevor Winser joined using this group's invite link
09/01/2025, 15:22 - Stephen joined using this group's invite link
09/01/2025, 15:22 - Trevor Winser: This is Trevor
09/01/2025, 15:33 - Tanmaya: Hi @12033009293 , please put up a msg after you submit the topics.
09/01/2025, 15:34 - Tanmaya: This is Tanmaya
09/01/2025, 16:33 - Trevor Winser: I submit the topics
09/01/2025, 17:18 - Tanmaya: Thanks
11/01/2025, 09:13 - Tanmaya: Good morning! Our project has not been updated on canvas. Do we need to follow up ?
11/01/2025, 09:31 - Stephen: As long as it was sent, it should be fine because of the email time stamp. We can ask in class on Tuesday if it isn't updated by then
11/01/2025, 11:18 - Trevor Winser: I presumed we needed to submit to canvas rather than email the TA. I emailed the prof and he told me to email the TA which I did so. We still have 3 of our top choices (excluding mine because it was taken), so hopefully we will get one of them

13/01/2025, 17:08 - Tanmaya: We've been assigned "Background subtraction". Next we need to fix a meeting time every week
14/01/2025, 19:54 - Tanmaya: Are you all free on Wednesdays or Fridays
Can you put a time preference too ?
14/01/2025, 20:09 - Trevor Winser: I would prefer Wednesdays and I am free from 11am to 3:30pm to meet
14/01/2025, 20:12 - Tanmaya: 11am is good for me too
14/01/2025, 20:24 - Karel: 11 am sounds good, just not tomorrow <This message was edited>
14/01/2025, 20:25 - Stephen: I can do between 11 and 3:30 as well. Are we wanting to meet tomorrow then?
14/01/2025, 20:25 - Stephen: Oh wait sorry I didn't see your message karel
14/01/2025, 21:18 - Tanmaya: We can start working next week - if u r on campus - come to the collegium at ASC
21/01/2025, 20:17 - Tanmaya: Hi, r we meeting tomorrow?
21/01/2025, 20:41 - Stephen: I think so, 11am asc collegium?
22/01/2025, 10:54 - Tanmaya: Hi - You can come to ASC 303 - entrance is from ASC 310
22/01/2025, 10:57 - Stephen: Here, the doors locked though
22/01/2025, 11:01 - Tanmaya:
https://www.sciencedirect.com/topics/computer-science/background-subtraction
22/01/2025, 11:01 - Trevor Winser: Oh sorry I did not have the marked in my calendar. I will be on campus in like 15 minutes
22/01/2025, 11:01 - Tanmaya: Sure
22/01/2025, 11:10 - Tanmaya:
https://www.sciencedirect.com/science/article/abs/pii/S1574013718303101
22/01/2025, 11:22 - Trevor Winser: I'm in the elevator
22/01/2025, 11:23 - Karel:
https://www.youtube.com/watch?v=715uLCHt4jE&list=PLd3hlSJsX_Imk_BPmB_H3AQjFKZS9XgZm&ab_channel=UCFCRCV
22/01/2025, 11:30 - Tanmaya: Background Subtraction - an overview | ScienceDirect Topics

Stephen : 4.3 Background subtraction
Tanmaya : Traditional and recent approaches in background modeling for foreground detection.
https://www.sciencedirect.com/science/article/pii/S1574013714000033

Karel : Background subtraction in real appl : Challenges current models and future direction
Trevor : Neural network
29/01/2025, 10:56 - Stephen: Just outside the door, if we're still meeting today
29/01/2025, 10:56 - Karel: ill will be 5 mins late
29/01/2025, 11:04 - Trevor Winser: ASC 310 right

29/01/2025, 11:39 - Tanmaya: 1. Trevor : Deeplearning
29/01/2025, 11:40 - Tanmaya: 2. Stephen : literature survey of models
29/01/2025, 11:41 - Tanmaya: 3. Tanmaya : Model description
29/01/2025, 11:41 - Tanmaya: 4. Karel : Applications, introduction
29/01/2025, 11:42 - Trevor Winser: Group: Ask prof about proposed projects
Ask TA about bibliography
29/01/2025, 11:42 - Trevor Winser: IMG-20250129-WA0002.jpg (file attached)
02/02/2025, 21:26 - Tanmaya: Hi, Can we meet at 12.15 instead of 11 this week ? <This message was edited>
02/02/2025, 21:28 - Stephen: Works for me. I'm not sure that I'll be able to get my write up done by Wednesday as I have quite a few things due before then but I can get it done by Friday
02/02/2025, 21:29 - Tanmaya: theres no hurry as long as you get started so we know where we are heading
02/02/2025, 22:38 - Karel: I will have another meeting at 12:30(just on the next room), but I can be present for the first 15 minutes
02/02/2025, 22:55 - Tanmaya: dont think we'll take long <This message was edited>
02/02/2025, 22:55 - Tanmaya: even 12.10 would do
03/02/2025, 13:09 - Tanmaya: Hi @12033009293 are you free after 12 or do you want to meet at 11 ?
03/02/2025, 13:55 - Trevor Winser: For Wednesday I should be free then
03/02/2025, 13:55 - Trevor Winser: I have classes from 9:30AM-11 and 3:30PM-5
03/02/2025, 13:56 - Tanmaya: Thanks - then we meet at 12.10 in ASC 310 ?
04/02/2025, 16:19 - Tanmaya: <Media omitted>
image_subtraction.pdf
04/02/2025, 16:19 - Tanmaya: Please go through it and suggest any changes - also I will paste your material in the same doc.
04/02/2025, 16:20 - Tanmaya: Don't write too much as there is word limit of 200 words
04/02/2025, 17:41 - Tanmaya: Hi, I'm free at 11 if u want to meet then - whatever works for all of u
05/02/2025, 07:06 - Tanmaya: Hey sorry for the confusion but what time r we finally meeting?
05/02/2025, 09:03 - Stephen: Either works for me
05/02/2025, 09:22 - Tanmaya: So is 11 okay then as Karel said he had another meeting at 12.30 ?
05/02/2025, 10:14 - Karel: ok thank you
05/02/2025, 10:44 - Trevor Winser: Oh we're meeting at 11? I will be a tiny bit late
05/02/2025, 10:45 - Tanmaya: thats fine - we'll wait <This message was edited>
05/02/2025, 10:58 - Stephen: Here, just outside
05/02/2025, 11:07 - Trevor Winser: ASC 310 right? I'm here
05/02/2025, 11:15 - Trevor Winser: trevoman18@gmail.com
05/02/2025, 11:16 - Stephen: stephen39lee@gmail.com
05/02/2025, 11:21 - Karel: kurenaifek@gmail.com

12/02/2025, 10:47 - Tanmaya: https://github.com/GianlucaPaolocci/Background-Subtraction-on-GPU-with-CUDA-and-OpenCV/blob/master/changeDetection.cu
12/02/2025, 10:51 - Tanmaya: IMG-20250212-WA0004.jpg (file attached)
12/02/2025, 10:54 - Trevor Winser: I guess the answer lies in what GPU everyone has
12/02/2025, 10:54 - Tanmaya: I'm just putting what I find here - just so not to lose info
12/02/2025, 10:55 - Tanmaya: I have access to nvidia computers so can run code for everyone
12/02/2025, 11:04 - Trevor Winser: Okay, gotcha
12/02/2025, 11:04 - Tanmaya: https://github.com/quatrope/ois
12/02/2025, 11:05 - Tanmaya: https://github.com/dguevel/PyZOGY
12/02/2025, 11:07 - Tanmaya: @12508999633 are you coming for the meeting
12/02/2025, 11:08 - Karel: yep
12/02/2025, 11:19 - Tanmaya: 1-s2.0-S1574013714000033-main.pdf (file attached)
1-s2.0-S1574013714000033-main.pdf
18/02/2025, 10:31 - Tanmaya: Hi - Can we meet either thurs or fri - I have to grade a midterm tomorrow
18/02/2025, 10:43 - Stephen: I can do Friday, but it would have to be in the afternoon
18/02/2025, 10:47 - Tanmaya: I'm okay with anytime
18/02/2025, 11:13 - Trevor Winser: Friday should work
20/02/2025, 08:03 - Tanmaya: You deleted this message
20/02/2025, 08:08 - Tanmaya: Hi
20/02/2025, 08:08 - Tanmaya: Have any of of you wriiten any part of the report
20/02/2025, 08:08 - Tanmaya: If so can u post it here and I can add it to the document before toms meeting
20/02/2025, 08:09 - Tanmaya: Also what time do u want to meet tom ?
20/02/2025, 08:48 - Stephen: I have a rough draft written, I'll be editing it tomorrow and then I can post it here when done
20/02/2025, 08:50 - Tanmaya: thanks - is it in word or latex
20/02/2025, 08:51 - Stephen: Google doc, I can't remember if I shared it though
20/02/2025, 08:53 - Tanmaya: no worries - I'll put it in latex once u finish
20/02/2025, 23:04 - Tanmaya: ?
20/02/2025, 23:31 - Karel: i can do 11/12
20/02/2025, 23:31 - Tanmaya: Online or in the lab ?
20/02/2025, 23:32 - Karel: i'll be at the lab
20/02/2025, 23:33 - Tanmaya: I'll come by 11 then
20/02/2025, 23:41 - Trevor Winser: Yes I can post in 1 sec
21/02/2025, 00:15 - Trevor Winser: ```
\section{Deep neural networks in background generation}

\begin{table}[h]
** \centering**
** \begin{tabular}{l l l}**

\toprule
**\textbf{Categories} & \textbf{Methods} & \textbf{Authors - Dates} **
\midrule
**\multicolumn{3}{l}{\textbf{Restricted Boltzmann Machines}} **
**& Partially-Sparse RBM (PS-RBM) & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b126}{Guo and Qi (2013)} **
**& Temp. Adaptive RBM (TARBM) & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b365}{Xu et al. (2015)} **
**& Gaussian–Bernoulli RBM & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b294}{Sheri, Rafique, Jeon, and Pedrycz (2018)} **
**& RBM (PTZ Cameras) & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b261}{Rafique, Sheri, and Jeon (2014)} **
\midrule
**\multicolumn{3}{l}{\textbf{Deep Auto-encoders Networks}} **
**& Deep Auto-encoder Networks (DAN) & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b367}{Xu, Ye, Liu et al. (2014)} **

```
—
21/02/2025, 00:15 - Trevor Winser: ```
**& DAN with Adaptive Tolerance Measure & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b366}{Xu, Ye, Li et al. (2014)} **
**& Encoder–Decoder CNN (ED-CNN) & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b258}{Qu et al. (2016)} **
\midrule
**\multicolumn{3}{l}{\textbf{Convolutional Neural Networks}} **
**& FC-Flownet & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b137}{Halfaoui et al. (2016)} **
**& BM-Unet & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b315}{Tao, Palasek, Ling, and Patras (2017)} **
\midrule
**\multicolumn{3}{l}{\textbf{Generative Adversarial Networks}} **
**& Deep Context Prediction (DCP) & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b309}{Sultana, Mahmood, Javed, and Jung (2018b)} **

**____ & ForeGAN-RGBD & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b308}{Sultana, Mahmood, Javed, and Jung (2018a)} **
**____ & Illumination Invariant ForeGAN & \href{https://www.sciencedirect.com/science/article/pii/S0893608019301303#b307}{Sultana and Jung (2019)} **
____ \bottomrule
__ \end{tabular}
__ \caption{Summary of Methods and Authors}
__ \label{tab:methods_summary}
\end{table}

https://www.sciencedirect.com/science/article/pii/S0893608019301303#b126

https://www.sciencedirect.com/science/article/pii/S1574013714000033
```
—
21/02/2025, 00:15 - Trevor Winser: If this doesn't work, I can send the latex file tomorrow
21/02/2025, 01:14 - Karel: \section{Introduction}
\subsection{Background and Motivation}

The use of computer vision in sports analytics has grown significantly in recent years, transforming performance assessment and game officiating. Applications such as player tracking, motion analysis, automated referee assistance, and ball trajectory estimation enable real-time statistics generation, coaching support, and post-game analysis \cite{Han2024}. These advancements benefit athletes, coaches, referees, and spectators by providing deeper insight into the game.

Among these applications, ball tracking remains a challenging problem due to the high-speed nature of play, frequent occlusions, and environmental factors such as illumination variations and background clutter \cite{He2020}. Although state-of-the-art tracking systems in sports such as tennis, soccer, and basketball leverage multi-camera setups and deep learning techniques \cite{Huang2023}, volleyball ball tracking remains underexplored. Volleyball introduces additional complexities due to its rapid directional changes, unpredictable movements, and frequent occlusions by players and the net \cite{Watanabe2021}.

In volleyball, ball movement serves as a critical indicator of team strategy, player coordination, and overall game dynamics. Effective tracking provides valuable performance metrics, including the number of touches per rally, attack efficiency, defensive responses, blocking effectiveness, and setter distribution. For example, analyzing the ball's trajectory can help coaches determine whether a team relies more on quick attacks, high sets or back-row plays, while opposing teams can use these data to identify spiking patterns and adjust their defensive strategies accordingly \cite{Han2024}.

Accurate ball tracking also enables the automated generation of detailed game statistics, such as:

\begin{itemize}
** \item \textbf{Pass Quality Ratings} – Assessing the accuracy of the first touch after a serve.**
** \item \textbf{Set Distribution Analysis} – Identifying setter tendencies and optimizing offensive strategies.**
** \item \textbf{Attack Efficiency} – Evaluating the success rates of different hitting angles and shot placements.**
** \item \textbf{Defensive Coverage} – Measuring how effectively a team responds to attacks, including block touches and successful digs.**
** \item \textbf{Rally Lengths and Transition Speed} – Understanding how quickly teams switch from defense to offense.**
\end{itemize}

One of the primary techniques for object detection and tracking in video streams is background subtraction, which separates moving objects from a static background \cite{Watanabe2021}. Although widely applied in fields such as traffic monitoring and surveillance, its potential for sports analytics, especially volleyball, remains relatively unexplored. Recent research has proposed the dynamic object presence probability (DOPP) to improve background subtraction by integrating optical flow estimation and adaptive model updates, leading to more robust foreground extraction in sports scenes \cite{Watanabe2021}.

\subsection{Challenges in Volleyball Ball Tracking}

Developing a reliable volleyball tracking system involves addressing several key challenges:

\begin{itemize}
** \item \textbf{Frequent Occlusions} – The ball is often obscured by players, the net, or referees, making consistent tracking difficult.**
** \item \textbf{Rapid Motion and Direction Changes} – Volleyballs travel at high speeds with unpredictable trajectories, which can challenge traditional tracking algorithms.**
** \item \textbf{Dynamic Backgrounds} – Unlike fixed environments such as tennis courts, volleyball matches feature constant player movement, changing lighting conditions, and spectator distractions.**
** \item \textbf{Appearance Similarities} – The volleyball may blend in with uniforms, the court surface, or lighting effects, leading to false detections.**
\end{itemize}

\subsection{Research Objectives}

This research aims to develop a background subtraction-based volleyball tracking approach that addresses the limitations of existing ball tracking methods. Specifically, we will evaluate both traditional and modern background subtraction models to determine their effectiveness in detecting the ball. Enhancements to these techniques will be explored to improve tracking accuracy, particularly in scenarios involving occlusions and dynamic backgrounds. In addition, trajectory estimation methods will be incorporated to refine detection during high-speed gameplay, ensuring more precise localization under challenging conditions.

To validate the proposed approach, university-level volleyball match footage will be used to assess its effectiveness in real-world applications. By integrating multiscale feature enhancement and multilevel cooperative trajectory matching, this research seeks to advance the state of volleyball tracking, contributing to more accurate performance analysis and strategic decision-making in the sport. <This message was edited>
21/02/2025, 01:14 - Karel: @article{He2020,
author = {He, Dianchen and Li, Li and An, Lina},
year = {2020},
month = {04},
pages = {1-1},
title = {Study on Sports Volleyball Tracking Technology Based on Image Processing and 3D Space Matching},
volume = {PP},
journal = {IEEE Access},
doi = {10.1109/ACCESS.2020.2990941}
}

@article{Huang2023,
title = {Artificial Intelligence-based Volleyball Target Detection and Behavior Recognition Method},
journal = {International Journal of Advanced Computer Science and Applications},
doi = {10.14569/IJACSA.2023.0140970},
url = {http://dx.doi.org/10.14569/IJACSA.2023.0140970},
year = {2023},
publisher = {The Science and Information Organization},
volume = {14},
number = {9},
author = {Jieli Huang and Wenjun Zou}
}

@INPROCEEDINGS{Watanabe2021,
author={Watanabe, Ryosuke and Chen, Jun and Konno, Tomoaki and Naito, Sei},
booktitle={2020 25th International Conference on Pattern Recognition (ICPR)},
title={Accurate Background Subtraction Using Dynamic Object Presence Probability in Sports Scenes},

** year={2021},**
** volume={},**
** number={},**
** pages={2521-2528},**
** keywords={Deep learning;Pose estimation;Probability;Pattern recognition;Object recognition;Optical flow;Tuning},**
** doi={10.1109/ICPR48806.2021.9412754}**
}

@Article{Han2024,
AUTHOR = {Han, Xiao and Wang, Qi and Wang, Yongbin},
TITLE = {Ball Tracking Based on Multiscale Feature Enhancement and Cooperative Trajectory Matching},
JOURNAL = {Applied Sciences},
VOLUME = {14},
YEAR = {2024},
NUMBER = {4},
ARTICLE-NUMBER = {1376},
URL = {https://www.mdpi.com/2076-3417/14/4/1376},
ISSN = {2076-3417},
DOI = {10.3390/app14041376}
}
21/02/2025, 10:05 - Stephen: I'll be driving around 11, I can probably hop in a call around 2 though
21/02/2025, 10:13 - Trevor Winser: Wait so what's happening. Are we meeting online at 11 or has the plan changed
21/02/2025, 10:13 - Trevor Winser: I have a game design document due by the end of today, so if we're meeting for long I'd like to know
21/02/2025, 10:16 - Karel: i can also meet at 2
21/02/2025, 10:19 - Tanmaya: You deleted this message
21/02/2025, 10:23 - Tanmaya: Let's meet at 11 and update Stephen
21/02/2025, 10:50 - Trevor Winser: In person?
21/02/2025, 10:50 - Trevor Winser: Or online
21/02/2025, 10:50 - Karel: im coming down now,
21/02/2025, 10:50 - Karel: should be there in about 10 mins
21/02/2025, 10:51 - Trevor Winser: Oh ok
21/02/2025, 11:02 - Trevor Winser: I'm heading down now
21/02/2025, 11:02 - Tanmaya: 👍
21/02/2025, 11:16 - Trevor Winser: Here
21/02/2025, 11:43 - Karel: https://paperswithcode.com/sota/sports-ball-detection-and-tracking-on-1

21/02/2025, 11:55 - Tanmaya: Hi @16048390544, we were just discussing on completing the document. When your part is complete - send a msg then either I can integrate it or give you access to overleaf if you are comfortable with coding.
21/02/2025, 11:55 - Tanmaya: Once the document is done - we thought we could start coding etc after the midterm
21/02/2025, 11:56 - Tanmaya: If you have any thoughts please let us know.
21/02/2025, 11:56 - Tanmaya: If we can get one revision by the end of tomorrow - we can then finalize it on Sunday
21/02/2025, 13:27 - Stephen: Sounds perfect. I haven't used overleaf before so I'm not familiar with the formatting. If you could do that, that would be great
22/02/2025, 15:31 - Stephen: Traditional Background subtraction
Background subtraction (BGS) has been extensively researched due to its wide variety of applications, particularly for traffic surveillance, ecological observation, and athletic performance evaluation, among others [α]. Because of its extensive applications, there is a significant amount of research in the field. Traditional BGS techniques typically comprise four main steps, which are:

1. **Background initialization**
2. **Background Modelling**
3. **Background Maintenance**
4. **Classification of pixels**

Background initialization involves computing the initial background image. This is used as the background reference for subsequent processing. This process is typically done offline [α]. Background modelling pertains to the model used to represent the background, such as by Mixture of Gaussians (MoG), neural network, Kalman filter, etc. [ε]. Background maintenance is the online portion of BGS, whereby the background is updated to account for changes in the image, such as lighting changes. Lastly, the pixels are classified as either background or foreground [α], traditionally a binary designation. Furthermore, there are four main categories of BGS models, outlined as follows:

1. **Mathematical Models: Statistical, fuzzy, and Dempster-Schafer models**
2. **Machine Learning Models: Tensor/Matrix decomposition, neural network, etc.**
3. **Signal Processing Models: Weiner, Kalman, correntropy, and Chebyshev**
4. **Classification/Clustering Models**

The main method for practical BGS implementation, despite being over 25 years old, is MoG, first proposed by Stauffer and Grimson [β] in 1999 to avoid explicitly modelling the pixel values. Its persistence is due to its ability to robustly deal with lighting changes, repetitive motions, and slow-moving objects. In their method, each pixel is modelled as a MoG. When a new pixel is introduced, the algorithm will either match it to an existing Gaussian or extend the variance of another. Thus, a swaying tree would fit into a given Gaussian distribution, while simple background averaging would have a blurry background tree.
Despite the extensive research in BGS, there are two major drawbacks. The first is a significant gap between research-focused BGS methods and actual implementation. Sophisticated research models can have excellent results, but are either offline methods or are computationally expensive, preventing practical implementations [α]. The second

main shortcoming is a combination of technological drawbacks, including illumination issues, camera jitter, and multimodal backgrounds [α, β, ε, η]. Several methods have been proposed for addressing these issues, including fuzzy models, deep learning, Robust Principal Component Analysis (RPCA), and semantic models [α]. A brief overview of these models is summarized here, except for deep learning models, which will be covered in the next section.

Fuzzy Models [ε]

Gaussian Mixture Models (GMMs) are typically used for fuzzy modelling. For fuzzy foreground detection, a multi- or unimodal distribution is used, instead of the typical binary (crisp) FG/BG designation. Colour features are the predominant feature of analysis, but texture, stereo, and edges have also been used. The features can also be combined through the use of Sugeno and Choquet integrals to more robustly deal with illumination changes and shadows. Fuzzy GMMs have better results than crisp GMMs, with fuzzy models able to model dynamic backgrounds more robustly.

RPCA

Principal Component Analysis finds the smallest subspace that represents the given dataset within a certain mean square error [ζ]. RPCA was originally done in batch algorithms (hence, offline), but has since expanded to include online algorithms such as incPCP and ReProCS [α]. RPCA can robustly handle illumination changes, however, it is susceptible to data outliers, which can be caused by camera jitter, noise, and dynamic backgrounds [ζ].

Semantic models [η]

Semantic models use a combination of BGS and semantic segmentation, such as the one used by Zeng et. al. [η]. Their model uses BGS to compute the preliminary BG/FG mask, while the semantic segmenter extracts object-level features. This model had robust performance, and performed better than some supervised deep learning models, demonstrating that traditional BGS methods are not obsolete.

Combinations of traditional computer vision methods are often the applications for BGS, whereby it provides an essential preprocessing step. When combined with neural networks and deep learning models, practically applicable models, such as Bin [δ] et. al. natural gas detection model, and Zeng et. al. [η] BGS and Semantic Segmentation model can be created. Merging traditional computer vision BGS with deep learning models appears to be the main future direction for BGS and its applications.

[α] https://www.sciencedirect.com/science/article/pii/S1574013718303101
[β] https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=784637
[δ] https://ieeexplore.ieee.org/abstract/document/9928408/metrics#metrics
[ε]https://www.taylorfrancis.com/reader/download/3a7bb05f-b921-4623-aca0-f1b520eca91a/chapter/pdf?context=ubx
[ζ] https://ieeexplore.ieee.org/document/5706961
[η] https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8645635 <This message was edited>

22/02/2025, 19:35 - Trevor Winser: Yo idk why, but my table on the latex is starting on the next page ignoring some elements that should go after it. If someone could help, that would be appreciated
22/02/2025, 19:36 - Tanmaya: I'll check it in a short while
22/02/2025, 22:51 - Tanmaya: I'll do it in the morning
23/02/2025, 08:56 - Tanmaya: @12508999633 - can you upload your reference file so that I can add to it
23/02/2025, 09:00 - Karel: I don't have write access, the references are also available here if you want to add a new file and paste it
23/02/2025, 09:23 - Tanmaya: Its fine, I created ref_IM.bib
23/02/2025, 09:23 - Tanmaya: you have edit access
23/02/2025, 09:25 - Karel: thank you! i dont know why i couldnt edit the project earlier
23/02/2025, 09:54 - Tanmaya: please can you send this link again - I cant seem to open it - [ε]https://www.taylorfrancis.com/reader/download/3a7bb05f-b921-4623-aca0-f1b520eca91a/chapter/pdf?context=ubx
23/02/2025, 10:09 - Tanmaya: @16048390544 can you do one thing - Go to the articles you are citing eg
23/02/2025, 10:09 - Tanmaya: <Media omitted>
click the cite at the botton
23/02/2025, 10:09 - Tanmaya: select Export citation to BibTeX
23/02/2025, 10:10 - Tanmaya: you will get something like this
23/02/2025, 10:10 - Tanmaya: @article{GARCIAGARCIA2020100204,
title = {Background subtraction in real applications: Challenges, current models and future directions},
journal = {Computer Science Review},
volume = {35},
pages = {100204},
year = {2020},
23/02/2025, 10:11 - Tanmaya: paste that here and in your text - add \cite{GARCIAGARCIA2020100204} - copy the name they have generated
23/02/2025, 10:14 - Tanmaya: @12033009293 - would you do the same in your section - leave the table and links only where you have cited.
23/02/2025, 10:15 - Trevor Winser: I can try to later today
23/02/2025, 10:16 - Tanmaya: @12508999633 - I have shifted what you have written to the proposal section - you have edit rights - can you do the references too - add to the reference file I have created
23/02/2025, 10:16 - Tanmaya: thanks - I will try and finish what I can - so just check the doc b4 u start - you have viewing rights as of now
23/02/2025, 10:19 - Tanmaya: <Media omitted>
image_subtraction (1).pdf
23/02/2025, 10:38 - Tanmaya: @12508999633 would you please read section 6 and 7 - and edit / fix as you see right
23/02/2025, 11:11 - Stephen: @article{GARCIAGARCIA2020100204,

**title = {Background subtraction in real applications: Challenges, current models and future directions},
journal = {Computer Science Review},
volume = {35},
pages = {100204},
year = {2020},
issn = {1574-0137},
doi = {https://doi.org/10.1016/j.cosrev.2019.100204},
url = {https://www.sciencedirect.com/science/article/pii/S1574013718303101},
author = {Belmar Garcia-Garcia and Thierry Bouwmans and Alberto Jorge {Rosales Silva}}
}
@INPROCEEDINGS{784637,
 author={Stauffer, C. and Grimson, W.E.L.},
 booktitle={Proceedings. 1999 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (Cat. No PR00149)},
 title={Adaptive background mixture models for real-time tracking},
 year={1999},
 volume={2},
 number={},
 pages={246-252 Vol. 2},
 keywords={Layout;Robustness;Gaussian distribution;Vehicle detection;Artificial intelligence;Laboratories;Image segmentation;Image sequences;Adaptive systems;Tracking},
 doi={10.1109/CVPR.1999.784637}}
@ARTICLE{9928408,
 author={Bin, Junchi and Bahrami, Zhila and Rahman, Choudhury A. and Du, Shan and Rogers, Shane and Liu, Zheng},
 journal={IEEE Transactions on Emerging Topics in Computational Intelligence},
 title={Foreground Fusion-Based Liquefied Natural Gas Leak Detection Framework From Surveillance Thermal Imaging},
 year={2023},
 volume={7},
 number={4},
 pages={1151-1162},
 keywords={Liquefied natural gas;Feature extraction;Sensors;Leak detection;Imaging;Convolution;Visualization;Natural gas industries;thermal imaging;background subtraction;visual surveillance;leak detection and repair survey;information fusion},
 doi={10.1109/TETCI.2022.3214826}}
@article{bouwmans2012background,
 title={Background subtraction for visual surveillance: A fuzzy approach},
 author={Bouwmans, Thierry},
 journal={Handbook on soft computing for video surveillance},

volume={5},
pages={103--138},
year={2012},
publisher={Taylor and Francis Group Abingdon, UK}
}
@INPROCEEDINGS{5706961,
author={Qiu, Chenlu and Vaswani, Namrata},
booktitle={2010 48th Annual Allerton Conference on Communication, Control, and Computing (Allerton)},
title={Real-time Robust Principal Components' Pursuit},
year={2010},
volume={},
number={},
pages={591-598},
keywords={Sparse matrices;Noise;Eigenvalues and eigenfunctions;Real time systems;Robustness;Covariance matrix;Pixel},
doi={10.1109/ALLERTON.2010.5706961}}
@ARTICLE{8645635,
author={Zeng, Dongdong and Chen, Xiang and Zhu, Ming and Goesele, Michael and Kuijper, Arjan},
journal={IEEE Access},
title={Background Subtraction With Real-Time Semantic Segmentation},
year={2019},
volume={7},
number={},
pages={153869-153884},
keywords={Semantics;Real-time systems;Image segmentation;Computational modeling;Lighting;Deep learning;Adaptation models;Background subtraction;foreground object detection;semantic segmentation;video surveillance},
doi={10.1109/ACCESS.2019.2899348}}
23/02/2025, 11:13 - Stephen: I'll send the updated text in just a second
23/02/2025, 11:27 - Stephen: This message was deleted
23/02/2025, 11:31 - Stephen: There are four main categories of BGS models, outlined as follows:

1. **Mathematical Models: Statistical, fuzzy, and Dempster-Schafer models**
2. **Machine Learning Models: Tensor/Matrix decomposition, neural network, etc.**
3. **Signal Processing Models: Weiner, Kalman, correntropy, and Chebyshev**
4. **Classification/Clustering Models**

The main method for practical BGS implementation, despite being over 25 years old, is MoG, first proposed by Stauffer and Grimson \cite{784637} in 1999 to avoid explicitly modelling the pixel values. Its persistence is due to its ability to robustly deal with lighting changes, repetitive motions, and slow-moving objects. In their method, each pixel is modelled as a MoG. When a new pixel is introduced, the algorithm will either

match it to an existing Gaussian or extend the variance of another. Thus, a swaying tree would fit into a given Gaussian distribution, while simple background averaging would have a blurry background tree.

Despite the extensive research in BGS, there are two major drawbacks. The first is a significant gap between research-focused BGS methods and actual implementation. Sophisticated research models can have excellent results, but are either offline methods or are computationally expensive, preventing practical implementations \cite{GARCIAGARCIA2020100204}. The second main shortcoming is a combination of technological drawbacks, including illumination issues, camera jitter, and multimodal backgrounds \cite{GARCIAGARCIA2020100204, 784637, bouwmans2012background, 8645635}. Several methods have been proposed for addressing these issues, including fuzzy models, deep learning, Robust Principal Component Analysis (RPCA), and semantic models \cite{GARCIAGARCIA2020100204}. A brief overview of these models is summarized here, except for deep learning models, which will be covered in the next section.

\subsection{Fuzzy Models \cite{bouwmans2012background}}
Gaussian Mixture Models (GMMs) are typically used for fuzzy modelling. For fuzzy foreground detection, a multi- or unimodal distribution is used, instead of the typical binary (crisp) FG/BG designation. Colour features are the predominant feature of analysis, but texture, stereo, and edges have also been used. The features can also be combined through the use of Sugeno and Choquet integrals to more robustly deal with illumination changes and shadows. Fuzzy GMMs have better results than crisp GMMs, with fuzzy models able to model dynamic backgrounds more robustly.

\subsection{RPCA}
Principal Component Analysis finds the smallest subspace that represents the given dataset within a certain mean square error \cite{5706961}. RPCA was originally done in batch algorithms (hence, offline), but has since expanded to include online algorithms such as incPCP and ReProCS \cite{GARCIAGARCIA2020100204}. RPCA can robustly handle illumination changes, however, it is susceptible to data outliers, which can be caused by camera jitter, noise, and dynamic backgrounds \cite{5706961}.

\subsection{Semantic models \cite{8645635}}
Semantic models use a combination of BGS and semantic segmentation, such as the one used by Zeng et. al. \cite{8645635}. Their model uses BGS to compute the preliminary BG/FG mask, while the semantic segmenter extracts object-level features. This model had robust performance, and performed better than some supervised deep learning models, demonstrating that traditional BGS methods are not obsolete.

Combinations of traditional computer vision methods are often the applications for BGS, whereby it provides an essential preprocessing step. When combined with neural networks and deep learning models, practically applicable models, such as Bin

\cite{9928408} et. al. natural gas detection model, and Zeng et. al. \cite{8645635} BGS and Semantic Segmentation model can be created. Merging traditional computer vision BGS with deep learning models appears to be the main future direction for BGS and its applications.
23/02/2025, 11:31 - Stephen: This should be the updated text, let me know if I missed anything
23/02/2025, 11:43 - Tanmaya: Thanks @16048390544 - can you read sections 1,2,3 and see you want any changes
23/02/2025, 11:43 - Stephen: Sure 👍
23/02/2025, 11:43 - Tanmaya: <Media omitted>
image_subtraction (2).pdf
23/02/2025, 11:57 - Tanmaya: <Media omitted>
draft.pdf
23/02/2025, 12:04 - Tanmaya: <Media omitted>
image_subtraction- abstract added.pdf
23/02/2025, 12:07 - Stephen: image_subtraction (2) edit suggestions.docx (file attached)
image_subtraction (2) edit suggestions.docx
23/02/2025, 12:17 - Tanmaya: Will integrate and get back
23/02/2025, 12:39 - Karel: <Media omitted>
I just double checked, I do not have edit priv
23/02/2025, 12:44 - Tanmaya: check now
23/02/2025, 12:45 - Karel: perfect, thank you
23/02/2025, 12:53 - Tanmaya: for applications - I dont have a citation as I got it by combining google search with chatgpt
23/02/2025, 12:54 - Tanmaya: also didnt understand if u want me to remove the numbering in section 3 - the rest is done
23/02/2025, 12:55 - Tanmaya: <Media omitted>
image_subtraction (3).pdf
23/02/2025, 12:55 - Stephen: For section 3 I was just think to put an extra blank line so that it looks more like the start of section 2 <This message was edited>
23/02/2025, 12:57 - Tanmaya: actually spacing is done by latex - Ive just started a new section
23/02/2025, 14:17 - Karel: confirmed the references, you can pass my edit rights to someone else if they need one. thx :)
23/02/2025, 14:51 - Trevor Winser: I will ask for them later today, but not right now in case someone would like to work before me
23/02/2025, 16:52 - Tanmaya: is the rest of it okay - did u get a chance to go through the whole doc
23/02/2025, 17:05 - Tanmaya: moved to trevor
23/02/2025, 17:05 - Tanmaya: everyone just read the whole doc and see what u feel
23/02/2025, 17:07 - Stephen: Looks good to me
23/02/2025, 18:08 - Trevor Winser: Okay I will work on them around 8-9
24/02/2025, 13:56 - Trevor Winser: I did finish btw
24/02/2025, 13:56 - Trevor Winser: Also, how are you guys doing A5

24/02/2025, 14:43 - Tanmaya: Submitted tho E values don't tally <This message was edited>
24/02/2025, 14:48 - Karel: Background subtraction is a fundamental technique in computer vision used to differentiate foreground objects from the background in images and videos. This method is essential in numerous applications, including video surveillance, traffic monitoring, and sports analytics. Despite significant advancements, challenges such as illumination variations, camera jitter, and multimodal backgrounds persist, necessitating the development of more robust approaches. This paper provides a comprehensive literature review of background subtraction techniques, ranging from traditional methods like Mixture of Gaussians (MoG) and Kalman filters to modern machine learning and deep learning approaches, including convolutional neural networks (CNNs) and generative adversarial networks (GANs). We analyze their effectiveness in various scenarios and discuss the trade-offs between computational efficiency, accuracy, and adaptability. Furthermore, we propose an application of background subtraction in volleyball analytics, focusing on improving ball tracking accuracy through enhanced object detection and motion analysis. Volleyball tracking presents challenges such as rapid ball movement, frequent occlusions, and dynamic backgrounds. Our methodology leverages adaptive background modeling, morphological operations for noise reduction, and deep learning-based classification techniques to enhance detection performance. The expected outcome of this research includes improving game analytics, object tracking accuracy, and real-time decision support, providing valuable insights for players, referees, coaches, and spectators alike.
24/02/2025, 14:48 - Karel: just pasting it here so i don't lose it
24/02/2025, 16:09 - Trevor Winser: What does this mean?
24/02/2025, 16:25 - Karel: just finished restructuring the report to look more like the template, can everyone please go through it once more and see if we are ready for submission? thx <This message was edited>
24/02/2025, 16:31 - Karel: <Media omitted>
image_subtraction.pdf
24/02/2025, 16:48 - Trevor Winser: Looks good to me. Sorry I wasn't able to contribute that much. For our next meeting, I'd like to discuss what we'll work on for the coding section
24/02/2025, 16:53 - Stephen: I have an interview during our next meeting till 12:30, could we meet later that Wednesday?
24/02/2025, 16:53 - Tanmaya: after me submit this - lets meet after the midterm
24/02/2025, 16:56 - Trevor Winser: I'm happy with that
24/02/2025, 17:12 - Stephen: That works
24/02/2025, 17:20 - Stephen: Just reviewed it, looks good. If you could change the sentence "A brief
overview of these models is summarized here, except for deep learning models, which will be covered in the next section." to "A brief
overview of these models is summarized here:" that would be great, since we re-formatted the DNN part

24/02/2025, 17:48 - Tanmaya: I'll just do a quick review and then we can submit - I wanted to add a little to the tech part
24/02/2025, 18:58 - Tanmaya: Can u please just proof read these two sections - semantic models, tech details,
24/02/2025, 18:58 - Tanmaya: <Media omitted>
image_subtraction (4).pdf
24/02/2025, 18:59 - Tanmaya: if no more changes we can submit and hope for the best :)
24/02/2025, 18:59 - Trevor Winser: Sounds good to me
24/02/2025, 19:08 - Stephen: Tech details look good, would the added part for semantic be better in the DNN section though?
24/02/2025, 19:10 - Tanmaya: good point - we just need some continuity betn the two sections - I'll move it
24/02/2025, 19:11 - Trevor Winser: I think either works, but yeah, changing the naming/intentions of section three would solve that
24/02/2025, 19:11 - Tanmaya: <Media omitted>
image_subtraction (5).pdf
24/02/2025, 19:13 - Stephen: Yeah, I think that flows a little better
24/02/2025, 19:13 - Trevor Winser: I agree
24/02/2025, 19:14 - Tanmaya: Once @12508999633 has a look - we can submit
24/02/2025, 19:14 - Tanmaya: do we all submit - also do we need team name in the file name or something
24/02/2025, 19:17 - Stephen: I imagine it's just 1 submission
24/02/2025, 19:17 - Trevor Winser: Uhhh, I don't think so
24/02/2025, 19:17 - Tanmaya: it shows on canvas as an assignment - to be safe guess all of us can submit and then we can ask tom
24/02/2025, 19:18 - Trevor Winser: Sure
24/02/2025, 19:18 - Trevor Winser: But if we're in a group, it should show the latest submission to everyone
24/02/2025, 19:20 - Tanmaya: <Media omitted>
this is what I see on canvas
24/02/2025, 19:22 - Stephen: If you let us know when you submit, one of us can check on our end if its also submitted
24/02/2025, 19:23 - Tanmaya: will do - just waiting for karel to respond then will submit
24/02/2025, 20:24 - Karel: am taking a look now will ping
24/02/2025, 20:26 - Karel: looks good to me
24/02/2025, 20:26 - Karel: we can submit
24/02/2025, 20:30 - Tanmaya: I'll submit and let u know
24/02/2025, 20:34 - Tanmaya: <Media omitted>
image_subtraction.zip
24/02/2025, 20:34 - Tanmaya: if u cant see on canvas please submit
25/02/2025, 10:28 - Tanmaya: Is the syllabus for midterm given anywhere
25/02/2025, 10:32 - Stephen: Just what he sent in the email I think
25/02/2025, 10:32 - Tanmaya: ohk thx - I'll check
25/02/2025, 14:14 - Tanmaya: Can we meet ta on 28th

25/02/2025, 14:14 - Trevor Winser: That works for me
25/02/2025, 14:15 - Tanmaya: I have a ta 12 to 2 any other tim wprks
25/02/2025, 14:19 - Trevor Winser: Class for me at 3:30-5 so 2-3:30?
25/02/2025, 14:19 - Trevor Winser: Or before 12
25/02/2025, 14:21 - Stephen: I can do 11-12 or 2-3:30
25/02/2025, 14:21 - Karel: should we meet before we meet the TA?
25/02/2025, 14:21 - Tanmaya: 9?
25/02/2025, 14:21 - Karel: I'm not sure if we have a 'concrete' next step to present per se yet
25/02/2025, 14:22 - Karel: or am i missing something
25/02/2025, 14:22 - Tanmaya: We still need to meet him
25/02/2025, 14:22 - Tanmaya: I guess we talk about implementing enabling ball tracking
25/02/2025, 14:23 - Stephen: I think it's just to talk to him about whether our topic makes sense
25/02/2025, 15:24 - Tanmaya: Can one of u send an email
25/02/2025, 20:47 - Tanmaya: did anyone get an appointment
25/02/2025, 22:22 - Karel: <Media omitted>
just sent the email
25/02/2025, 22:22 - Tanmaya: thank you
26/02/2025, 23:17 - Karel: Hi Karel,

I can meet you starting at 3 pm. Join this link by that time:
https://meet.google.com/kim-ycei-dww

Best Regards,

Omar
26/02/2025, 23:25 - Tanmaya: Thanks
28/02/2025, 15:03 - Stephen: Have you guys joined the meeting?
28/02/2025, 15:05 - Stephen: I'm in, we're just waiting now
28/02/2025, 15:11 - Tanmaya: Sorry I forgot
I'll join in a min
28/02/2025, 15:11 - Trevor Winser: He just left
28/02/2025, 15:11 - Trevor Winser: ig bc we took too long
28/02/2025, 15:11 - Karel: oh shoot
28/02/2025, 15:12 - Karel: i also forgot
28/02/2025, 15:12 - Tanmaya: So sorry
28/02/2025, 15:12 - Tanmaya: Did u talk tohim
28/02/2025, 15:12 - Stephen: He only had 10 minutes till he had to meet with the next group. I didn't present so we have to drop into the office hours next Thursday between 9-10 am, so just whoever of us are able to make it

28/02/2025, 15:13 - Tanmaya: Ok sure
28/02/2025, 15:13 - Tanmaya: Next Thurs is the midterm right
28/02/2025, 15:13 - Stephen: yes
28/02/2025, 15:14 - Tanmaya: I'll join
Putting a reminder right away
28/02/2025, 15:15 - Stephen: I can join at 9:30
28/02/2025, 15:21 - Karel: got it, so sorry about today. I completely missed it
28/02/2025, 15:24 - Trevor Winser: No worries, it happens
04/03/2025, 12:51 - Stephen: Are we meeting tomorrow at our usual time, or just on Thursday with the ta?
04/03/2025, 13:59 - Trevor Winser: I think just Thursday would work best
04/03/2025, 14:05 - Tanmaya: Thursday seems good
05/03/2025, 17:14 - Trevor Winser: Hey team, I am properly sick, so I think it would be best for me to not attend tomorrow's meeting. The professor also agreed to offload my midterm mark to the final. Please let me know what the TA says and I can try to get some code running soon
06/03/2025, 08:36 - Tanmaya: Hi, as there are no office hours today - I have emailed Omar to check if he can give us another time
06/03/2025, 15:38 - Tanmaya: Friday 11am
06/03/2025, 15:38 - Tanmaya: is the meeting
06/03/2025, 19:22 - Trevor Winser: Kk. I will let you know if I am able to attend in the morning depending on whether I'm still sick
06/03/2025, 19:23 - Tanmaya: Take care, we'll update you
07/03/2025, 01:01 - Karel: which link would the meeting be on?
07/03/2025, 07:14 - Tanmaya: I don't know, I'll email him in a while
07/03/2025, 10:27 - Tanmaya: I havent got a reply yet - guess we can join on the TA link on canvas
07/03/2025, 11:00 - Tanmaya: Hi
Trying to connect
Some issues with my laptop
Give me a min
07/03/2025, 11:01 - Stephen: nw, TAs not here yet
07/03/2025, 11:03 - Tanmaya: https://meet.google.com/uyt-rtzk-psg
07/03/2025, 11:15 - Stephen: - volleyball application is good
- must modify an existing component, must be internally new. Understand how the command works internally.
- can't just use existing commands
- doesn't have to improve performance, if our changes can be justified.
- only need to compare to traditional computer vision methods
- live demo with running code
07/03/2025, 11:17 - Tanmaya: Hi - After the meeting I have couple of suggestions - Lets split the work - maybe Karel and Trevor can work on the application front - implement that using existing matlab imsubtract

07/03/2025, 11:18 - Tanmaya: Meanwhile Stephen and I can go into the details of imsubtract and check what modifications are feasible
07/03/2025, 11:18 - Tanmaya: I;ve just listed names - feel free the change from one grp to the other
07/03/2025, 11:32 - Trevor Winser: I'm confused, are you asking us to make the rendition that uses current techniques and then you'll do a version that tries something new?
07/03/2025, 11:45 - Tanmaya: What I mean is if u use imsubtract as a function call - we can later replace it with the new call without changing what you do
07/03/2025, 11:46 - Trevor Winser: Ohhh I understand
07/03/2025, 11:47 - Trevor Winser: Is that the part they're wanting us to replace? Not the section that detects the background itself?
07/03/2025, 11:51 - Tanmaya: He wants us to make modifications to what matlab has implemented
07/03/2025, 11:58 - Trevor Winser: Okay, sounds good
12/03/2025, 08:16 - Stephen: Are we meeting at our usual time today?
12/03/2025, 08:31 - Tanmaya: Yes
12/03/2025, 10:22 - Trevor Winser: I created a simple background subtraction demo with matlab functions. Could someone give me the link to the GitHub repo we're using?
12/03/2025, 10:30 - Tanmaya: Lets discuss when we meet
12/03/2025, 11:01 - Stephen: Just outside
12/03/2025, 11:11 - Tanmaya: @12508999633 @12033009293 are you joining ?
12/03/2025, 11:11 - Trevor Winser: Yes I am here now
12/03/2025, 11:12 - Trevor Winser: At elevator
12/03/2025, 11:15 - Trevor Winser: RGB = imread('peppers.png');

```
L = superpixels(RGB,500);
figure(1);
imshow(RGB);
h1 = drawpolygon('Position',[72,105; 1,231; 0,366; 104,359;...
      394,307; 518,343; 510,39; 149,72]);
roiPoints = h1.Position;
roi = poly2mask(roiPoints(:,1),roiPoints(:,2),size(L,1),size(L,2));

BW = grabcut(RGB,L,roi);
figure(2);
imshow(BW)

maskedImage = RGB;
maskedImage(repmat(~BW,[1 1 3])) = 0;
figure(3);
imshow(maskedImage)
```

12/03/2025, 11:26 - Tanmaya:
https://www.geeksforgeeks.org/python-opencv-background-subtraction/

12/03/2025, 11:31 - Tanmaya:
https://www.sciencedirect.com/science/article/pii/S0167865505003521
12/03/2025, 11:50 - Tanmaya: @12033009293 and @12508999633 we will need data so if one of you could get the code working and other focus on getting the data - it would help
12/03/2025, 11:57 - Tanmaya: try running this
12/03/2025, 11:57 - Tanmaya:
https://docs.opencv.org/3.4/d5/de8/samples_2cpp_2segment_objects_8cpp-example.html#a25
12/03/2025, 11:58 - Trevor Winser: What exactly do you mean by data? Like the accuracy?
12/03/2025, 11:58 - Tanmaya: just videos, frames required for testing
12/03/2025, 11:59 - Tanmaya: so we can freeze that and work only on those pics
12/03/2025, 12:00 - Trevor Winser: Sounds good. I might be able to squeeze that in today to download a video or two of random volleyball footage. I do have footage of my own that we could use but it is from a weird angle
12/03/2025, 14:39 - Tanmaya: try this code too
12/03/2025, 14:39 - Tanmaya: import cv2

```
# Create the background subtractor
bg_subtractor = cv2.createBackgroundSubtractorMOG2()

# Read video frames and apply background subtraction
cap = cv2.VideoCapture('video.mp4')

while cap.isOpened():
    ret, frame = cap.read()
    if not ret:
        break

    # Apply background subtraction
    fg_mask = bg_subtractor.apply(frame)

    # Display result
    cv2.imshow('Foreground Mask', fg_mask)

    if cv2.waitKey(30) & 0xFF == 27:  # Press 'Esc' to exit
        break

cap.release()
cv2.destroyAllWindows()
```

13/03/2025, 14:04 - Karel:
https://universe.roboflow.com/primaryws/volleyball_ball_object_detection_dataset/dataset/1

same thing, if you have a Kaggle account instead:
https://www.kaggle.com/datasets/pythonistasamurai/volleyball-ball-object-detection-dataset?resource=download <This message was edited>
13/03/2025, 15:16 - Karel: <Media omitted>
13/03/2025, 15:21 - Karel: i pushed my code and output here:
https://github.com/karel-harjono/BallDetection
13/03/2025, 15:22 - Karel: I don't remember if we had a GitHub repo, if there is i can re push it
13/03/2025, 15:33 - Karel: otherwise, please drop your github handle below so i can add to the repo
13/03/2025, 15:48 - Stephen: D3stroyer9
13/03/2025, 17:43 - Tanmaya: tanmaya11
13/03/2025, 18:24 - Trevor Winser: trevorwinser
13/03/2025, 18:24 - Trevor Winser: Thank you for setting that up, it looks good
13/03/2025, 20:23 - Tanmaya: <Media omitted>
gmm.pptx
13/03/2025, 20:23 - Tanmaya: @12508999633 mog2 was giving better results right ?
13/03/2025, 20:24 - Karel: yes
13/03/2025, 20:24 - Tanmaya: great
13/03/2025, 20:24 - Karel: This message was deleted
13/03/2025, 20:25 - Tanmaya: if possible can you run it in 2 steps
13/03/2025, 20:25 - Tanmaya: • learningRate=1: Sets the first frame as the fixed background.
• learningRate=0: Prevents updates, keeping the background unchanged.
13/03/2025, 20:25 - Tanmaya: first set learningRate = 1 and then in loop learningRate = 0
13/03/2025, 20:26 - Tanmaya: we can expt with fixing background instead of dynamic and compare results and times
16/03/2025, 13:21 - Tanmaya: @12508999633 did u run ur code on collab ?
16/03/2025, 13:26 - Karel: no, but it's an ipynb and on the repo, you should be able to run it on collab i think
16/03/2025, 13:27 - Tanmaya: ok thx - was getting some errors on my system hence was wondering whether to shift to collab
17/03/2025, 15:49 - Tanmaya: import cv2

```
# Initialize video capture
cap = cv2.VideoCapture('video.mp4')  # Use 0 for webcam

# Create Background Subtractor MOG2
bg_subtractor = cv2.createBackgroundSubtractorMOG2()

# Read the first frame
ret, first_frame = cap.read()
if ret:
    bg_subtractor.apply(first_frame, learningRate=1)  # Set first frame as background
```

```
while cap.isOpened():
    ret, frame = cap.read()
    if not ret:
        break

    # Apply background subtraction with learningRate=0 (freeze background)
    fg_mask = bg_subtractor.apply(frame, learningRate=0)

    # Show results
    cv2.imshow('Foreground Mask', fg_mask)
    cv2.imshow('Original Frame', frame)

    if cv2.waitKey(30) & 0xFF == 27:  # Press 'Esc' to exit
        break

cap.release()
cv2.destroyAllWindows()
```

17/03/2025, 15:50 - Trevor Winser: Is this the one from that demo we found?
17/03/2025, 15:50 - Tanmaya: sorry - Karel and I are just working - meant to send this code to hi,
17/03/2025, 15:51 - Trevor Winser: All good. Is there anything I can take a look at? I feel like I haven't done enough to contribute and want to make sure I can do something helpful.
17/03/2025, 16:07 - Tanmaya: 1. nmixtures = 5;
This sets the number of Gaussian components per pixel.
Default is 5, meaning each pixel is modeled as a mixture of 5 Gaussians.
Higher values can model more complex backgrounds but increase computational cost.
2. backgroundRatio = 0.9f;
Determines the fraction of data that is considered background.
Default is 0.9, meaning 90% of the observed data is treated as background.
Helps filter out transient foreground objects.
3. varThresholdGen = _varThreshold * 0.5f;
Used for generating new Gaussian distributions.
Affects how easily new components are added to the mixture.
4. varThreshold = _varThreshold;
Threshold for determining whether a pixel belongs to the background.
Higher values allow more variation in the background.
Lower values make the model stricter, reducing noise but potentially missing some background dynamics.
17/03/2025, 16:08 - Tanmaya: import cv2

```
bg_subtractor = cv2.createBackgroundSubtractorMOG2()
bg_subtractor.setNMixtures(5)  # Set number of Gaussian mixtures
```

5 is default
17/03/2025, 16:11 - Tanmaya: 4. Combining Techniques
For best results, combine: ✅ Background subtraction (to remove players).
✅ HoughCircles (to detect round objects).
✅ HSV thresholding (to filter based on color).
17/03/2025, 16:13 - Tanmaya: import cv2
import numpy as np

 # Initialize background subtractor
bg_subtractor = cv2.createBackgroundSubtractorMOG2(history=500, varThreshold=20, detectShadows=False)

 # Define HSV color range for volleyball (adjust if needed)
lower_yellow = (20, 100, 100) # Lower HSV threshold
upper_yellow = (30, 255, 255) # Upper HSV threshold

 # Start video capture
cap = cv2.VideoCapture("volleyball_game.mp4") # Replace with 0 for webcam

while cap.isOpened():
** ret, frame = cap.read()**
** if not ret:**
**   break # Exit if video ends**

** # Resize frame for faster processing**
** frame = cv2.resize(frame, (640, 480))**
** blurred = cv2.GaussianBlur(frame, (5, 5), 0)**

** # Apply background subtraction**
** fg_mask = bg_subtractor.apply(blurred)**

** # Convert to HSV for color filtering**
** hsv = cv2.cvtColor(frame, cv2.COLOR_BGR2HSV)**
** color_mask = cv2.inRange(hsv, lower_yellow, upper_yellow)**

** # Combine masks (background + color)**
** combined_mask = cv2.bitwise_and(fg_mask, color_mask)**

** # Find contours to detect moving ball**
** contours, _ = cv2.findContours(combined_mask, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)**

```
    for contour in contours:
        if cv2.contourArea(contour) > 500:  # Filter small objects
            x, y, w, h = cv2.boundingRect(contour)
            cv2.rectangle(frame, (x, y), (x + w, y + h), (0, 255, 0), 2)

    # Convert to grayscale for HoughCircles
    gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)

    # Detect circles using Hough Transform
    circles = cv2.HoughCircles(gray, cv2.HOUGH_GRADIENT, dp=1.2, minDist=20,
                               param1=50, param2=30, minRadius=10, maxRadius=50)

    if circles is not None:
        circles = np.uint16(np.around(circles))
        for i in circles[0, :]:
            cv2.circle(frame, (i[0], i[1]), i[2], (0, 0, 255), 2)  # Draw circle
            cv2.circle(frame, (i[0], i[1]), 2, (255, 0, 0), 3)  # Draw center

    # Show the frames
    cv2.imshow("Volleyball Detection", frame)
    cv2.imshow("Background Subtraction", fg_mask)

    # Press 'q' to quit
    if cv2.waitKey(25) & 0xFF == ord('q'):
        break

cap.release()
cv2.destroyAllWindows()
```

19/03/2025, 09:34 - Stephen: Are we meeting the same as usual today?
19/03/2025, 09:55 - Tanmaya: yes
19/03/2025, 10:42 - Trevor Winser: How did you guys manage to install requirements.txt? I'm getting a pathing error due to the way some of the libraries are specified
anaconda-anon-usage @ file:///C:/b/abs_e8r_zga7xy/croot/anaconda-anon-usage_1732732454901/work
19/03/2025, 10:50 - Trevor Winser: I will be 5 minutes late
19/03/2025, 10:56 - Stephen: Just outside
19/03/2025, 11:08 - Trevor Winser: Here
19/03/2025, 11:09 - Tanmaya: @12508999633 u r coming right ?
19/03/2025, 11:35 - Karel: https://github.com/karel-harjono/BallDetection
19/03/2025, 14:58 - Karel: i just pushed a cleaned up version of the repo
21/03/2025, 17:20 - Tanmaya: Hi, the deadline is 31st so we have some time <This message was edited>
21/03/2025, 17:37 - Trevor Winser: Yep. I will make time to work on it this Sunday. I will try to document / get more video examples set up

22/03/2025, 12:11 - Tanmaya: Hi
22/03/2025, 12:11 - Tanmaya: <Media omitted>
backgroundSubtraction.pptx
22/03/2025, 12:13 - Tanmaya: My suggestion
Stephen starts the intro
I do the little math part
Karel does the application with the demo (Slides 10 - 11)
Trevor concludes
22/03/2025, 12:13 - Tanmaya: please let me know what u feel as we then need to go onto the report
22/03/2025, 13:09 - Trevor Winser: This should be good for my schedule as I can summarize our findings/results later next week for the conclusion
22/03/2025, 14:00 - Stephen: Sounds good to me
26/03/2025, 10:55 - Stephen: Just outside the door, if we're still meeting today
26/03/2025, 10:56 - Karel: im still on the way
26/03/2025, 11:00 - Trevor Winser: Ah sorry. I completely forgot about this. I don't think I'll be able to come.
26/03/2025, 11:43 - Tanmaya: Hi @12033009293 we r thinking of going over the presentation on Sunday evening
26/03/2025, 11:44 - Tanmaya: Also if you can finish
5. Discussions
- Comment on the pros and cons of your system.
- Discuss overall performance and any abnormal results (if found)
- Discuss how your results compare to existing method(s)
6. Future Work
Possible improvements that could be applied to your system.
26/03/2025, 11:44 - Tanmaya: These sections for the report by Saturday so we can integrate and submit by the 31st
26/03/2025, 11:44 - Tanmaya: Let me know when u r working and I'll give u access to overleaf
26/03/2025, 11:45 - Tanmaya: @12508999633 once I'm done worling I'll make you the owner - so two of u can work simultaneously
26/03/2025, 11:46 - Tanmaya: @12033009293 can u give us a timeline when u can work on the report in order to give u access
26/03/2025, 11:49 - Trevor Winser: I can work on it tomorrow
26/03/2025, 11:50 - Tanmaya: great - I'll give u access tonight till friday night then
26/03/2025, 11:50 - Trevor Winser: Sounds good to me
26/03/2025, 11:51 - Tanmaya: You also need to update the journal once @12508999633 posts it here
26/03/2025, 12:02 - Karel: progress journal link: https://docs.google.com/document/d/1rzk1LWW1z_HwYxXGS_T3R9wUSjQpxAc0WPeRvBDp8rA/edit?usp=sharing <This message was edited>
26/03/2025, 12:02 - Tanmaya: thanks
26/03/2025, 19:17 - Tanmaya: Hi @12033009293 I've added u to overleaf

26/03/2025, 19:17 - Trevor Winser: Okay, thank you
26/03/2025, 19:17 - Tanmaya: Thats the template - I still havent updated - u can just add sections as required - we will fill the rest
26/03/2025, 20:24 - Trevor Winser: Okay. I figured as much
27/03/2025, 18:18 - Trevor Winser: Also, I got the program running in a .py file because the ipynb wasn't working for imports still. Did we ever find a fix for that or no?
27/03/2025, 20:22 - Karel: VID-20250327-WA0000.mp4 (file attached)
27/03/2025, 20:51 - Tanmaya: That looks cool
27/03/2025, 20:51 - Tanmaya: U removed the players?
27/03/2025, 21:02 - Trevor Winser: Nice
27/03/2025, 22:06 - Tanmaya: You deleted this message
27/03/2025, 22:06 - Tanmaya: try this too
27/03/2025, 22:24 - Tanmaya: <Media omitted>
output.avi
27/03/2025, 22:25 - Trevor Winser: Woah
27/03/2025, 22:25 - Trevor Winser: neat
27/03/2025, 22:25 - Trevor Winser: does that show all the ball candidate positions?
27/03/2025, 22:26 - Tanmaya: its showing players + ball but we can try to modify further
27/03/2025, 22:26 - Tanmaya: I could show just one team too
27/03/2025, 22:26 - Tanmaya: just diff versions for the demo
27/03/2025, 22:26 - Trevor Winser: nice
27/03/2025, 22:33 - Tanmaya: I thought of keeping the players as it should not be mixed with tracking
28/03/2025, 00:04 - Trevor Winser: Did we ever get functionality to block certain zones from being tracked
28/03/2025, 08:51 - Tanmaya: Hi, I've filled in whats in the template into overleaf so check while filling your respective sections and then delete
28/03/2025, 08:52 - Tanmaya: Also fill in your names - for affiliation (comp sci) u can copy mine - guess Stephen will have to change his
28/03/2025, 09:12 - Trevor Winser: I didn’t finish. I will continue today
28/03/2025, 10:22 - Tanmaya: I have updated most of my part - @12508999633 let me know when u can work so will shift ownership to u and I can again work on sunday to finalize
28/03/2025, 10:34 - Karel: i can work
28/03/2025, 11:19 - Trevor Winser: is the statement "Two static balls next to each other may be seen as moving" true? What flaws do we have with our system besides faulty detection
28/03/2025, 11:20 - Trevor Winser: because I noticed after the game ball left the screen, it would jitter between two balls in a basket
28/03/2025, 11:20 - Tanmaya: I have a few will list them in a while
28/03/2025, 11:21 - Tanmaya: @12508999633 can u accept so I can change ownership
28/03/2025, 11:25 - Karel: sorry what do i need to accept?
28/03/2025, 11:25 - Tanmaya: overleaf invite
28/03/2025, 11:27 - Karel: accepted

28/03/2025, 11:32 - Tanmaya: @12033009293 r u working now
28/03/2025, 11:32 - Tanmaya: I cant seem to be able to change ownership
28/03/2025, 11:41 - Trevor Winser: I was but I can stop to let Karel work
28/03/2025, 11:41 - Karel: that ok i'm still reading, i'll just note down any comments i will be making
28/03/2025, 11:42 - Trevor Winser: kk
28/03/2025, 20:02 - Trevor Winser: I have volleyball from 6 to 7. Any other time works
28/03/2025, 21:48 - Karel: <Media omitted>
28/03/2025, 21:49 - Karel: just for reference in case ppl are writing the intro/background
29/03/2025, 03:31 - Karel: <Media omitted>
Computer_Vision___Final_Report.pdf
29/03/2025, 03:31 - Karel: @12508996045 i'm done editing, you can pass the access back to @12033009293 , thx!

I commented out the "Additional Stuff" and "Flowchart" (the flowchart seems to be cliping to the other row) section for now, but feel free to add them in to one of the section, I'm thinking maybe the limitations or smth? also, I'm using \ref{fig:...} but the figure number doesn't seem to be clickable, do you know why that is? not a big issue tho, just wondering <This message was edited>
29/03/2025, 07:04 - Tanmaya: I'll fix that
29/03/2025, 07:04 - Tanmaya: @16048390544 you can send me your stuff and I'll add it in
29/03/2025, 07:30 - Tanmaya: The flow chart seemed to be a requirement - I couldnt get it to look nice so put it as a placeholder
29/03/2025, 07:30 - Tanmaya: I've added another couple of statements to the limitations
29/03/2025, 08:10 - Tanmaya: @12033009293 you are adding the future work right ?
29/03/2025, 08:12 - Tanmaya: @12508999633 need your email id to update in the doc
29/03/2025, 08:50 - Tanmaya: <Media omitted>
Computer_Vision___Final_Report.pdf