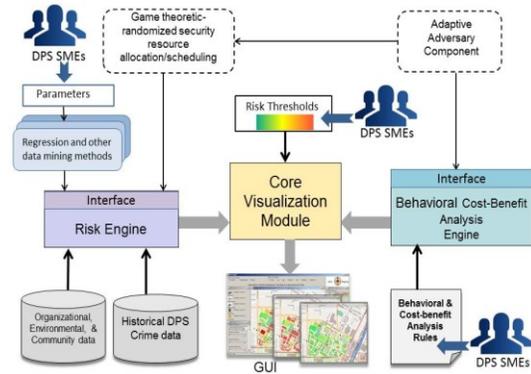


Development of Predictive Situational Awareness and Patrolling System

This project will apply predictive analytics methods to provide advanced situational awareness of crime risks at the tactical and strategic levels related to the USC Department of Public Safety patrol environment (with a focus on generalizing the technology where possible).

1. **Theme Area:** Risk and Decision Analysis - Management of Risks from Intelligent, Adaptive Adversaries
2. **Principal Investigator (PI):** Tatyana Ryutov
3. **Institution:** ISI USC
4. **Co-Investigators:** Michael Orosz
5. **Research Transition Lead:** Michael Orosz
6. **Keywords:** infrastructure risk assessment, situational awareness, predictive patrolling, data mining, spatiotemporal analytics



7. Brief Description:

The purpose of this project is to improve USC Department of Public Safety (DPS) situational awareness at the tactical and strategic levels and to develop strategies that foster more efficient and effective patrolling. Using regression and other data mining techniques to explore available data sets can provide insights into crime patterns that are unique to a given region [1]. This project will develop solutions to identify likely targets, crime types, and anticipated crime times of occurrence using dynamic data-driven statistical and geospatial analyses. In addition, the project will develop techniques for cost-benefit analysis of countermeasure allocation based on anticipated behavior of the criminals. The results will include a suite of crime event prediction and mitigation solutions and a prototype tool that have a high transition potential to DPS and other stakeholders. The project builds on the current DPS_DEPLOY effort – a real-time decision support tool (see figure above) for improving security on the University of Southern California campus and the near-by community. The researchers will work closely with the DPS to collect data and expert knowledge, validate and test modeling approaches and results and to ensure the developed system addresses the tactical and strategic needs of DPS.

8. Research Objectives:

This research project will: (1) collect and analyze additional historical DPS crime data, other relevant information related to USC campus and neighborhood community, and judgments from DPS experts; (2) develop mathematical models for forecasting likely targets, crime types and times for intervention; (3) develop a set of criminal behavior rules and corresponding cost-benefit analysis techniques for DPS countermeasure allocation; (4) validate and test the developed modeling approaches and results with the DPS historical data; (5) document the research findings; (6) implement and integrate new capabilities with the current version of the system (DPS_DEPLOY) developed by the team members; (7) demonstrate the prototype at the USC and evaluate the operation of the prototype; (8) generalize the technology for use in other physical infrastructure environments; and (9) plan for future integration within the current DPS command and control environment (actual integration is out of the scope of this project).

9. Research Transition Objectives:

This project will develop crime prediction and countermeasure allocation models and tools to be used by the USC DPS to facilitate decision making process. Specifically, DPS has indicated a need for risk-based models and tools that will help them to work more proactively and efficiently. The models and tools will be developed in close collaboration with the DPS, with the goal of developing user interfaces to facilitate key requests routinely experienced in the course of their work. In addition, the team will focus on generalizing the technology for use in other physical infrastructure environments such as maritime port (i.e., update PortSec analytics), stadium and other physical infrastructure operations.

10. Interfaces to CREATE Projects:

This project will further extend the prototype system DPS_DEPLOY developed based on the extended and modified version of the PortSec/InfraSec platform. In particular, the development of predictive models for USC campus infrastructure security will help inform the threat identification/likelihood module within the overall risk and decision modeling framework of the PortSec/InfraSec. The project will investigate integration requirements and interfaces between DPS_DEPLOY, other CREATE technologies (ARMOR/PROTECT and Adaptive Adversaries), and the current crime/dispatch tracking systems available at DPS.

11. Previous or current work relevant to the proposed project:

The researchers developed a proof-of-concept DPS_DEPLOY system prototype as a part of the CREATE Patrol Deployment Project (DPS_DEPLOY). The current implemented prototype provides the following capabilities:

- Using the DPS historical criminal data geospatially displays past criminal activities based on (1) crime type: infractions, misdemeanors and felonies, and (2) time options: all historical data, specific year, semester, date, time of the day, etc.
- Supports crime risk calculations based on a simple set of rules

The proposed project will extend the DPS_DEPLOY system with the ability to not only display past crimes (heat maps), but also predict future criminal events. The enhanced tool will provide additional visualization options. Additionally, the tool will support assessment of the representative features of various region types and the correlated crime levels, types, and times. These new capabilities will enable design of crime- and region-specific countermeasures better tailored to the actual crime problems.

12. Major Deliverables, Research Transition Products and Customers:

The project deliverables will include a technical report, a suite of data-driven crime prediction and countermeasure allocation models, and the implementation of the prototype tool. This tool will have a high transition potential to DPS. Predictive methods provided by the tool will allow DPS to work more proactively and efficiently with limited resources. After multiple discussions with the DPS personnel, the project team has identified strong interest to interact and serve as a potential customer for this product. The researchers met with Chief John Thomas and Deputy chief Jonnie Adams on November 24th 2014. The purpose of the meeting was to demonstrate the current prototype, discuss planned extensions, collect feedback related to the utility of the tool, missing functionality, etc. They were very enthusiastic about the tool, found it very useful and gave us valuable feedback. They are willing to help us with expert data to develop our behavioral rules for cost-benefit analysis of countermeasure allocations. They noted that the real time

planning capability of the tool will be very useful for them to plan their counter measure allocations (e.g., in order to reduce risk in region X one needs just one patrol officer rather than typical allocation of two). Additionally, the tool will be useful to new people who may lack experience working in the USC campus area. Potentially the developed system can be used for estimating security needs for future community planning and development (e.g., University village). The modeling solutions and insights can also be potentially transitioned to other domains and infrastructure stakeholders, such as other university law enforcement/safety organizations, stadium security organizations, ports, etc.

13. Technical Approach:

Mining of the data to develop situational awareness and predictive policing model will be accomplished using data-driven statistical learning techniques. Regression models will be built to predict crimes based on historic crime data. Our comprehensive predictive system will include two types of models: extrapolative and leading indicator forecasting (as recommended by Gorr [3]). Extrapolative forecast models capture the historic time-based patterns. Time trend estimates will employ “drift” estimators, such as exponential smoothing, that capture the most recent trend for extrapolation. Leading indicators show great promise since this method has the ability to "see pattern changes coming" [3]. Thus, this method is very good at predicting large changes in crime levels, while extrapolative methods are better for small to medium changes. Therefore, in case the leading indicator model forecasts a large change in crime dynamics, it has to be used for risk assessment, otherwise the extrapolative method's results should be used.

We can experiment with regressions of various complexities on the same data set, compare results, and select the best method. There are many time series forecasting models, ranging from simple to very complex. Fortunately, research [2, 3] has found that simple models such as the Holt two parameter exponential smoothing method with pooled seasonality are at least as accurate as complex models. The limitation of the extrapolation methods is its inability to explain characteristics of the predicted crime hot spots that make them hot, limiting the extent to which the method can inform prevention efforts.

Leading indicators (or explanatory variables) offer the ability not only to predict future crimes, but to identify underlying causes of the future hot spots [3]. Therefore, this approach can assist in the identification of crime problems and enable officers to target intervention efforts to very narrowly defined geographic areas. The analysis of historic data to determine the leading indicator relationship will depend largely on the type of causal relationship. Linear regression is one possible method, where we regress historic values of the variable of interest against the lead indicator values, with either a specific lag time if that can be causally deduced, or with a varying lag time to produce the greatest r-squared fit if one is estimating the lag time.

Leading indicator selection. Choice of variables is critical to the success of the model. To select a suitable set of covariates, the researchers will consult with DPS experts to utilize their domain experience. Preliminary set of leading indicators:

- Lesser crimes that lead to serious crimes
- Suspicious activity calls, disorderly conduct. Certain lesser crimes and dispatch calls for service (e.g., simple assaults, drug calls for service, and shots fired calls for service) lead to serious violent crimes [4]. Thus if in the past month there is an increase in leading-indicator crimes then it is likely that serious violent crimes will increase in the next month.
- Environmental changes that shift location of crime e.g., mall or parking lot construction

- Weather, higher temperature results in increase in certain types of crimes [15]
- Demographic shifts, e.g., during breaks and summer semester
- Environmental characteristics, e.g., land use - shopping/housing/parking, proximity to major streets. According to [5] most historical homicide hot spots involved public housing, were located in economically depressed sections of cities, contained drug markets, and had major roads running through them, providing easy access into and out of the area.
- Special events, e.g., football games, festivals, fairs, new students move-ins

A successful method for estimating leading indicator models is the Bayesian Vector Autoregressive model (BVAR) that uses prior beliefs to overcome collinearity and degrees of freedom problems that typically arise in applications of vector autoregressive (VAR) models [6].

Preferences of offenders. Research suggests that offender decision-making [7, 8] can be understood from a rational choice perspective [9] with offenders considering the costs and benefits of possible choices and making decisions that optimize some expectation of utility. Theories of human routine activity theory [10] suggests that for a crime to occur, a motivated offender must encounter a suitable target in the absence of a capable protector, thus crime occurrence is a function of the routine activities of offenders, potential victims, and protectors.

Research suggests that past victimizations of individual addresses, places, and businesses can be very accurate predictors of future victimizations, even when relying on the previous month's victimization [11]. An opposing effect to crime attractors is *crime displacement*. Increased enforcement in one area may displace criminal activity to other [12]. While some models of offender preferences exist [13, 14], they are not mature enough to be used in practice. We will build an initial model fully based on the expert knowledge of DPS SMEs. Based on known patterns of potential victims (e.g., typical student activities at certain times and areas) and defenders we will define rules for potential offender's strategies. Drawing on DPS expertise, spatial and temporal patterns can be expected in the sequential crimes committed by serial offenders. Rules will be developed with exploration of whether certain strategies are more apparent in certain area types or for particular types of offenders.

Cost-benefit analysis. Based on the collected DPS expert knowledge we will design and develop a model that determines: (1) cost of each type of countermeasure allocation (e.g., camera monitoring, foot patrol, patrol car, etc.), (2) resulting reduction in risk in the affected region; and (3) potential increase in risk in other regions.

System Performance Evaluation.

Historical DPS data will be divided into training and testing sets. The training data set will be used to tune the system performance and the testing data set will then be fed to the models to test accuracy of crime forecasting.

Data Visualization. In addition to current capabilities briefly described earlier in this discussion, the extended DPS_DEPLOY will display the crime forecasts generated by statistical models to facilitate interactive analysis to visually identify concentrations and patterns and to communicate those findings. The enhanced tool will provide additional visualization options:

1. Geospatially display crimes related to specific regions, specific time intervals, and **crime types** (e.g., theft, auto burglary, vandalism, etc.)
2. Display crime dynamics: increase/decrease in crime number and severity. This may serve as a crime early warning: draw attention to areas and crime types with anticipated increase.
3. Pin maps of current crimes for use in detailed crime analyses of targeted areas.

4. Countermeasure allocation cost-benefit analysis based on **behavioral** rules.

14. Major Milestones and Dates:

1. DPS expert knowledge elicitation: collect additional historical DPS crime data, USC infrastructure data, behavioral patterns of victims and criminals–October 2015
2. Develop statistical prediction models–January 2015
3. Implement additional visualizations to efficiently and intuitively communicate forecasted crime risk and countermeasure allocation risk-benefit analysis –March 2015
4. Collect DPS feedback, finalize models, analysis, and prototype look and feel –April 2015
5. Conduct case studies for model validation based on historical DPS crime data –May 2015
6. Integrate the models with existing DPS deploy prototype –June 2016
7. Collect DPS feedback, finalize models and prototype; write final report –June 2016

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16. Budget:

This one-year project will be conducted for \$50K. This includes part of the salaries for the principal investigator and the co-investigator; weekly trips to attend meetings at USC; one trip to a conference to present results; project-related materials and supplies.

17. Brief Bios:

Principal Investigator (Ryutov):

Dr. Tatyana Ryutov is a computer scientist at USC ISI. She obtained her MS in Applied Mathematics from Moscow State University, PhD in Computer Sciences from USC. She has over 15 years of research experience across multiple areas of cyber security, including security policies, access control and authorization, intrusion detection, trust negotiation, decision support. Currently, she is the Co-PI of the NSF-funded cyber-security project Understanding and Influencing Security and Privacy Decision-making (UISPD) project. Currently she is working on the implementation of the DPS_DEPLOY system prototype for the CREATE Patrol Deployment Project (DPS_DEPLOY) project. She also currently works on developing a policy system for the Department of Energy/Los Angeles Department of Water and Power jointly-funded Smart Grid Regional Demonstration Project (SGRDP).

Co-Investigator (Orosz): Assistant Director, USC Information Sciences Institute and Research Associate Professor in the USC Department of Civil and Environmental Engineering. Dr. Michael Orosz has over 30 years of experience in commercial and government software development, basic and applied research and development, project management, academic research, and has developed and deployed several commercially successful products. His research interests include decision systems, predictive analysis, integrated modeling environments, distributed system of systems, operational risk management and intelligence human-computer interfaces. Dr. Orosz has successfully led projects in developing command and control, intelligence analysis and model-based decision-support systems for applications ranging from protecting the Nation's food supply, ensuring maritime and seaport security, protecting the Nation's infrastructures and cities against terrorism events and enhanced C2I and analytics technologies used in the Intelligence Community.

Dr. Orosz is an investigator at the DHS National Center for Risk and Economic Analysis of Terrorism Events (CREATE) where he leads the development of InfraSec – an infrastructure terrorism risk assessment and security resource allocation system currently focused on large spectator venues such as sport stadiums, PortSec – a seaport infrastructure version of InfraSec currently focused on Ports of Los Angeles/Long Beach operations. He previously was an investigator at the DHS National Center for Food Protection Defense (NCFPD) and the DHS National Center for Foreign Animal and Zoonotic Diseases (FAZD) where he also served (2006-2009) as the Information Analytics Science Leader and member of the executive committee. In addition, Dr. Orosz has recently or is presently managing projects funded by DARPA, DHS, DOE, IARPA, NASA, NRO, NSA, NSF, ONR, and the USMC. Dr. Orosz received a B.S. in Engineering from the Colorado School of Mines, a M.S. in Computer Science from the



University of Colorado, and a Ph.D. in Computer Science from the University of California, Los Angeles. Prior to joining USC, Dr. Orosz worked in the aerospace/defense, motion picture entertainment, engineering consulting, and heavy-mining (natural resource extraction) industries.