Advanced Game Theory - TI

Cooperative game theoretic centrality analysis of terrorist networks: The cases of Jemaah Islamiyah and Al Qaeda - Lindelauf, Hamers & Husslage (2013, European Journal of Operational Research)

Philipp Schirmer

February 16, 2022

Content

Motivation

- Problem to tackle: **identification** of key players in terrorist networks
- Agencies possess **large volumes** of raw, heterogeneous, often incomplete and inaccurate data on terrorist networks
- Common feature of social network analysis is that it **only uses the structure of networks**, not other available information
- Two additional types of info: on **individual terrorists** (e.g. financial means, bomb building skills...) or **information on relationships** between terrorists (e.g. frequence and duration of contact, quantities of weapons moved...)

Research Question

- RQ: Use cooperative game theory to **develop rankings of individuals** in terrorist networks based on both the structure of the terrorist network and additional information on the terrorists and their relationships
- Aim: Inform allocation of scarce observation resources and the **destabilization of the terrorist network** by the removal of the highest ranking members

Research Methods

- Present a **general framework** that includes three stages:
  - construct the network (input)
  - define the game theoretic model (modeling)
  - analyze the rankings of players (output)
- Introduce a **weighted connectivity game** that is able to take both the structure of the terrorist network as well as information about the individual terrorists into account
- Handle **additional information by assigning values to coalitions**

Standard centrality measures

- Graph $G = (N, E)$, with N set of persons and E edges, $ij \in E$ indicating the relationship between person i and j
- **Degree centrality** - "know more, more important":
$$C_{degree}(i) = \frac{d(i)}{|N| - 1}$$
- **Betweenness centrality** - "important, when enabling information flow between others":
$$C_{between}(i) = \frac{2}{(|N| - 1)(|N| - 2)} \sum_{\substack{k,j \in N \setminus i \\ k<j}} \frac{s_{kij}}{skj}$$
- **Closeness centrality** - "quantifies the distance from a person to all others":
$$C_{close}(i) = \frac{|N| - 1}{\sum_{j \in N} l_{ij}}$$

Game theoretic centrality 1/4

- Cooperative game is a **pair** (N, v), where N denotes the set of players and v maps a value $v(S)$ to each possible coalition S
- Let value for each coalition be defined by the network structure of the coalition **as well as by additional information**
- $v^{conn}(S) = \begin{cases} 1, & \text{if connected} \\ 0, & \text{otherwise} \end{cases}$

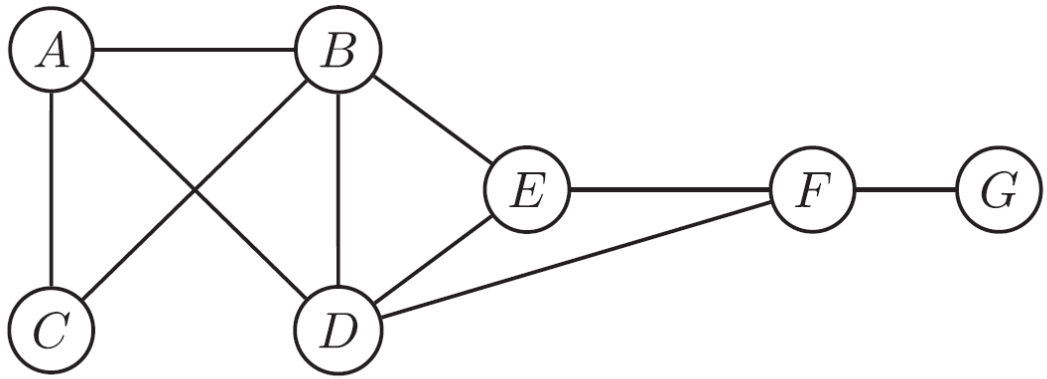

Fig. 1. Example of a network.

Game theoretic centrality 2/4

- Use additional information to **modify the value of coalitions**: get a weighted connectivity game v^{wconn}
- Use **Shapley Value** to allocate power of coalition over all players, calculates weighted average of the marginal contributions

$$\phi_i(v) = \sum_{S \subseteq N, i \in S} \frac{|s|!(|N| - 1 - |S|)!}{|N|!}[v(S \cup \{i\}) - v(S)] \qquad (1)$$

- In practice **each new case** leads to a **new weighted connectivity game**

Game theoretic centrality 3/4

Example 1: **Info about relationship**, e.g. A and C have much more contact, then relationship AC gets a higher value ($f_{AC} = 4$) assigned than other pairs (all 1):

$$v^{wconn1}(S) = \begin{cases} max_{i,j \in S, i \neq j} f_{ij} & \text{if } S_G \text{ is conneted} \\ 0 & \text{otherwise} \end{cases}$$

Example 2: **Info about individuals**, e.g. E took part in previous attack C has financial means ($w_C = 4$, $w_E = 11$, and $w_i = 1$ for all others)

$$v^{wconn2}(S) = \begin{cases} \sum_{i \in S} w_i & \text{if } S_G \text{ is conneted} \\ 0 & \text{otherwise} \end{cases}$$

Example 3: **Info about relationship and individual**

$$v^{wconn3}(S) = \begin{cases} \left(\sum_{i \in S} w_i\right) max_{\substack{i,j \in S \\ i \neq j}} f_{ij} & \text{if } S_G \text{ is conneted} \\ 0 & \text{otherwise} \end{cases}$$

Game theoretic centrality 4/4

Table 2
Rankings for network in Fig. 1 based on standard and game theoretic centrality.

Degree	Betweenness	Closeness	Wconn1	Wconn2	Wconn3
B^*	F	D	A	E	F
D^*	D	B^*	C	F	C
$A^\bullet$	B	E^*	F	B	A
$E^\bullet$	E	$A^\bullet$	D	D	E
$F^\bullet$	A	$F^\bullet$	B	C	D
C	C^*	C	E	A	B
G	G^*	G	G	G	G

- There are **less persons of equal game theoretic rank** than there are for standard centrality ranks
- Leads to **new insights** who is important

Case study 9/11

- Osama bin Laden issued a **fatwa** (1998)
- **Plane hijackings**, targets: WTC, NY; Pentagon and one crashed in Pennsylvania
- 19 hijackers
- Two data sources: Krebs (2002) and the commission report (Kean et al. (2002))

Case study 9/11

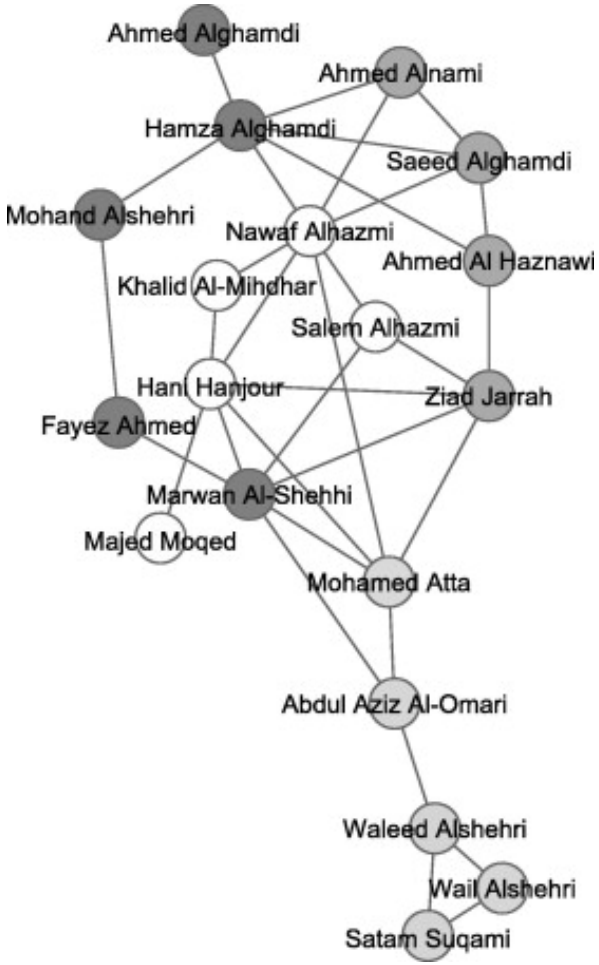

Figure: Operational network of hijackers of Al Qaeda's 9/11 attack. AA-77 (white), AA-11 (lightgray), UA-93 (gray) and UA-175 (darkgray).

Case study 9/11

Table 4
Example of some indicators and assigned weights.

Description indicator	Example(s)	Person(s)	Weight
Attending meetings on terror attack planning	Kuala Lumpur meeting January 2000	Nawaf Al-Hazmi Khalid Al-Midhar	+1
Signs of radicalization	Antisemitic and anti-American speech, talk about jihad and martyrdom, writing a will	Mohamed Atta Marwan Al-Shehhi Ziad Jarrah	+1
Affiliations	Al-Quds mosque Hamburg	Mohamed Atta Ziad Jarrah	+1
Accomplice to previous attacks	Attack on USS Cole	Khalid Al-Midhar	+1
Attending terrorist training camps	Traveling to training camps in Pakistan and Afghanistan	Mohamed Atta Marwan Al-Shehhi Ziad Jarrah	+1

Figure: Indicators and weights

- Use info about individuals (Ex. 2), **"Give out danger-points"**
- Open: **What is possible** with more accurate (classified) data...

Case study 9/11

Table 6
Rankings for Al Qaeda's 9/11 network based on standard and game theoretic centrality.

Degree	Betweenness	Closeness	Wconn2
N. Alhazmi	N. Alhazmi	N. Alhazmi*	A. Aziz Al-Omari
M. Al-Shehhi*	A. Aziz Al-Omari	M. Atta*	H. Alghamdi
H. Alghamdi*	M. Atta	M. Al-Shehhi•	Wd. Alshehri
H. Hanjour*	M. Al-Shehhi	H. Hanjour•	H. Hanjour
M. Atta•	Wd. Alshehri	Z. Jarrah	M. Al-Shehhi
Z. Jarrah•	H. Alghamdi	H. Alghamdi◇	M. Atta
S. Alghamdi	H. Hanjour	S. Alhazmi◇	N. Alhazmi
A. Aziz Al-Omari◇	Z. Jarrah	A. Aziz Al-Omari	Z. Jarrah
Wd. Alshehri◇	F. Ahmed	S. Alghamdi	M. Alshehri
A. Al-Haznawi◇	M. Alshehri	A. Al-Haznawi	K. Al-Midhar
S. Alhazmi◇	A. Al-Haznawi	F. Ahmed★	A. Al-Haznawi
A. Alnami◇	S. Alhazmi	A. Alnami★	F. Ahmed
F. Ahmed★	S. Alghamdi*	K. Al-Midhar	S. Alhazmi
M. Alshehri★	A. Alnami*	M. Alshehri	S. Alghamdi
K. Al-Midhar★	K. Al-Midhar*	M. Moqed	A. Alnami
S. Suqami★	S. Suqami*	Wd. Alshehri	S. Suqami*
W. Alshehri★	W. Alshehri*	A. Alghamdi	W. Alshehri*
A. Alghamdi°	A. Alghamdi*	W. Alshehri°	A. Alghamdi
M. Moqed°	M. Moqed*	S. Suqami°	M. Moqed

- Conclude **different key players**
- Aziz Al-Omari *bridges* between to parts of network
- Led to **more insights** in the roles and relationships

References

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