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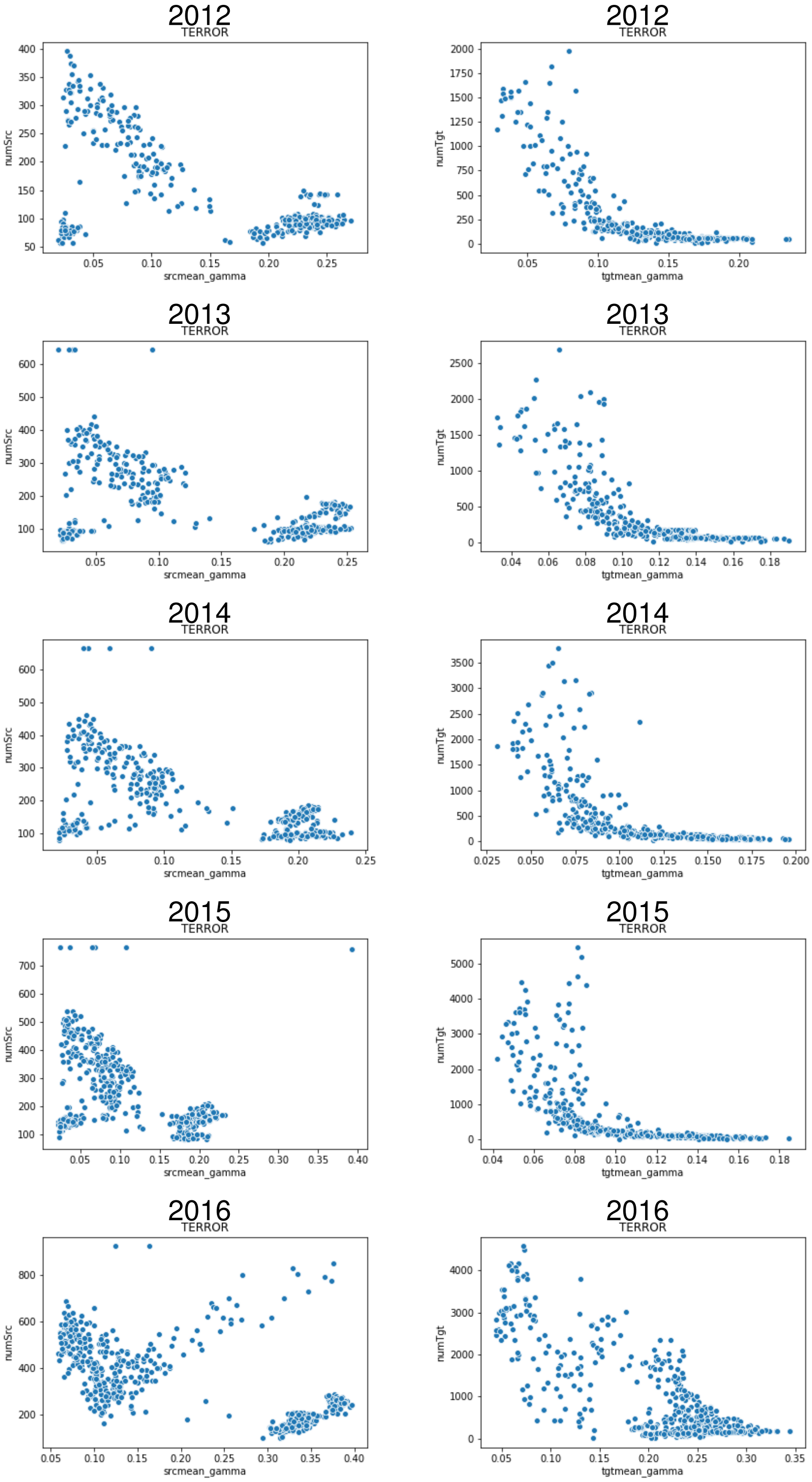
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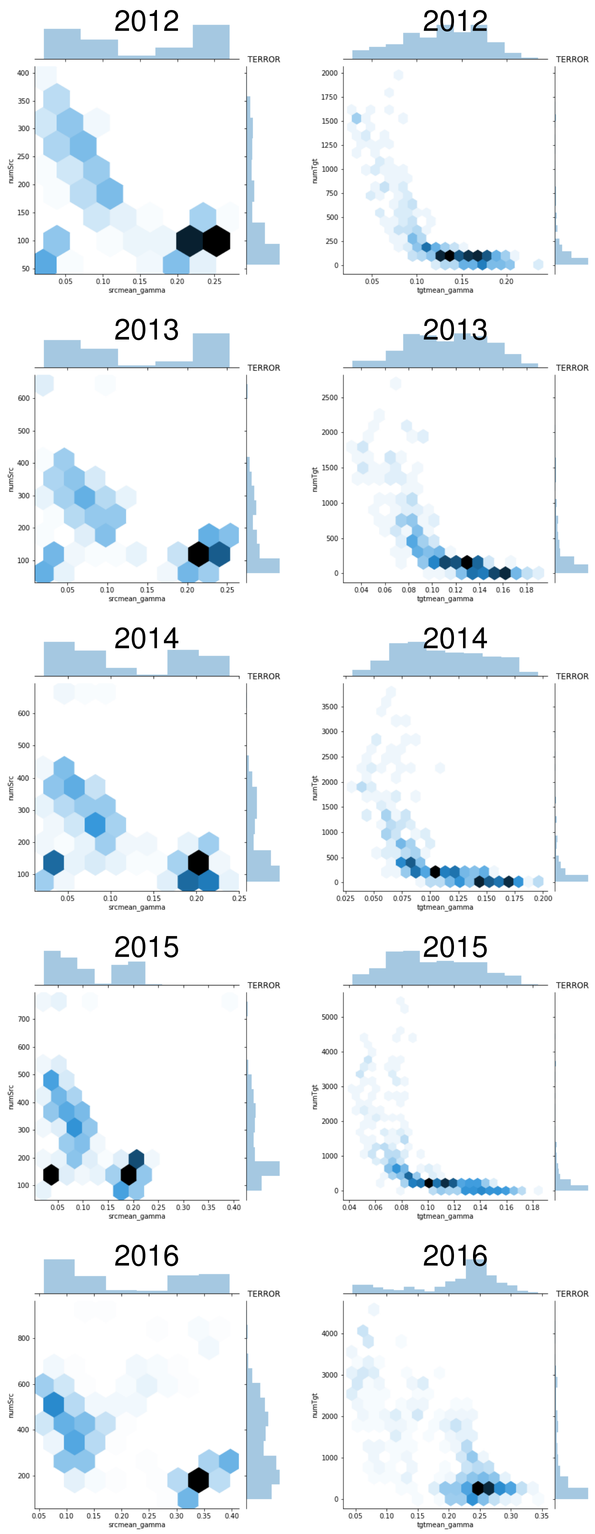
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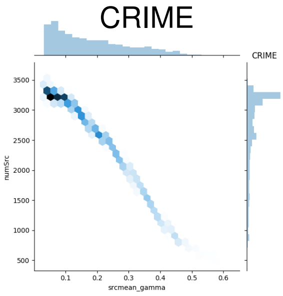
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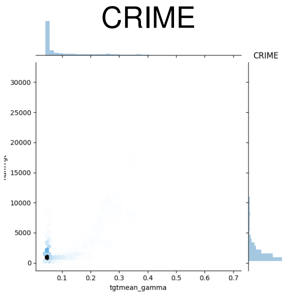
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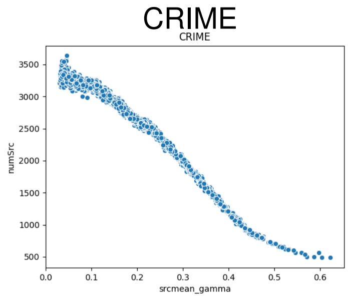
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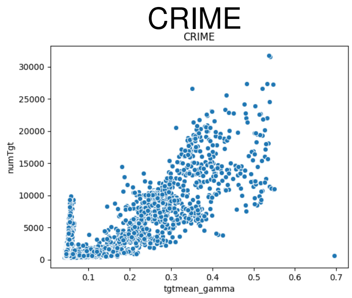
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Detailed simulation of social phenomena is currently used by the DoD to undertsand the evolution of social structures, and the emergence of relevant organizational hierachies in theatres of conflict. In the modern reality of assymmetric warfare often against local insurgencies in conlfict countries, informing military strategy with expected social impacts is instrumental for long-term policy success. In this work, we aim to define, develop and demonstrate principles for validating complex social simulations. Additionally, our investigations will extend social theory with the deep undertsanding of the principles that 1) enable us to compare and constrast complex systems, 2) disambiguate real and simulated phenomena, 3) chart effective principles to narrow such distinctions to ultimately realize more realistic models and predictions, and 4) develop computable stragegies to disambiguate closed vs open systems, *i.e.* identify the existence and delineate the role of external influences driving systemic outcomes.

Social phenomena unfold as complex interdependent system of systems operating at multiple scales of organization in space and time. While over a century of work in social theory has teased out a few of the important guiding principles around which such large scale systems organize, first principle quantitative rules akin to the laws of physics, are generally missing. Thus, unlike physics, social scientists do not have a "standard model" — a neat set of equations believed to be not just a *good* model of the physical univese, but rather an actual representation of the exact ground truth. Under this scenario, physicists can work out simulations that confidently reflect reality, and build gargantuan particle accelerators to test when and if rare events deviate from simulated outcomes to search for *new physics*, and validate existing theory. The reality for social scientists is harsher — with no such universal set of equations (*or the hope of ever finding one*), the veracity of complex social simulations is forever suspect. How do we know we have built in the right amount of complexity? How do we know if the simulated systemes have the same emergent structures, and any conclusion or observation in such systems have even a tenuous connection to reality?

Answering these questions are of crucial importance to national security. Without quantified confidence on the large scale social simulations that are becoming increasingly important in military strategy and foreign policy, incorrect recommendations has the potential for catastrophic long-term consequences.

TABLE 1: Dynamical Measures Proposed For Precise Chracterization of Complex Systems

	Measure	Property Measured	Description
1.	$\mu_\mathbf{c}$	Complexity	The level of complexity of multi-scale multi-variate spatially extended systems require new measures of compelxity that capture statistical compelxity, structure of connectedness, and cross-talk.
2.	$\mu_\mathbf{s}$	Stability	Stability in systems of interest might be finely poised between instability regimes, with the possibile manifestation of self-orgnized criticality.
3.	$\mu_\mathbf{r}$	Resilience	Qunatify the ability of systems of interest to recover from directed and random perturbations, akin to homeostasis in living systems.
4.	μ_ω	Frequency-like	Generalization of frequecny domain tools and measures to non-linear multi-scale spatio-temporal system of systems with categorical and ordinal variables.
5.	$\mu_\mathbf{e}$	External Influence	Estimate the pssibility having an open vs a closed system.
6.	$\partial\mu_i/\partial t$ $i = \mathbf{c}, \mathbf{s}, \mathbf{r}, \omega, \mathbf{e}$	Evolution & Influence	How the measures of dynamical properties evolve in time characterizes the evolution of emergent rules and drivers, indicative of the rate of information generation either within, or via influence import.

What we propose is defining measures that chraterioze diverse aspects of the emergent dynamics. The challenge here is to define of craft these measures that are application agnostic, and thus capable of evaluation objectuvely by looking at dfata from diverse real-life and soimluated scsarios. Technically speaking, we are infact designbing chraceroizations for complex spatio-=termporal systems, with unknow or poor;y understood rules, operating t multiple spatial and temporal scales, with variables that can be a mix of categoriacal, ordinal as well as discrete and continuous, is subject to noisy and possibly adversarially corrupted observations.

Why is this great, and never before done.

Measures of Complexity

Characteriztion of complexity has intrigues mathematicians, physicistys and philosophers for centuries. Social systems bring new challanges for the reasons described above. It is unclear if teh fundamental ideas of descriptional complexity adequately capture the notion of interest in our case. Intutively, we aim to investigate th eidea that real systems are somehow more complex — maybe irreducibly complex — and simulations however detailed often lack this tell-tale signatures of real-world complexity.

Measures of Stability

Measures of Reslience

Time -domain Measures & Analytics

Measures of External Influence

Systems of Interest

Crime, Terrorism, Simualted worlds from current DARPA programs, Robo Soccer, Real-life Soccer

1 Executive Summary

We aim to detect, and quantify cognitive dissonance in individuals, communities, and sub-populations, and ultimately craft a general theory of belief shift over time driven by the purported human need of maintaining internal cognitive consistency. In addition to identifying dissonance, we bring together psycho-social theory, stochastic processes, and large deviation theory to propose a theoretical framework to predict likely choices of response strategies invoked to reduce cognitive conflict, and model the long-term stochastic dynamics of belief evolution. We aim to validate our proposed theory and tools on publicly available large social survey data sets, and in focused longitudinal experiments with human subjects.

Cognitive dissonance[?] refers to the psychological stress arising from holding two or more contradictory beliefs, ideas or values. Festinger in his *A Theory of Cognitive Dissonance*[?] posited that humans have an intrinsic drive to hold all our beliefs in harmony. To maintain cognitive consistency, individuals might attempt to reduce the importance of the conflicting beliefs (trivialization), acquire new beliefs (rationalization), or alter the conflicting attitude, opinion, belief or behavior. Thus, Festinger's thesis in effect postulates a mechanism of belief shift over time, and suggests that such processes might be effectively modulated via interventions suitably informed by quantitative estimates of dissonance.

Since Festinger's original formulation, researchers have theorized alternative mechanisms that maintain cognitive consistency.[?], [?], [?] Notwithstanding the actual psychological processes in play, the central goal of this work is well defined: *Can we quantify cognitive dissonance in individuals, or communities? And can we predict the routes they take to reduce conflicts in their cognitive processes?*

This is a problem of crucial importance for DoD operations, especially in conflict countries. In the modern reality of asymmetric and urban combat operations often directed against local insurgencies, a tool that recognizes cognitive dissonance in the populace, and can predict belief shifts over time, is vitally important for long term strategy. As an example, ability to shift away from violent behaviors might negate the need of military action, saving considerable resources. In addition, the proposed work will establish a fundamentally novel approach to analyzing, and interpreting large scale survey data, thus advancing socio-psychological theory. At the same time, ability to predict belief shifts among the US population can inform key policy decisions.

The proposed set of measurable milestones will demonstrate verifiable progress within the first 6 months, with computation of dissonance vectors for the entire General Social Survey (GSS) dataset, with belief shifts modeled under simple scenarios. By the 10th milestone, we aim to have validated our belief shift models in large scale longitudinal databases, as well as in focused field experiments.

Our technical challenges arise from the qualitative nature of the notion of dissonance. The complexities of social structures, and the diversity of ideas and beliefs that the human mind processes, makes it problematic to objectively quantify — or even reliably recognize — the notion of cognitive conflict. Perhaps even more difficult is the detection of such conflicts at scale, with realistic observational data.

Naive attempts at directly quantifying the role of historical and societal drivers behind beliefs, opinions and values — and how those evolve — is an intractable proposition.

Our approach simplifies the problem by formulating a computable measure of cognitive dissonance as a measure of surprise: when asked a diversity of questions, dissonance with respect to a specific topic manifests as a deviation from a model estimate of the expected and the actual recorded response. Effectively modeling expected responses with little or no prior knowledge of the emergent dependencies between the survey responses, is non-trivial. We plan to develop a novel machine learning framework called the recursive decision forests, specifically designed to seek out dependency structures in response databases without resorting to brute force searches in exponential spaces, and ultimately obtain quantitative estimates of cognitive dissonance.

The proposed work will be carried out over a period of 24 months in the base period, followed by 12 months in the option period, at a total cost of 1M USD.

2 Goals and Impact

The goals of this project are twofold: 1) detecting and quantifying cognitive dissonance in populations, communities and individuals, irrespective of geography, social and demographic context, and 2) develop data-validated theoretical models of belief shifts over time arising from the differential choice of dissonance reduction strategies employed by individuals. Within these broad goals, we aim to develop quantitative scalable measures of cognitive dissonance, characterize uncertainty bounds on our predictions. We plan to extensively validate our findings on large scale social survey data sets spanning multiple decades of recorded responses on a vast diversity of contentious issues from tens of thousands individuals from diverse socio-economic and demographic backgrounds.

Innovation: From Socio-psychological Theory To Data-driven Inference

Our proposed work is starkly novel in the level of mathematical rigor, the scalable computational tools, and the elegant quantitative adoption of a qualitative theory in psychology. The key innovation here is the formulation of the notion of cognitive dissonance as a **quantitative measure of surprise**; computed as the deviation of an individual's response to survey questions from what is predicted by data-inferred models from the responses of a wider random population to a broader set of queries. We bring together key insights from social and psychological theory, stochastic processes, and large deviation theory, to develop a novel machine learning framework (**recursive decision forest**) specifically designed for the problem at hand. Current research in the theory of cognitive dissonance is mostly qualitative, and the use of sophisticated learning algorithms custom is rare to non-existent.

Impact: Actionable Modulation of Local Opinions in Theaters of DoD Operations

- **Ability to quantify cognitive dissonance in US population and beyond.** The ability to understand if there is cognitive dissonance arising from opinions on specific contentious issues can potentially emerge as key tool in crafting policy. For the DoD, this capability will be a vital decision support tool when engaged in military operations in conflict countries.
- **Belief Shift Prediction.** Perhaps more crucial is the ability to understand how beliefs would shift as a result of cognitive conflict; thus allowing decision-makers to have actionable knowledge to modulate social interaction outcomes, particularly in foreign theaters of DoD operations.
- **Extending Social Theory.** The successful validation of the our proposed tools will revolutionize the analysis of large scale survey data. The ability to distill incipient micro-structural cross-dependencies and predict psycho-social dynamics at the level of sub-populations to individuals is currently beyond the state of the art, limited to mostly large scale trend analysis.

Deliverables include validated software, to be deposited in open source repositories; results from validation experiments; reports as determined by DARPA; and published research articles.