Physica A 443 (2016) 380–384

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Quantitative patterns in drone wars

Javier Garcia-Bernardo [a], Peter Sheridan Dodds [b,*], Neil F. Johnson [c]

[a] Department of Computer Science, The University of Vermont, Burlington, VT 05401, United States

[b] Department of Mathematics & Statistics, Vermont Complex Systems Center, Computational Story Lab, & The Vermont Advanced Computing Core, The University of Vermont, Burlington, VT 05401, United States

[c] Department of Physics, University of Miami, Coral Gables, FL 33124, United States

HIGHLIGHTS

- Drone warfare death tolls fundamentally differ from other kinds of warfare.
- Statistics indicate that attacking side holds complete control.
- A simple model captures observed statistics.

ARTICLE INFO

Article history:
Received 16 May 2015
Available online 1 October 2015

Keywords:
Warfare
Drones
Terrorism
Scaling

ABSTRACT

Attacks by drones (i.e., unmanned combat air vehicles) continue to generate heated political and ethical debates. Here we examine the quantitative nature of drone attacks, focusing on how their intensity and frequency compare with that of other forms of human conflict. Instead of the power-law distribution found recently for insurgent and terrorist attacks, the severity of attacks is more akin to lognormal and exponential distributions, suggesting that the dynamics underlying drone attacks lie beyond these other forms of human conflict. We find that the pattern in the timing of attacks is consistent with one side having almost complete control, an important if expected result. We show that these novel features can be reproduced and understood using a generative mathematical model in which resource allocation to the dominant side is regulated through a feedback loop.

1. Introduction

Dating back to physicist L. F. Richardson's pioneering work nearly 100 years ago [1], the quantitative analysis of human conflict has attracted research interest from across the social, biological, economic, mathematical, and physical sciences [2–7]. As in a wide range of other human activities [8,9], power laws have been identified in the severity distribution of individual attacks in insurgencies and terrorism [10,4–6], and in the temporal trend in events [10,11,5]. These studies found that across a diverse catalogue of insurgent wars in which a relatively small opponent such as an insurgency (Red Queen [11]) fights a larger one such as a state (Blue King [11]), the probability distribution for the severity s – the number of fatalities – of an event (i.e., clash or attack) is given by $P(s) \propto s^{-\alpha}$ where $\alpha \sim 2.5$, while the trend in the timing of attacks is given by $\tau_n = \tau_1 n^{-b}$, where τ_n is the time interval between events n and $n+1$, $n = 1, 2, \ldots$ and b is the escalation parameter. When $b = 0$, the Blue King and Red Queen are evenly matched, with both effectively running on the same spot—hence the

* Corresponding author.
E-mail addresses: javier.garcia.bernardo@gmail.com (J. Garcia-Bernardo), peter.dodds@uvm.edu (P.S. Dodds), njohnson@physics.miami.edu (N.F. Johnson).

http://dx.doi.org/10.1016/j.physa.2015.09.055
0378-4371/

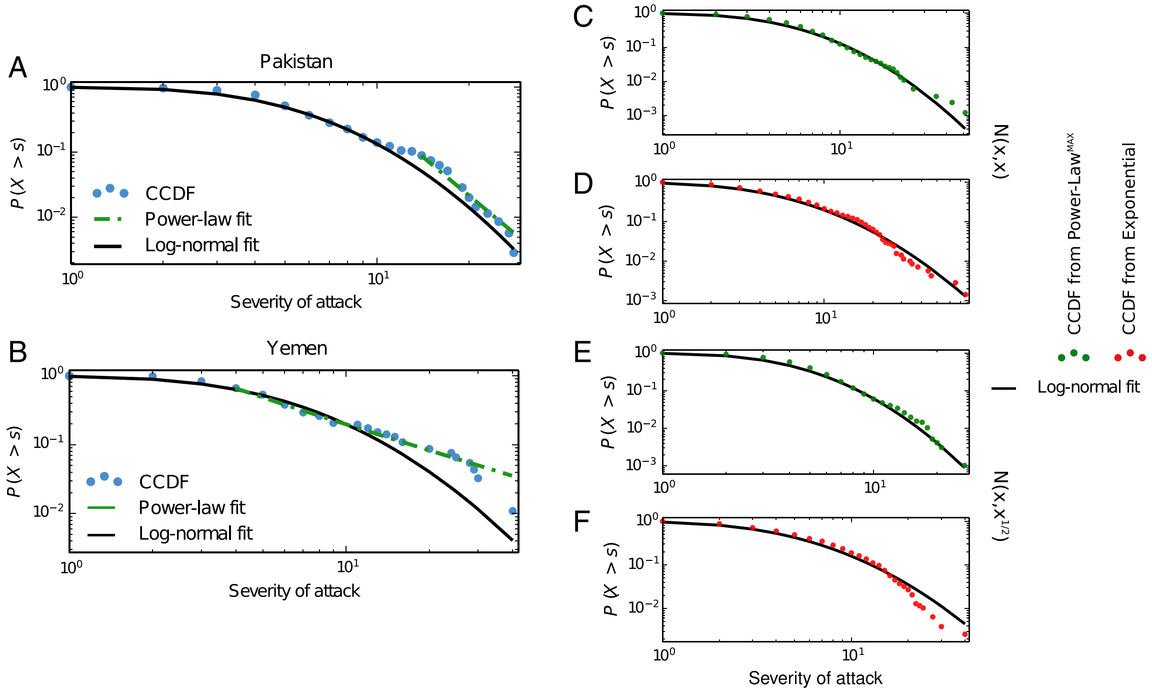

Fig. 1. The severity of drone attacks approximately follows a lognormal distribution. Complementary Cumulative Distribution Function (CCDF) of the severity of attacks (blue dots and solid line) and best fits to power-law (dashed green) and lognormal (solid black) distributions for drone attacks in Pakistan (A) and Yemen (B). The optimal parameters for each distribution are (A) Power-law: $\alpha = 4.82$, Log-normal: $\mu = 1.60$ and $\sigma = 0.64$, (B) Power-law: $\alpha = 2.21$, Log-normal: $\mu = 1.65$ and $\sigma = 0.77$. (C–F) CCDFs of the severity of attacks and best fits to log-normal distributions. (C and D) The attack size is drawn from a normal distribution $N(\mu, \sigma)$ with μ and σ corresponding to (C) the largest value in 100 random numbers drawn from a power-law ($\alpha = 4$) and (D) a random value from a exponential distribution ($\lambda = 5$). (E and F) The attack size is drawn from a normal distribution with μ and σ^2 corresponding to (E) the largest value in 100 random numbers drawn from a power-law ($\alpha = 4$) and (F) a random value from a exponential distribution ($\lambda = 5$). The maximum likelihood parameters for the lognormal fits are (C) $\mu = 1.48$ and $\sigma = 0.73$, (D) $\mu = 1.51$ and $\sigma = 0.93$, (E) $\mu = 1.33$ and $\sigma = 0.63$, (F) $\mu = 1.44$ and $\sigma = 0.86$. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

terminology surrounding the Red Queen [11]. When $b \neq 0$, there is an escalation in the frequency of attacks which can be interpreted as a relative advantage between the Red Queen and the Blue King [11]. The power-law finding for the distribution of event severities is consistent with the Red Queen (i.e., insurgent force) evolving dynamically as a self-organizing system composed of cells (i.e., clusters) that sporadically either fragment under the pressure of the Blue King (e.g., state) or coalesce to create larger cells, and taking the severity of attacks as proportional to the sizes of the resulting cells [6].

Here, we examine event patterns in the new form of human conflict offered by unmanned combat air vehicles (drones) [12]. We focus on Pakistan and Yemen because of their association with drone strike campaigns, using data from the New America Foundation and the South Asia Terrorism Portal databases. The situation of drone wars differs from the typical situation for insurgencies and terrorism in that the attacks are now carried out by the Blue King on the Red Queen. Moreover, the sophistication of the action-at-a-distance technology means that any delay in the Blue King's next attack is likely to have come from a constraint within Blue itself (e.g., political opposition) as opposed to any direct counter-adaptation by the Red Queen. Our findings show that drone attacks tend to deviate from the universal patterns observed in the severity and timing for insurgencies and terrorism, and instead suggest a new regime in which the Blue King has almost complete control over the conflict. We develop a generative model in which the timing of attacks is determined solely by the resources of the Blue King, but are regulated by a positive feedback loop due to the Blue King's internal sociopolitical and economic constraints. We show that this simple model reproduces the main features of the original data and hence the unique nature of drone warfare.

2. Results and discussion

Fig. 1(A) and (B) show the complementary cumulative distribution function (CCDF) of the severity of drone attacks using the New America Foundation database. We fit power-law and lognormal distributions (dashed green and solid black lines respectively; see Methods) for attacks in Pakistan (Fig. 1(A)) and Yemen (Fig. 1(B)). We find that the severity of the strikes is approximately described by lognormal distributions, particularly in the case of Pakistan. In the case of Yemen, for which we have far less data, the lognormal is more tentative with the larger events deviating most. This finding of approximate log-normality is consistent with the notion that a drone has a specific design and targets (predominantly houses and vehicles)