

SOMA Models of the Behaviors of Stakeholders in the Afghan Drug Economy: A Preliminary Report

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Presented by Amy Sliva

Foreign Policy in Afghanistan

- Afghanistan has gone from the periphery to the forefront of foreign policy
- Ending the opium trade is a major element in bringing stability to the region
- Goal: devise policy initiatives that work *within* the Pashtun culture and anticipate the reactions of members of this society
- Challenges to policy-making in Afghanistan
 - » Society is based on Pashtun tribal divisions and customary law
 - » Tribal customs and behaviors are only understood by experts or actual Afghan citizens.
 - » Available experts are few and far between

A solution: Computational Models

- Computational models of agents involved in cross-sections of Afghan society can make cultural information more accessible
 - » Models can provide information on expected behaviors in a given scenario
 - How will Afghan farmers react to a policy of destroying opium crops?
- The Stochastic Opponent Modeling Agents (SOMA) system is a prototype solution for cultural modeling
 - » Probabilistic logic framework to represent the likely actions of an agent under certain conditions
 - » Several algorithms for reasoning within this framework

Outline

- Description of Afghan tribal society and the Afghan drug trade
- Overview of the SOMA framework and reasoning system
- Use of SOMA to construct behavioral rules for agents in the Afghan drug trade
- Demonstration of SOMA
 - » Predict the most probable actions of agents in the drug trade

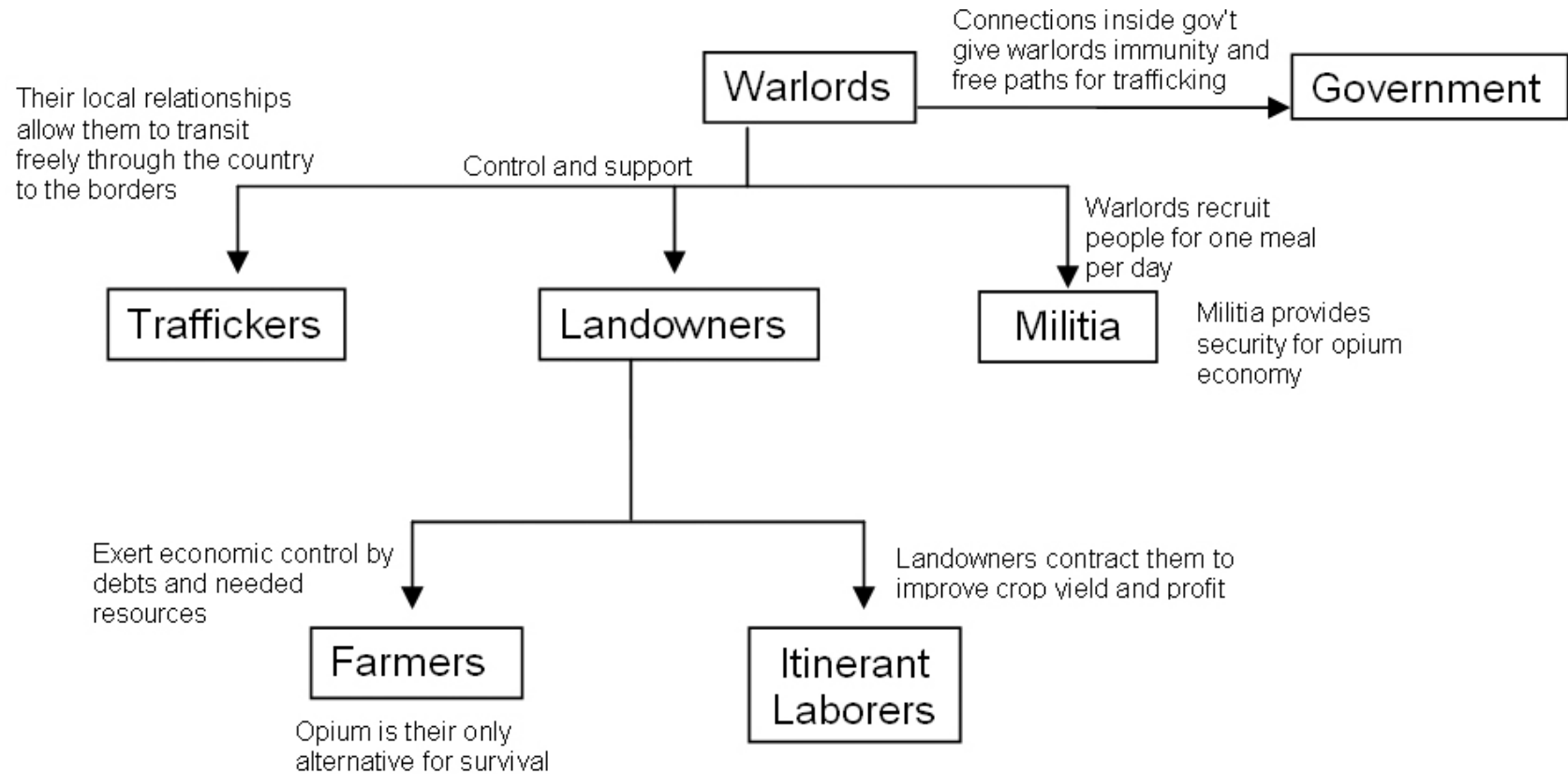
Opium Production in Afghanistan

- Afghanistan is the largest opium producer in the world
 - » 3.5 million kilograms per year
 - » poppies can yield about \$15,000 per hectare per year, about ten times the value from wheat cultivation
- The bulk of the production is headed to Europe
- Drug money has been linked to terrorism
 - » Funding for Al-Qaeda
 - » Used by Pakistani intelligence to support terrorist activities in Kashmir
- Pashtun tribes on Afghan-Pakistani border play a major role
 - » Control the activities required in the production and transportation of opium
 - Poppy cultivation
 - Transportation (i.e., truck/cargo companies)
 - Customs posts

Agents in the Afghan Drug Trade

- **Malik:** intermediary between the village and central government, solves communal disputes, and maintains communal property
- **Khan:** large, feudal landowner who controls resources, provides jobs to laborers and land to sharecroppers, and arbitrates conflicts
- **Ulema:** The Ulema shura is a group of religious leaders who lead prayers, give sermons, and resolve conflicts involving Shariah
- **Member of Shura:** The Shura is a tribal council that meets only as problems arise in order to solve them.
- **Warlord:** large, regionally based commander who controls the area. Warlords collect taxes, control borders, control local resources, produce and sell drugs, arms, etc.
- **Farmer:** worker of the land, who may own the land or rent it from khans or warlords.
 - » Poppy cultivation gives access to land or seasonal employment
 - » Tribal salaam system---farmers are given an advance payment on future production
 - Poppies are reliable and favored by lenders
- **Village Citizens**

Relationships of Agents in the Drug Trade



Proposed Solutions to End the Drug Trade

1. Destroy the poppy fields
 - » Reduces supply and drives up prices
2. Destroy the production laboratories
 - » Corrupt officials warn labs of raids
3. Invest money in basic infrastructure (irrigation, road and terrace construction, other crops, livestock, and electrification)
 - » Push poppy cultivation into other, less developed areas
4. Legalize opium production---export opium under UN licenses to pharmaceutical companies or produce manufactured morphine/codeine
 - » Price of illegal opium = \$113/kg; current legal price in India = \$28/kg; proposed UN price around \$52/kg
5. Enlist help of fundamental Islamic clerics and Islamic law for enforcement
 - » Legitimizes past enemies
6. Take distributors out of the loop (hire for legal exporting positions)
 - » Still siphon off opium for illegal sale at higher prices

The SOMA Language

- Assumptions:
 - » Finite set L_{cons} of constant symbols, and L_{pred} of predicate symbols
 - » Infinite set V of variable symbols
 - » Terms and atoms are defined in the usual way.
- Subset L_{act} of L_{pred} are designated as action symbols
 - » $p(t_1, \dots, t_n)$, where $p \in L_{act}$, is an action atom
- **COA/state**: A *course of action (COA)* is any set of ground action atoms. A *state* is any finite set of ground non-action atoms.

The SOMA Language (cont.)

- **ap-annotated formula:** If F is an action formula and $\mu = [\alpha, \beta] \subseteq [0, 1]$, then $F : \mu$ is called an *action probabilistic-annotated formula*
- **SOMA-rule:** If F is an action formula, A_1, A_2, \dots, A_m are action atoms, B_1, \dots, B_n are non-action atoms, and μ, μ_1, \dots, μ_m are ap-annotations, then $F : \mu \leftarrow A_1 : \mu_1 \wedge \dots \wedge A_m : \mu_m \wedge B_1 \wedge \dots \wedge B_n$ is called a *SOMA-rule*.
 - » An entity (e.g. a group g , a person p etc.) will take action F with probability in the range μ if B_1, \dots, B_n are true in the current state and if the entity will take each action A_i with a probability in the interval μ_i for $1 \leq i \leq m$.
- **SOMA program:** A *SOMA program* is a finite set of SOMA-rules.
- We use a fixed point operator to obtain a SOMA program with action predicates only in the head

```
support(X,Y): [0.75, 0.9] ← is_warlord(X) ∧ profit_from_alliance(X,L) ∧ is_leader(L,Y)
                             ∧ soc_or_pol_religious_regime(Y).
buy_war_materials: [0.9, 1] ← is_warlord(X) ∧ needs(X,show_strength).
```

Reasoning with the SOMA Language

- Goal of reasoning with SOMA is to find the most probable actions that an agent will take in a given situation
 - » Given a SOMA program and a state, what is the most probable COA
- $CONS(\Pi, s)$: Linear constraints associated with a SOMA program Π and a state s
 - » Associate a variable p_i with each COA c_i (denoting the probability of c_i representing the “real” course of action)
 - » If $F : [l, u] \leftarrow B_1 \wedge \dots \wedge B_n$ is a ground instance of a rule in Π and $\{B_1, \dots, B_n\} \subseteq s$ then the constraint $l \leq \sum_{c_i \models F} p_i \leq u$ is in $CONS(\Pi, s)$
 - » $\sum_{wi} p_i = 1$ is in $CONS(\Pi, s)$

Finding the Most Probable COA

- $low(c_i)$ is the lowest probability that the COA c_i can have in any solution to the linear program
- $up(c_i)$ is the highest probability that the COA c_i can have
- We cannot give an exact point probability for a COA because we make no simplifying assumptions (e.g. independence)
- *Naive* algorithm for finding the most probable COA does a brute force search
 - » Finds the low probability for each COA and chooses the maximal one.
 - » We can do better.

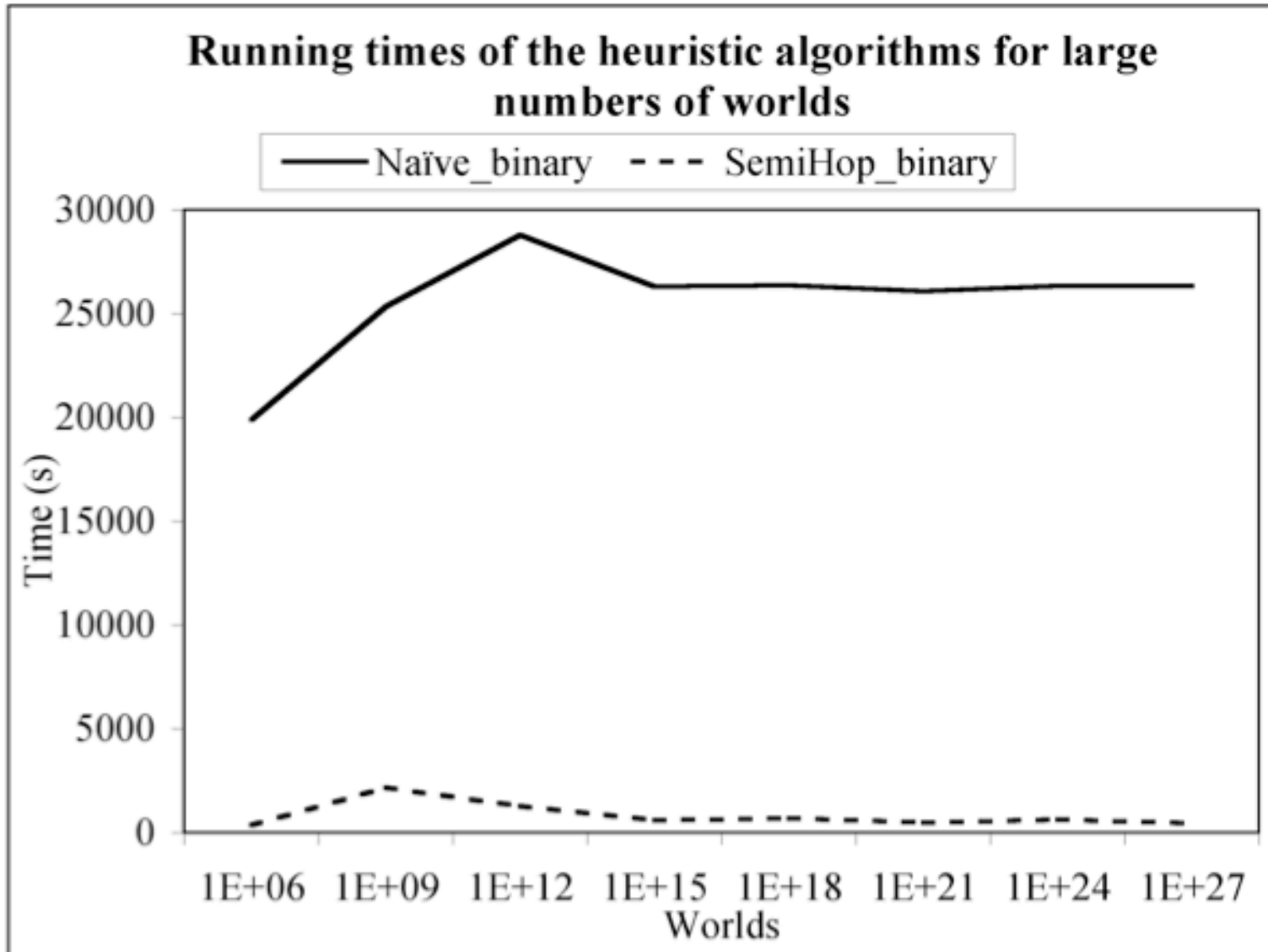
Head Oriented Processing (HOP) Algorithms

- COAs can be grouped into equivalence classes
 - » Two COAs are equivalent if they satisfy the heads of exactly the same rules
 - » We can represent an entire equivalence class with a single variable p_i in the linear constraints
- The number of variables in the constraints is often dramatically reduced
- While the computation necessary is reduced, the result is still exact
 - » We are guaranteed to return the equivalence class containing the most probable COA

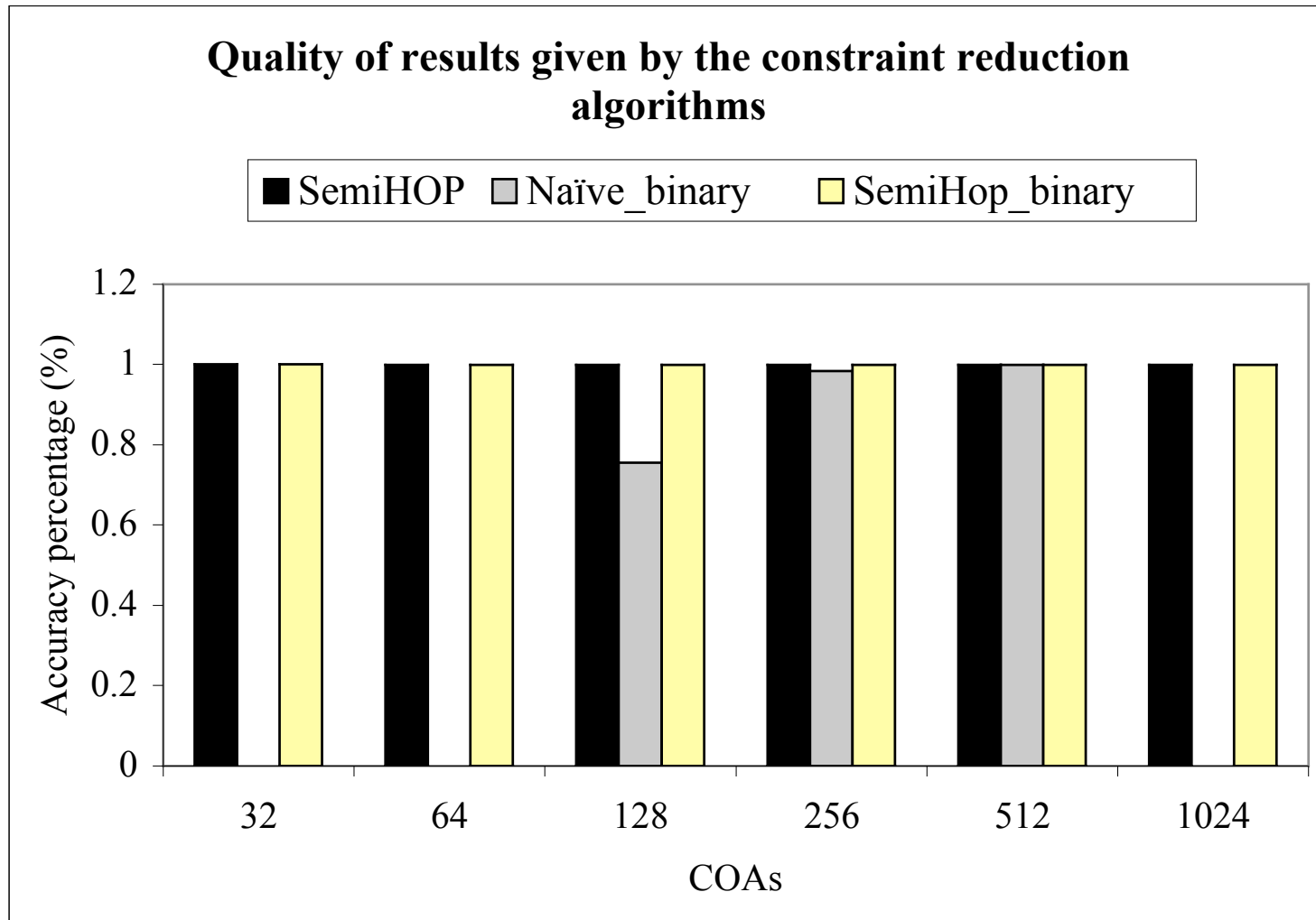
Heuristic Approximation Algorithms

- Goal to reduce the number of variables in the linear program
- **Random Sampling Heuristic:**
 - » Make an *a priori* commitment to only look at some set S_k of k variables
 - » Eliminate variables not in S_k from any summation in constraints of type (1)
 - » Solve for the most probable COA as in the naive algorithm, minimizing each variable in S_k with respect to the reduced set of constraints and returning the variable (and value) with the highest value.
- **Binary Heuristic:**
 - » Modify the lower bounds of a reduced set of constraints
 - » If the reduced constraints are solvable we return the same solution as the random sampling heuristic
 - » If not, we set the lower bound to zero and use a binary search to find the tightest solvable bounds

Running Time Results



Solution Accuracy Results



Models of Agents in the Drug Trade

- Rules were created with the help of experts, but are still prototype models
- Some Sample Rules:
- **Farmer:**
 - » cultivate_poppy(X): [0.7,0.9] \leftarrow is_farmer(X) \wedge has_debt(X)
 - If a farmer is in debt, he will cultivate poppies with probability between 0.7 and 0.9
 - » cultivate_poppy(X): [0.9,1.0] \leftarrow is_farmer(X) \wedge rents_land_from(X,K) \wedge is_khan(K) \wedge selects_poppy_for_cultivation(K)
 - If a farmer will cultivate poppies with 90-100% probability if he rents land from a khan who decides to cultivate poppies
- **Khan:**
 - » reject(X,Y): [0.8, 0.95] \leftarrow is_khan(X) \wedge is_international_visitor(Y) \wedge is_nationalist(X)
 - If a khan is a nationalist, he will reject an international visitor with 80-95% probability

The SOMA System in Action

SOMA: Stochastic Opponent Modeling Agents

Views Run Help

Afghan Tribal Village

Afghan Drug Trade

Agents

- Citizen
 - Malik
 - Mirab
 - Khan
 - Ulema
 - Member of Shura
 - Police Chief
 - Warlord
 - Farmer**
 - Children

Terrorism in Peru

SOMA Rules

Show SOMA
Show English

$\leftarrow \text{welcome}(X,Y) \wedge \text{reject}(X1,Y1) \wedge Y=Y1 \wedge X=X1.$
It is not possible for an agent to welcome and reject the same entity at the same time

$\leftarrow \text{overtly_assist}(X,Y) \wedge \text{reject}(X1,Y1) \wedge X=X1 \wedge Y=Y1.$
It is not possible for an agent to overtly assist and reject the same entity at the same time

$\text{welcome}(X,Y):[0.75,0.85] \leftarrow \text{is_farmer}(X) \wedge \text{increases_quality_of_life}(X, Y).$
A Farmer will welcome people into the village if doing so could increase the quality of his life

$\text{reject}(X,Y):[0.8,1.0] \leftarrow \text{is_farmer}(X) \wedge \text{threatens}(X,\text{income},Y).$
A Farmer will reject people from the village if they could threaten his income

$\text{reject}(X,Y):[0.8,1.0] \leftarrow \text{is_farmer}(X) \wedge \text{threatens}(X,\text{land},Y).$
A Farmer will reject people from the village if they could threaten his land

$\text{reject}(X):[0.8,1.0] \leftarrow \text{is_farmer}(X) \wedge \text{threatens}(X,\text{possesions},Y).$
A Farmer will reject people from the village if they could threaten his possessions

$\text{covertly_assist}(X,Y):[0.8,0.95] \leftarrow \text{is_farmer}(X) \wedge \text{bribes}(Y,X).$
A farmer will covertly assist someone who has bribed him.

$\text{covertly_assist}(X,Y):[0.8,0.95] \leftarrow \text{is_farmer}(X) \wedge \text{threatens}(Y,X).$
A farmer will covertly assist someone if he is threatened and forced to do so

LCCD Laboratory for Computational Cultural Dynamics

What if...

SOMA: Stochastic Opponent Modeling Agents

Village Afghan Drug Trade: Farmer is khan(mc

Trade er(a
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SOMA Rules

Show SOMA
Show English

← welcome(X, Y):
It is not possible

← overtly_assist(X, Y):
It is not possible

welcome(X, Y):
A Farmer will v

reject(X, Y):[0.8, 1.0]
A Farmer will r

reject(X, Y):[0.8, 1.0]
A Farmer will r

reject(X):[0.8, 1.0]
A Farmer will r

covertly_assist(X, Y):
A farmer will co

covertly_assist(X, Y):
A farmer will co

Modify State

Add and remove items from the current state of the world

| Current State | State Literals |
|---|--|
| consults(safdar, ahmed). drought. has_debt(ayub). increases_quality_of_life(peace, ayub). is_farmer(ayub). is_involved_in_drug_trade(badsha). is_khan(mohammad). is_malik(safdar, village1). is_member_shura(ahmed). is_warlord(badsha). land_dispute(ayub, badsha). lives(ayub, village1). needs(ayub, money). respects(safdar, sharia). solves_conflicts_satisfactorily(safdar). yields_greater_revenue(drug_trade, legal_ | area(northern_peshawar). believes_in_cause(badsha, terrorism). consults(safdar, ahmed). dominates(badsha, northern_peshawar). drought. expects_rewards(badsha, terrorism). has_debt(ayub). has_lands(ali, northern_peshawar). has_lands(mohammad, northern_peshawar). helps_in(safdar, community_affairs). increases(poppy_ban, credibility, badsha). increases(poppy_ban, power, badsha). increases_quality_of_life(peace, ayub). is_farmer(ayub). is_in(route2, northern_peshawar). is_in(route3, northern_peshawar). is_international_army(us_troops). is_international_visitor(us_troops). is_involved_in_drug_trade(badsha). is_khan(ali). is_khan(mohammad). |

Remove Add

Done

Laboratory for Computational Cultural Dynamics

Find the COAs

SOMA: Stochastic Opponent Modeling Agents

Afghan Drug Trade: Farmer

Compute Most Probable World

Choose options below to run a most probable worlds calculation on an active agent model.

Compute Most Probable Worlds

Agent:

Algorithm:

▼

Number of Worlds:

ty at the same tim
entity at the same
of_life(X, Y).
increase the quali
his income
his land
his possessions

The Results

Most Probable World Results

1. World: {fight(ayub,land,mohammad), fight(ayub,land,badsha), arrange_salaam(ayub,mohammad), switch_crop(ayub,poppy,barley), support(ayub,peace), join_jaba(ayub), fight(ayub,ayub,mohammad), fight(ayub,haji,badsha), cultivate_poppy(ayub), fight(ayub,ayub,safdar), elect_malik(ayub,mohammad), support(ayub,safdar), support(ayub,taliban), get_involved_in_drug_trade(ayub), switch_crop(ayub,poppy,wheat)}

Probability: 0.400001

2. World: {fight(ayub,land,mohammad), fight(ayub,land,badsha), arrange_salaam(ayub,mohammad), switch_crop(ayub,poppy,barley), support(ayub,peace), join_jaba(ayub), fight(ayub,ayub,mohammad), fight(ayub,haji,badsha), cultivate_poppy(ayub), fight(ayub,ayub,safdar), elect_malik(ayub,mohammad), support(ayub,safdar), support(ayub,taliban)}

Probability: 0.800001

3. World: {fight(ayub,land,mohammad), fight(ayub,land,badsha), arrange_salaam(ayub,mohammad), switch_crop(ayub,poppy,barley), support(ayub,peace), join_jaba(ayub), fight(ayub,ayub,mohammad), fight(ayub,haji,badsha), cultivate_poppy(ayub), fight(ayub,ayub,safdar), elect_malik(ayub,mohammad), support(ayub,safdar), support(ayub,taliban), get_involved_in_drug_trade(ayub)}

Probability: 0.400001

Close

The Results

1. World: {fight(ayub,land,mohammad), fight(ayub,land,badsha), arrange_salaam(ayub,mohammad), switch_crop(ayub,poppy,barley), support(ayub,peace), join_jaba(ayub), fight(ayub,ayub,mohammad), fight(ayub,haji,badsha), cultivate_poppy(ayub), fight(ayub,ayub,safdar), elect_malik(ayub,mohammad), support(ayub,safdar), support(ayub,taliban), get_involved_in_drug_trade(ayub), switch_crop(ayub,poppy,wheat)}
 - Probability: 0.400001
2. World: {fight(ayub,land,mohammad), fight(ayub,land,badsha), arrange_salaam(ayub,mohammad), switch_crop(ayub,poppy,barley), support(ayub,peace), join_jaba(ayub), fight(ayub,ayub,mohammad), fight(ayub,haji,badsha), cultivate_poppy(ayub), fight(ayub,ayub,safdar), elect_malik(ayub,mohammad), support(ayub,safdar), support(ayub,taliban)}
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 - Probability: 0.400001

Additional Models and Applications

- Currently developing models for the Waziri, Shinwari, and Mohmand tribes
- Modeling possibilities for post-Musharraf Pakistan
- Refining algorithms to automatically extract SOMA models from event data
 - » Event data gathered by social scientists representing organizational behavior over 25 years
 - » Applied to Hezbollah, FRC-ANO, PKK, KDPI, Baath Party
 - » Extracting for Afghan National Liberation Front, Afghan Social Democratic Party, Council of Understanding and National Unity of Afghanistan, Harakat-e-Islami, Hezb-i Islami Khalis, Hizb-i-Islami Afghanistan, Hizb-e-Wahdat e Islami Afghanistan

Evaluations

- Models developed from expert opinions
 - » Make predictions with our models
 - » Validate and update our systems based on what events actually occur in the future
- Models developed from automatically extracted data
 - » Create models from the first 15 years of data
 - » Test it on the last 5 years of data
 - » We are just getting started on this process

Conclusions

- Growing need to be able to reason about cultural groups
- Using computational models to understand cultural behaviors is rather new
 - » Still a long way to go
- The current system can infer the most probable response that groups might have to a given situation
- Can aid in determining culturally relevant policies for eliciting desired responses

Questions?