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June 29th, 2016

LOS ANGELES POLICE DEPARTMENT
Officer Benjamin Hong

Dear Officer Hong:

Enclosed are two copies of the Statement of Work (SOW) and two copies of this cover letter. The SOW outlines our team's current understanding of the problem and addresses our planned approach to a solution.

Please show your approval of the SOW by signing both copies of the cover letter in the space provided on this page, or by indicating your proposed changes, and returning one copy of each (SOW and signed cover letter) to me by Friday, July 8. Otherwise, after that date, we will assume the LAPD's tacit approval.

Sincerely,

Stephanie A. Allen

Stephanie Allen
RIPS Project Manager

Institute for Pure and Applied Mathematics (IPAM)
Attn RIPS: Stephanie Allen

Enclosure: Los Angeles Police Department RIPS Work Statement

Cc: Susana Serna, RIPS Program Director
Stacey Beggs, IPAM IPAM Assistant Director

Accepted this________day of June 2016

By: ______________________________

# RIPS 2016 Project Work Statement
# Sponsor: Los Angeles Police Department
# Change Point Detection Methods Applied to Body-Worn Video


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Industry Sponsor: Commander Sean Malinowski (LAPD Chief of Staff); Ms. Maggie Goodrich (LAPD CIO), Sgt. Javier Macias, Sgt. Dan Gomez, Mr. Arnold Suzukamo (LAPD-IT Bureau), Officer Benjamin Hong


June $29^{th}$, 2016

# 1 Introduction

Body-worn video (BWV) has come about as another source of information regarding police-public interactions. To produce this video, police officers wear specially designed cameras on their chests to record their interactions with the public. This video then may be utilized when there is public disagreement about police conduct. Furthermore, these cameras have been shown to increase professionalism in the police force [1]. However, the video from the cameras has not been analyzed thoroughly because of the sheer quantity of data produced by them.

The Los Angeles Police Department (LAPD) seeks to protect and to serve the residents and visitors of the city of Los Angeles via patrol, traffic, and specialized divisions. The Department recently undertook a pilot project in its Central Division whereby police officers received body cameras to document their work in the field. The Department gave police officers license to turn the cameras on when they felt their interactions should be recorded. The Research in Industrial Projects for Students (RIPS) LAPD student research group will work with a sample of this data to develop change point detection methods that will help to streamline the video recording and analysis processes.

# 2 Problem Statement

In this project, we will work to develop change point detection algorithms to apply to video data. A significant change in the content of BWV may occur at the time an officer exits a car and engages in public interactions. However, it is not realistic to require an officer to record the time of exit from a vehicle—for example, in a dangerous situation. The same reasoning applies for other possible change points, such as entering or exiting buildings. Therefore, being able to automatically identify change points in a video stream would both greatly improve the efficiency of BWV analysis and reduce storage requirements. Our immediate goal is to identify the moment of exit from a car because this is a very clear change. We also seek to minimize the false alarm rate as we develop our identification algorithms.

# 3 Mathematical Background

The mathematical background required for this project is primarily statistical; specifically, it lies in the field of change point detection [3]. Change point detection methods exist to identify critical points in a series where the underlying distribution changes. A wide range of these methods exist. One popular and extensible change point detection method is the cumulative sum algorithm (CUSUM); one variation of this algorithm computes a log-likelihood ratio after each new data point, adds this ratio to the sum of the previous ratios, and tests this aggregate ratio against a chosen threshold [4, 16]. CUSUM is commonly used for change point detection and thus provides a good framework for exploration. The complex spatio-temporal inferential challenges posed by videos may require the use of other change point algorithms drawn from Bayesian methods and kernel methods. Bayesian methods like Gaussian processes are able to deal well with the temporal correlation in videos [5]. Kernel methods can identify interesting features in videos across space and time [6]. Video-specific algorithms also exist for scene labeling and change point detection; these may be applicable as well [7].

# 4 Computing Background

The bulk of the computing background for this project will involve methods of image and video representation and processing [2, 3]. The machine learning and the computer vision literature provide a variety of methods well-suited to our task. Within machine learning, representation learning algorithms are used to learn low-dimensional feature vectors from high-dimensional input like video. Many of these methods are framed in the theory of artificial neural networks. Specifically, networks such as denoising autoencoders and convolutional nets have seen great success in recent years [8, 9]. These methods work by hierarchically building an increasingly complex sequence of features from video patches. Other machine learning tools from nonlinear dimensionality reduction may be useful as well; for example, kernel principal component analysis finds a nonlinear map from a higher-dimensional set of data to a lower-dimensional one, where inference can be more tractable [10].

From computer vision approaches, we will explore a variety of image processing algorithms. These include methods for image segmentation and boundary detection, as well as local feature detection algorithms such as SIFT (Scale-Invariant Feature Transform) and SURF (Speeded Up Robust Features) [11, 12]. All these methods will provide different ways of describing the relevant features of our images compactly. Once derived from an image, these features can be intelligently consumed by a regularizing classifier like a support vector machines ("SVM") [13, 14]. SVMs work by finding a number of hyperplanes in $n$-dimensional space that optimally segment data into two or more classes [15].

# 5 Possible Solutions and Project Objectives

Our first objective is to build a classifier to detect if an image has or has not been taken within a car. We plan to use multiple machine learning algorithms such as convolutional neural networks and support vector machines. During the process, we will also perform data analysis on the body-worn video we receive. After developing this classifier, we plan to develop change point detection algorithms to identify the time at which the sequence of images changes from being inside a car to outside a car, which would indicate that the door has been opened. The method developed is intended to work with already recorded videos in storage (offline data). We hope that it will also work on sequentially received video frames (online data).

If time permits, we will work to generalize our change point detection methods to handle more complicated representations of the images. First, we will explore ways to extract multiple features from images, compute difference images, or use other methods of representing the images through time. Then, we will build upon established change point detection methods to write algorithms which can be applied on the extracted time series to identify the variation in the data that results from the opening of a door. If we are successful, we will then proceed to developing methods to deal with online data. The methods developed during this phase of the project may provide a framework for detecting additional change points beyond just the opening of a car door.

Our implementation will be carried out in *MATLAB* and/or *Python*. As we use and develop image processing and change point detection methods, we will also evaluate the efficacy of these methods.

# 6 Deliverables

In the following subsections, we will outline the materials we plan to provide to the LAPD and also the assistance from the LAPD required by this student research group.

## 6.1 RIPS to LAPD

- Thursday, July $21^{st}$, 2016: We will give a Midterm Presentation regarding our progress on the proposed project.
- August $15^{th}$, 2016 - August $19^{th}$, 2016: We will present our final results during RIPS's Projects Day, which will be scheduled sometime between August $15^{th}$ and August $19^{th}$.
- Friday, August $19^{th}$, 2016: We will deliver our final project report. We will be sure to include our analysis of the video data and explanations of our change point detection algorithm(s) in this report.
- Friday, August $19^{th}$, 2016: We will provide the code for our proposed algorithm(s).

  Any Code sent by the 2016 LAPD RIPS student research group to the LAPD will be in compliance with the Software Disclaimer attached to this Work Statement.

## 6.2 LAPD to RIPS

- Receipt of body-worn video data by Week 2 (June $27^{th}$, 2016 - July $1^{st}$, 2016)
- Timely response to RIPS LAPD student research group communications

- Weekly meetings and/or conference calls with a representative from the LAPD if necessary
- Site visit at LAPD

## 7 Timeline

Weeks 1-2 (6/20 - 6/24 and 6/27 - 7/1)

- Gather and review background reading
- Compose and submit work statement (by the end of Week 2)
- Begin data analysis and development of change point detection methods

Weeks 3-4 (7/5 - 7/8 and 7/11 - 7/15)

- Continue work on change point detection methods
- Visit the LAPD site during Week 3
- During the later half of Week 4, start to prepare for the Midterm presentation

Week 5 (7/18 - 7/22)

- Prepare and give Midterm presentation (date to be determined)

Weeks 6-8 (7/25 - 7/29, 8/1 - 8/5, and 8/8 - 8/12)

- Continue working on research
- During Week 8, work on the final report, code, and presentation

Week 9 (8/15 - 8/19)

- Finish research
- Finalize report and code for change point detection methods (for submission to LAPD)
- Present final presentation on RIPS's Projects Day to LAPD (date to be determined)

## References


[1] Barak, A., Farrar, W. A., & Sutherland, A. (2014). The Effect of Police Body-Worn Cameras on Use of Force and Citizens' Complaints Against the Police: A Randomized Controlled Trial. In *Journal of Quantitative Criminology*, 1-27.

[2] Poppe, R. (2010). A survey on vision-based human action recognition. In *Image and Vision Computing*, 28(6), 976-990.

[3] Radke, Richard J., et al. (2005). Image change detection algorithms: a systematic survey. In *Image Processing, IEEE Transactions*, (14)3, 294-307.

[4] Tsechpenakis, G., Metaxas, D. N., Neidle, C., & Hadjiliadis, O. (2006). Robust Online Change-point Detection in Video Sequences. *Conference on Computer Vision and Pattern Recognition Workshop (CVPRW '06)*. doi:10.1109/cvprw.2006.176

[5] Saatci, Y., Turner, R., Rasmussen, C. E. (2010). Gaussian Process Change Point Models. *27th International Conference on Machine Learning (ICML 2010)*.

[6] Yamada, M., Kimura, A., Naya, F., & Sawada, A. (2013). Change-Point Detection with Feature Selection in High-Dimensional Time-Series Data. *23rd International Joint Conference on Artificial Intelligence IJCAI-13*.

[7] Ranganathan, A. (2010). PLISS: Detecting and Labeling Places Using Online Change-Point Detection. *Robotics: Science and Systems VI*. doi:10.15607/rss.2010.vi.024

[8] Vincent, P., Larochelle, H., Bengio, Y., & Manzagol, P. (2008). Extracting and composing robust features with denoising autoencoders. In *Proceedings of the 25th international conference on Machine learning (ICML '08)*. doi:10.1145/1390156.1390294

[9] Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep convolutional neural networks. In *Advances in neural information processing systems*, 1097-1105.

[10] Hoffman, H. (2007). Kernel PCA for Novelty Detection. In *Pattern Recognition*, (40), 863-874, 2007.

[11] Lowe, D. G. (2004). Distinctive Image Features from Scale-Invariant Keypoints. In *International Journal of Computer Vision*, 60(2), 91–110. doi:10.1023/b:visi.0000029664.99615.94

[12] Bay, H., Tuytelaars, T., & Gool, L. V. (2006). SURF: Speeded Up Robust Features. In *Computer Vision – ECCV 2006 Lecture Notes in Computer Science*, 404–417. doi:10.1007/11744023_32

[13] J. Liu, J. Luo, & M. Shah. Recognizing realistic actions from videos "in the wild". In *CVPR*, 2009.

[14] H. Wang, M. M. Ullah, A. Klaser, I. Laptev, C. Schmid, et al. (2009). Evaluation of local spatio-temporal features for action recognition. *21st British Machine Vision Conference (BMVC '09).*

[15] Vapnik, V. (1995). *The Nature of Statistical Learning Theory.* Springer-Verlag, New York, NY, 1995.

[16] Kawahara, Y., Sugiyama, M. (2009). Change-Point Detection in Time-Series Data by Direct Density-Ratio Estimation. In *Proceedings of the 2009 SIAM International Conference on Data Mining*, 389-400, 2009.

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July 14, 2009

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