CitadelPolice: An Interactive Visualization Environment for Scenario Testing on Criminal Networks

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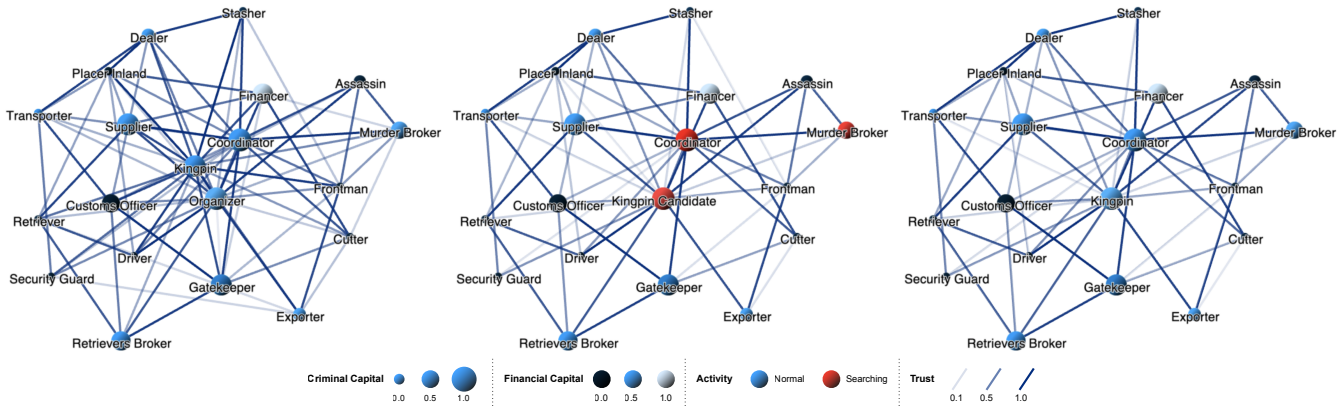

Figure 1: *A visualization created with CitadelPolice displaying a sample criminal network with 20 agents in a Fruchterman-Reingold force-directed layout weighed by edge "Trust" over time; from an undisturbed network on day 1 (left), the kingpin is removed on day 5 (not visualized), triggering a conclave to decide on a replacement on day 10 (middle), to the network having recovered on day 35 (right). Each agent assumes a different role, displayed with textual annotations.*

Abstract

Criminal networks have proven to be highly resilient against law enforcement interventions. This resiliency has driven researchers to investigate these networks further. However, the obtained insights reaching law enforcement agencies are generally highly case-dependent or extremely general. Therefore, CitadelPolice aims to provide an environment for visualizing criminal network models on a comprehensive and interactive dashboard. The main advantage of CitadelPolice is that it allows law enforcement to independently test specific scenarios and discover the most effective disruption strategy before deploying it. To achieve this, we used a computational network model based on collaboration with and data from the Dutch Police Force, named the Criminal Cocaine Replacement Model and implemented this on a web-based graph visualization and simulation tool named Citadel. Using this, we can interactively visualize the network while running simulations. To test the effectiveness of the network visualization and implementation of the model, we performed sequential usability testing and compared the results over time.

CCS Concepts

• ***Human Centered Computing*** → *HCI* → *Usability Testing, Web-based interaction; Visualization* → *Graph drawings.*

1. Introduction

The current state of the Dutch Criminal Cocaine Network is critical. The network operates with high efficiency, large amounts of cocaine are being shipped to the port of Rotterdam, retrieved and sold throughout the country or transported across the border to other European countries [SBR*23]. Associated with this profit-based organized crime are (threats of) violence, endangering the safety of people that come in contact with the criminal network [RKK22]. And although there is plenty of police intervention, the networks recover through temporarily prioritizing security over efficiency and finding replacements for the removed criminals [Ber21]. This prompted both researchers and law enforcement to reconsider the prevailing intervention methodology. The intervention approach has already shifted highly over the past decades from the "Mr. Big" removal to targeting more specialized and broker roles [Ste20]. But further research is necessary and an approach suited well within this time is the use of computational models to gain more insight into these criminal networks and find better disruption techniques. However,

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the missing link until now was the bridge between the researchers creating these models and law enforcement agencies having access to real data and scenarios in which intervention needs to be executed. The CitadelPolice project bridges this gap between law enforcement and recent research through the creation of an interactive graph visualization dashboard on which law enforcement officers can independently investigate different intervention scenarios and their outcomes through manipulation of the criminal network.

2. Methods

The methods used for this project are the Criminal Cocaine Replacement Model (CCRM) and an online graph visualization and manipulation tool called Citadel. Both are still in development and this project plays a role in steering their evolution. However, the main component of this research was the implementation of the model into the tool.

2.1. Criminal Cocaine Replacement Model

The CCRM is an Agent-Based Model on a network which simulates the recovery of a hypothetical, but realistic, sub-segment of the Dutch Criminal Cocaine Network after the removal of a central node, e.g. a kingpin or a specialist [ONV*23]. It models how a replacement is selected through a conclave in which important agents that were close to the removed node decide on a candidate (see the middle graph of Figure 1). The candidate is chosen based on their role, relations with other criminals and their distance and resemblance to the removed node. The CCRM is the current use case for this project but will be expanded to include the general development of the network over time and more intervention strategies.

2.2. Citadel

Citadel is a React web application using Cytoscape.js, which visualizes online hosted JSON and GraphML graphs and allows its users to map one or multiple visual attributes. The mapping possibilities, loosely based on Bertin's Semiology of Graphics [Ber67], are size (radius for nodes; width for edges), lightness, saturation, opacity, hue, shape and text. Categorical attributes are limited to the last three of these mappings. For node positions, several graph layout algorithms are supported or they can be determined based on attribute values that are mapped to x- and y-position, e.g. geographical location. This versatile visual design enables users to explore and analyze various attributes of interest, all possibly leading to valuable insights, such as observing fluctuations in an agent's criminal capital based on their mindset or comparing fitness values between roles.

To further inspect the graph visualization, there are options for zooming and dragging and a single command can re-center the graph. For inspecting the graph itself, the user can select a (cluster of) node(s) or edge(s) to see all attributes and their values. Single node or edge selection allows users to change the attribute values. Clusters show these attribute values in a histogram and include statistics on the count, and for ordered attributes, the minimum, maximum, mean and median.

Citadel further facilitates the connection of a (local) simulation in the form of a stateless step function, after which the user can run one or multiple simulation steps. The results can be viewed as an animation or by flipping through the time steps. The motivation for using Citadel lies in the possibility to manipulate the graph through simulation. This provided us with the unique possibility to interactively test intervention scenarios and get immediate visual feedback, even during a simulation run. Other graph visualization tools, like Gephi, require separate steps for simulation setup and visualization.

Table 1: Results on the usability and effectiveness of CitadelPolice. The values are the mean percentages from 10 observations with their standard deviation.

	Baseline	**After Improvement**
Usability	$41.00\% \pm 19.76\%$	$59.25\% \pm 20.07\%$
Effectiveness	$46.18\% \pm 18.87\%$	$72.47\% \pm 10.13\%$

2.3. Implementation

To run the CCRM with Citadel, the model and network states were transformed to fit the graph format and simulation paradigm of Citadel. In addition, to make the simulation interactive, the step function needed to contain triggers for specific events or dynamics. An example of this is that when the "Kingpin" is removed from the graph, the remaining agents are triggered to search for a new one. Further, the mental map is preserved throughout the simulation by keeping the node positions fixed (dynamic stability) or by animated incremental changes (transition period) [BBDW17; NF02].

3. Evaluation

To evaluate CitadelPolice, we assessed how understandable and usable the implemented model is for brand-new users. Since access to domain experts was limited, we used highly educated general users with varying ages and educational backgrounds as participants. We applied sequential testing sessions to reflect on and aid further development of the implementation. Usability was measured through a standard self-reporting questionnaire, the System Usability Scale (SUS). We evaluated effectiveness by posing questions to users regarding the network and simulation, which gauged their comprehension of network dynamics and the system's capabilities. Effectiveness is the percentage of those questions answered correctly.

The results are shown in Table 1. While the baseline results indicated a need for further advancements, the second testing session showed improvements in both usability and effectiveness. According to the non-parametric Mann-Whitney U test with $\alpha = 0.01$, the effectiveness scores are significantly higher ($U = 10, p = 0.003$) from the baseline session, but usability is not ($U = 26, p = 0.075$).

4. Conclusion

In conclusion, CitadelPolice should provide law enforcement with a novel tool to disrupt the criminal cocaine network in the Netherlands. We created the possibility for law enforcement to cultivate specialized interventions by independently simulating disruption methods and comparing the outcomes. In effect, we hope this leads to more effective disruptions, more efficient use of resources and making our country safer. For now, we are continuing development and improvement of CitadelPolice.

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