Incentive Dynamics in Organized Crime

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ABSTRACT

This project explores Games on a Network, specifically focused on competitions among organized criminal networks. We identified and investigated different norms and incentives of organized crime rings, and propose a network generation procedure based on the findings. In our model, organized criminal networks ("gangs") can create periodic value from the controlled territory. More members operating in a fixed amount of territory leads to a higher value extracted per period. On the flip side there is a cost to increasing gang size, determined by the gang's profit distribution policies. Different monetary distribution policies within the gang results in a variety of network structures. Using the generated network structures, we created an agent-based model to simulate the competition between two gangs. Early exploration reveals that even a simple combat model over two networks can produce rich, sensitive and hard-to-predict dynamics, which may have implications for network resilience and group competition dynamics in general. Our code can be found here.

Introduction

This work aims to explore the dynamics of group competition by focusing on the extreme case: competition or combat between organized crime networks. Under the setting of limited resources (territory), groups (gangs) compete each other to maximize the profit. Each gang is modeled as a network structure defined by the characteristics such as maintenance cost of each member, tribute on earnings paid to leadership, and the amount of total controlled territory. The combat process is modeled as an agent-based turn-based game. It is shown that local decision making can influence the network structure and state, which determines the performance and resilience of the network.

This work has three parts. First, a network generation process is proposed to represent the internal structure of a gang. Next, a turn-based game is designed to simulate the competition between two gangs. Finally, the results of the simulation is presented and the implications are discussed.

Criminal Network Typology

In 2002 the United Nations Office on Drugs and Crime (UNODC) conducted a survey of forty selected organized criminal groups in sixteen different countries.[1] The general profile to describe each group includes

"structure; size; use of violence; scope of activities; level of transborder operations; corruption; level of political influence; extent of activity in the legitimate economy; and the degree of cooperation with other organized crime groups."[1]

The report breaks down network structure/typology into the following categories

- Standard hierarchy
- Regional hierarchy
- Clustered hierarchy
- Core group
- Criminal network

Organized criminal groups are formed by a network of individuals engaged in criminal activity, and most successful organized criminal groups have hierarchical structures. Resource (e.g., money) and information (e.g., orders) flow inside the network, which create incentives for individual participation. Inspired by this fact, this work assumes that network analysis of the hierarchical structure of organized criminal networks has meaningful implications to the understanding of group decision making and the resulting operational performance.

Agent-Based Combat Simulation

To probe network resiliency we developed a simplified agent-based network combat model inspired by the Observe-Orient-Decision-Action (OODA) Loop[2] developed by John Boyd and modeling paradigms from the EINSTein model described in Ilachinski's Artificial War[3].

The intent of our study is to keep the combat model as simple as possible and focused on network structure in order to highlight how local decisions propagate across the network. We borrow from Ilachinski the following features:

"**Simplicity**. Keep rules small, and by defining those rules as simply as possible. The idea is to qualitatively probe the behavioral consequences of the interaction among a large number of notional variables, not to provide an explicit detailed model of the minutiae of real-world combat."[3]

"**Goal-directed**. agents base their actions on simple goals that they are motivated to fulfill."[3]

"**Boundedly rational**. all actions are derived from a well-defined, logical inference engine applied to localized information."[3]

In our model, organized criminal networks ("gangs") can create periodic value from controlled territory. The more members operating in a fixed amount of territory leads to a higher value extracted per period. On the flip-side there is a cost to increasing gang size, determined by the gang payout incentives. When asked to attack a rival gang to acquire their territory, gang members must decide whether to **fight** alongside or **defect**. The opportunity for defecting leads gang bosses to misattribute the power of the gang if lower level nodes are not properly incentivized, making the gang susceptible to takeover by a smaller network.

Methods

Criminal Network Structure Generation

Single member pay-off modeling

We model the gain of a single gang member in two parts: a) exploited values from the directly controlled territory; b) tributes from the downstream subordinates.

The amount of value one member can exploit from the territory (alone) is expected to have diminished returns since the energy and time for a person is limited. In this case, we use the logarithm function to capture concavity:

$$g(T) = ln(T) \tag{1}$$

where T is the amount of territory one member directly controlled and $g(T)$ is the amount of value one can extract from the territory by oneself alone.

The diminishing returns to controlled territory incentivizes the gangster to recruit other members with which to share the territory, in exchange for tribute. However, recruiting others also has cost (e.g., salary/maintenance). In other words, the gangster "lease" parts of the territory to other members of the gang in return of "rent", while paying "maintenance cost" to sustain the relationship. We model the total payoff of the member as the following:

$$g(T,N;\alpha,R) := \log\frac{T}{N} + \alpha\cdot(N-1)\cdot\log\frac{T}{N} - (N-1)\cdot\log\frac{T}{R} \tag{2}$$

where T is the total territory owned by the gangster; N is the number of subordinates; α is the portion of gains required from the subordinate as the tribute; and R is the average maintenance cost for one subordinate. Note for anyone except the big boss (the Don), one has to pay his/her tribute to the upstream boss. So Equation 2 becomes

$$g(T,N;\alpha,R) := (1-\alpha)[\log\frac{T}{N} + \alpha\cdot(N-1)\cdot\log\frac{T}{N} - (N-1)\cdot\log\frac{T}{R}] \tag{3}$$

The cost R is modeled to decrease as the network depth increases. This is because as the network layer increases, the available territory (and the potential profit) for each member in the layer decreases (the territory of a layer is split from the upstream node). In other words, low rank members control less territory than high ranking members. Additionally, low rank members have low maintenance cost (e.g., salary). To account for this fact, the cost in every new layer $(l+1)$ is modeled as a fixed proportion r to the parent layer l cost:

$$\bar{R} = \frac{R_{l+1}}{R_l} \tag{4}$$

The proportion $\bar{R}$ is set to be 2 in this work for model stability purposes after numerous experiments.

The network generation process

A hierarchical criminal network can be automatically generated given initial territory T_{init}, tribute proportion α, and member maintenance cost R.

Each gang was initialized with one single member (the Don) with an initial territory. Then the criminal network is generated recursively using Equation 2 and Equation 3. Specifically, the Don splits the territory to recruit new members by maximizing his/her own total payoffs (Equation 2). Each member may further split his/her own territory to maximize the payoff (Equation 3). The process stops as the bottom layer member has no incentive to further split the territory as the cost ($(N-1)\cdot\log\frac{T}{R}$) exceeds the benefit ($\log\frac{T}{N}+\alpha\cdot(N-1)\cdot\log\frac{T}{N}$).

The characteristics of a gang is captured by the hyper-parameters α and R. For example, a "generous" gang may focus on the well-being of its gang members. In other words, every member not only charges a small amount of tribute from the subordinates (small α) but also pays well for them (large R). On the other hands, having small R and large α signals a highly exploitative gang. The generated network structures for the two gangs (with the same initial territory amount) is illustrated by Figure 1.

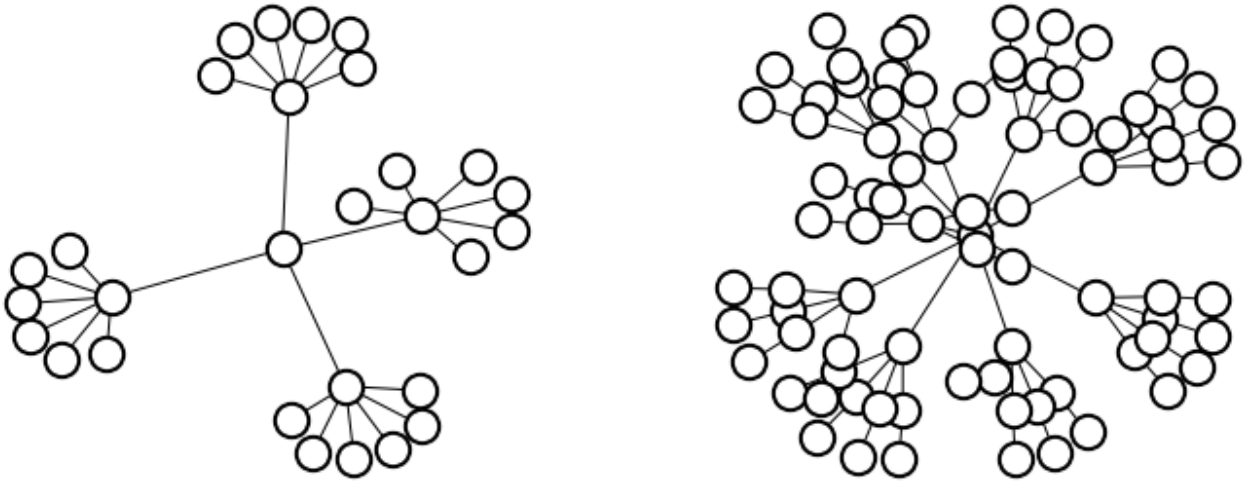


Figure 1. The generated structure for a "generous" gang (Gang A, left, $\alpha = 0.5$ and $R = 4$) and a "exploitative" gang (Gang B, right, $\alpha = 0.8$ and $R = 3$). Both are initialized to 300 units of territory.

Having small tribute ratio α and large maintenance cost discourages a member to split the territory, as shown by the left figure (Gang A) in Figure 1. The network has only three layers and each layer has limited number of members. On the other hand, a highly exploited gang (Gang B) encourages each member to recruit new members due to the high tribute ratio. Consequently, it has many more layers (5 versus 3) and thus many more members (82 versus 29) comparing to the generous case. However, Gang A has more wealth than Gang B (36.41 Vs 12.88). This is because comparing to Gang B, each member in Gang A fully utilizes the value of the territory (i.e., has larger territory). Also, having less members means the total maintenance cost for the group is small, even though the individual cost is high.

Gang Combat Simulation

We also present a way of simulating one on one gang combat in this study. Specifically, we modeled how two gangs compete for limit resource (total territory) to maximize the profit. The combat of gangs is simulated through a turn-based game, with the following procedure:

- Initialization: Two gangs, configured by separate parameters (α, R, T_{init}), are initialized. Each gang may have different structure and territory distribution. The total available territory is also specified in this stage. One gang is randomly selected as the attacker.

- Observe. We assume each gang has limited information about the opponent. To model the information gap, the attacking gang randomly choose an opponent member to "interrogate". The attacker only get the downstream structure information of the interrogated opponent. All the other information about the opponent remains unknown.

- Recruit. Based on the obtained information, the attacking gang decides whether to attack through recruiting fellow members to the cause. The recruiting process involves selecting the minimum substructure of the network that overpowers (have more members) the "probed" opponent substructure. If there is no such structure exists in the network, the attacking gang give up the right to act.
- Attack. If the attacking gang recruits enough people to act, then the game enters the attacking stage. The attack process is modeled as a Bernoulli random process. All the members of the attacker and the opponent group (substructure of the gang) are ranked from the lowest level (least subordinate) to the highest level (mos subordinate). Starting from the lowest level members of both groups, duels are conducted one by one. The duel is modeled with both sides has the equal chance of winning. If the attacker wins, the winning gang takes the loser's territory, and the loser is removed from the network. If the attacker loses, the loser is removed from the attacking gang and the territory goes back to the loser's boss. The attacking stage ends when one side has no member left. Note that the network structure of both sides may change in this stage due to the loss of members.
- Redistribute. The territory distribution between the two gangs and within each gang changes after the attacking stage. New members are recruited for the excessive territory using the network generation process described in the previous section. Note that the network structure of both sides may change in this stage.
- Switch and Repeat. Attacker becomes defender, and the game goes on. In other words, restart from the "observe" stage with switching sides, unless the desired number of simulation iterations is satisfied.

Results

We are early into out exploration, but in this working paper we explore an example of simulated combat between two gangs, Gang A and B parameterized as follows.

- Gang A: $\alpha = 0.6, R_0 = 3, \bar{R} = 2$
- Gang B: $\alpha = 0.7, R_0 = 4, \bar{R} = 2$

The simulation starts with 1000 units of territory split evenly between Gang A and B. Before the simulation starts, the gangs are initialized as a single node holding 500 units of territory and we run the network generation procedure. Figure 2 shows the network structure generated by the two sets of parameters.

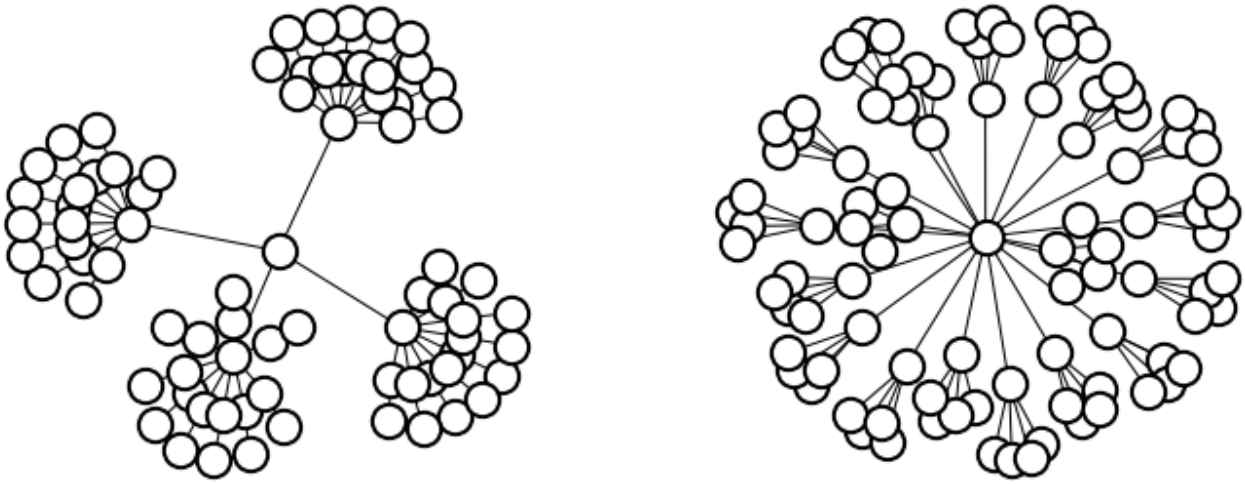
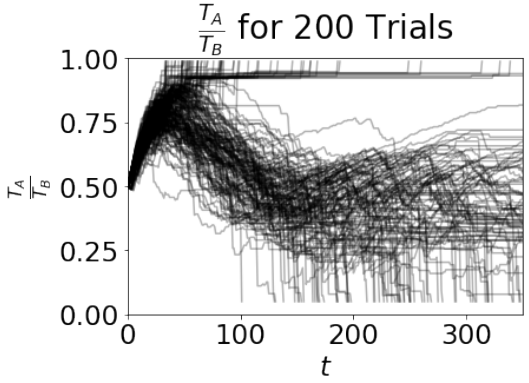
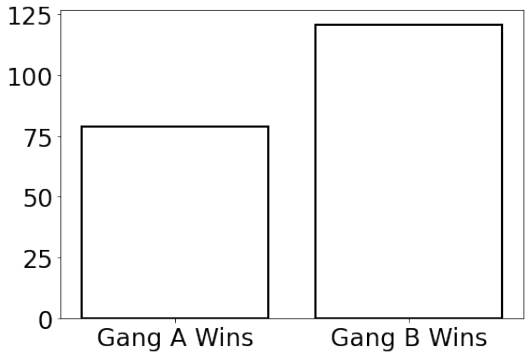


Figure 2. Gang A (left) and Gang B (right) Network Structure

Figure 3a showcases the time evolution of territory controlled for each gang plotted for 200 combat simulations. On the y-axis is the percentage of total territory held by Gang A. All runs begin with Gang A rapidly taking over enemy territory, and



(a) Percentage of territory held by Gang A at iteration t over the course of 200 simulation trials.



(b) Number of Gang A wins ($T_A > T_B$) and Gang B wins

Figure 3

in some instances, they proceed to wipe out Gang B entirely (sometimes Gang B appears to be able to hold on to the final $\approx 10\%$ for a while). But in many trials, Gang B is able to rebuild and take territory from Gang A, sometimes even completely winning. Even though Gang B seems really vulnerable starting out, it seems that Gang A struggles to control territory in the face of an underground Gang B, who ends up coming back and controlling more of the territory in a majority of trials.

Conclusion

We present a way of generating member structures for gangs based on a simple "tribute payment" model. Agent-based bottom-up combat simulation is modeled to simulate the competition between two gangs on acquiring finite resources. Early exploration reveals that such a simple combat model can produce rich, sensitive and hard to predict dynamics. In the future work we are interested in understanding the dynamic landscape of the $(\alpha, R, \bar{R})$ space, and dive deeper into the general implications about network resilience and group competition dynamics brought by the model.

References

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3. Ilachinski, A. *Artificial war: Multiagent-based simulation of combat* (World Scientific, 2004).