**Tennis Ball Tracking: 3D Position Inference from Recorded Video (non-Android)**

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**Project Overview:**
This project intends to analyze high-definition video frames of a tennis ball moving in a tennis court to determine ball speed, based on an estimation of its three-dimensional location relative to the court. Given a recorded video taken from the side of a tennis court using a camera on tripod (Fig. 1), we intend to implement and apply the following pipeline components, as inspired by our references:

- Image segmentation and identification of court lines and the ball
  - Frame differences
  - Template matching
  - Edge detection (finding court lines)
  - Adaptive thresholding (shadow removal, etc)
  - Deblurring of ball in motion (used for size/depth calculation)
- Geometric processing of the court features and ball
  - Estimation of the position and orientation of the camera, given the pixel coordinates of court features/lines
  - Model the position of the ball given its pixel coordinates, assuming a fixed lens is used during calibration
  - Estimation of ball distance-to-camera based on its apparent size
- Statistical post-processing
  - Filtering of inferred ball location under uncertainty
- Further (if we have time):
  - Estimation of spin speed using a marked ball



Fig. 1: a possible input frame for our algorithm

**Proposed Work Breakdown:**
All team members will be involved in all stages of the project, but each team member will take the lead on the following tasks:
- Megan: camera setup/calibration, video capture, camera location inference
- Tori: Ball detection (video -> ball coordinates)
- Kyle: Court detection (video -> court edges coordinates)
- All: tennis players for data collection
- Megan is also enrolled in EE 367 and will be combining the two projects

**References:**

1. T. Qazi, P. Mukherjee, S. Srivastava, B. Lall and N. R. Chauhan, "Automated ball tracking in tennis videos," *2015 Third International Conference on Image Information Processing (ICIIP)*, Waknaghat, 2015, pp. 236-240, URL: http://ieeexplore.ieee.org/document/7414772/ - This paper analyzes algorithms for detecting and tracking a tennis ball in videos of tennis matches filmed from a quadcopter.

2. C. Lyu, Y. Liu, B. Li and H. Chen, "Multi-feature based high-speed ball shape target tracking," *2015 IEEE International Conference on Information and Automation*, Lijiang, 2015, pp. 67-72. doi: 10.1109/ICInfA.2015.7279260., URL: http://ieeexplore.ieee.org.stanford.idm.oclc.org/stamp/stamp.jsp?tp=&arnumber=7279260&isnumber=7279248 - This paper discusses algorithms for stabilizing videos and uses a method called random forest segmentation for extracting possible ball locations in the image

3. Archana, M., Geetha, M.K.: An efficient ball and player detection in broadcast tennis video. In: Berretti, S., Thampi, S.M., Srivastava, P.R. (eds.). AISC, vol. 384, pp. 427–436. Springer, Heidelberg (2016)., URL: https://link.springer.com/content/pdf/10.1007%2F978-3-319-23036-8_37.pdf - This paper proposes a new algorithm for ball detection that utilizes frame difference, logical and operations, thresholding, and dilation to track the motion of the tennis ball in broadcast tennis video.

4. Yan, F, Christmas, W and Kittler, J (2005) *A Tennis Ball Tracking Algorithm for Automatic Annotation of Tennis Match* In: British Machine Vision Conference, 2005-09-05 - 2005-09-08, Oxford, UK. - This paper uses motion segmentation and foreground blob detection to determine probable locations for the tennis ball. However, part of the difficulties with ball tracking is handling motion blur and ball occlusion, which this paper handles by modeling the ball with a LTI-system and using a particle filter to determine the most probable location for the ball given the images.

5. B. Ekinci, M. Gokmen, "A ball tracking system for offline tennis videos", International Conference on Visualization Imaging and Simulation 2008, URL: http://www.wseas.us/e-library/conferences/2008/bucharest2/vis/vis06.pdf - This paper processes videos from a fixed camera to extract the background of an image and generate ball location candidates. A Kalman Filter is then used to narrow down the candidates to the most probable ball location.

6. Yu, X. Sim, C.-H. Wang, J.R. Cheong, L.F., A trajectory-based ball detection and tracking algorithm in broadcast tennis video, ICIP Image Processing, Vol. 2, pp. 1049- 1052, 2004, URL: http://ieeexplore.ieee.org/document/1419482/  The focus of this paper is on leveraging limited visual cues to track the tennis ball more accurately in broadcast tennis videos, and describes an algorithm for inferring ball position based on previous/later frames.