Modeling Social Influence via Combined Centralized and Distributed Planning Control

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Abstract. Real world events are driven by a mixture of both centralized and distributed control of individual agents based on their situational context and internal make up. For example, some people have partial allegiances to multiple, contradictory authorities, as well as to their own goals and principles. This can create a cognitive dissonance that can be exploited by an appropriately directed psychological influence operation (PSYOP). An Autonomous Dynamic Planning and Execution (ADP&E) approach is proposed for modeling both the unperturbed context as well as its reaction to various PSYOP interventions. As an illustrative example, the unrest surrounding the Iranian elections in the summer of 2009 is described in terms applicable to an ADP&E modeling approach. Aspects of the ADP&E modeling process are discussed to illustrate its application and advantages for this example.

Introduction

We propose using an Autonomous Dynamic Planning and Execution (ADP&E) approach that integrates both a centralized and distributed planning control capability to more realistically model complex social group interactions. In our recent survey of implemented models within social science, they do not successfully model future influence operations because they do not integrate enough cognitive realism in each automated-human (agent) to represent real world conditions and events. This makes the current models unsuitable for large-scale, complex problem domains. More specifically, implemented models fail to capture several aspects of human behavior because these models do not include the ability to adjust to very large, partially observable, and uncertain environments, nor use human abilities in dynamic planning to maintain agility in these ever-changing environments.

In addition, many techniques assume a completely distributed (decentralized) approach that uses simplified cognitive agents with common goals to create swarm-like behavior [1]. This leads to emergent events when the cumulative cognitive state reaches a tipping point. In the same context, other techniques rely on completely centralized control of agents to optimize their coordination and lead to more optimal strategies of cooperative event behavior, which can suspend reactions of discontent and generate strong unified positions [2]. Both of these approaches are goal-directed, but the centralized approach relies more on reputational or social utility, while the distributed approach relies more on intrinsic or expressive (i.e., individual or psychological) utility.

Real world events are actually driven by a mixture of both centralized and distributed control of individuals (agents) based on their situational context and internal makeup. Given the level and type of education, age, interests, experiences, religious affiliation, economic status, etc., individuals have varying degrees of both centralized and distributed behavioral influences that either enhances or detracts from their current environmental status or cross-cuts their current environmental circumstances. For example, some people may have partial allegiances to multiple contradictory authorities (e.g., religious vs. science, dictator vs. democracy, etc.), which could create a cognitive dissonance within these people.

This further could create an opportunity for change, given their uncertainty in their future, and their willingness to seek change from their current conditions. Does this form an opportunity for external forces to intervene and pursue a psychological influence operation (PSYOP) to redirect the event toward a change beneficial to its interests, or does meddling at such a time backfire and strengthen the opposition's claims and perhaps tip the balance in our adversaries favor? An autonomous dynamic planning and execution (ADP&E) framework has been built that includes variability in searching, selecting, and rewarding plans based on both individual and group behavior. Difficult questions such as this PSYOP mentioned above can be addressed in modeling and simulation if centralized and distributed planning are successfully integrated within the model via this ADP&E framework. They will thus better model the balance of using both centralized and distributed planning-influence control and further understand its sensitivity through simulating interactions among similar and differing social groups with differing parameter sets.

Background

Currently implemented cognitive approaches can be analyzed from a game theory perspective to determine their problem domain footprint. On the one hand, reactive planning algorithms, such as temporal difference reinforcement learning can learn two-player stochastic games, such as Backgammon [3]. On the other hand, deep search algorithms, such as decision-tree search using alpha-beta pruning can plan many moves ahead for a two-player deterministic game, such as chess [4]. However, note that these games are both two-player and fully observable, while the real-world is many players and partially observable. Further, hybrid solutions have been proposed to handle more complex real world and game problems [5]. We propose using a more powerful hybrid approach that integrates more realistic features of social interaction by extending an ADP&E approach with both a centralized and distributed planning capability.

An illustrative example will be investigated to better model and predict cumulative behavior amongst more cognitively realistic agents based on their interaction. The analyzed example will be akin to the situation in regards to the 2009 Iranian elections, where there was a ruling faction and a dissenting faction in conflict. The ruling faction has some centralized authority for control of individuals and the dissenting faction also has some centralized authority for control of individuals. In addition, the individuals have some intrinsic freedom to choose the centralized control or act more independently among themselves. There are pressures from both sides (rulers or dissenters) and in both directions (centralized and distributed).

We can enhance a current city simulation with some new features to better realize the behavior portrayed by the media. A small city has already been implemented for game playing multi-agent scenarios that includes movement models and line-of-sight. Agents can move based on prescribed waypoints and connections and observe based on proximity and line-of-sight. Communication connectivity can be added to the model for simulating the short-range (e.g., talking, signaling), mid-range (e.g., megaphone, video recording) and long-range (e.g., internet, cell phone) communication channels. The ruling authority can cut some communication as they did in Iran, but the dissenting faction can adapt their behavior by using alternative forms of communication. Also, peaceful and violent behavior can be exhibited from both sides, and scaling of confrontations can be investigated. However, individuals and group behaviors and communications will be limited to both simplify and exemplify the approach.

A design and implementation strategy has been studied on the election defiance scenario in Iran. This paper describes an approach to implementing such a simulation and describes the benefits of such a system.

Approach

We describe here a five step approach to designing, implementing, and demonstrating a social science simulation to study the causal precursors that drive the effects in the current situation in Tehran, where protests continue sporadically against the conservative regime.

1. A baseline is necessary to allow interaction among actors. This has been accomplished using technologies that form urban environments into game models [6]. Figure 1 provides a simple viewpoint of a small city model with a variety of connected waypoints (not illustrated).
2. The players of the simulation or game need to be identified. In the case of the Iranian situation, eight player types are identified and described.
3. Each player must have enough planning ability to interact with the other players in a similar environment and illustrate realism in thought processes and ability to reassess and change strategies. This can be accomplished by integrating intrinsic-, extrinsic-, and expressive-utility in each player, and this is described from each player's point of view. These utilities are implemented via a value function that is an integral part of the ADP&E system.
4. The interactions must be identified according to the current power structure and number of agents under each authoritarian player. The interactions are identified in Figure 2 and each interactive link will be described in detail.
5. Each player is identifiable as a planner in an ADP&E system, where their plans and perceptions impact all players involved simultaneously, and where higher order affects are plausible and likely. In other words, within each planner, their parameters dictate their behavior and interaction in an attempt to maximize their own utility, while readjusting their plans to counter other planners' activities. Once implemented, parameters can be tuned to illustrate social behavior on a more complex scale.

Step 1: Urban Environmental Game Models

In previous work, an automated technique has been developed to: generate an urban terrain movement model for computer gaming from a Compact Terrain DataBase (CTDB), increase the simulation speed of operations to allow much faster than real time operations, and a programming interface for planning algorithms has been defined to integrate multiple planners into the model. An example city model is shown in Figure 1.

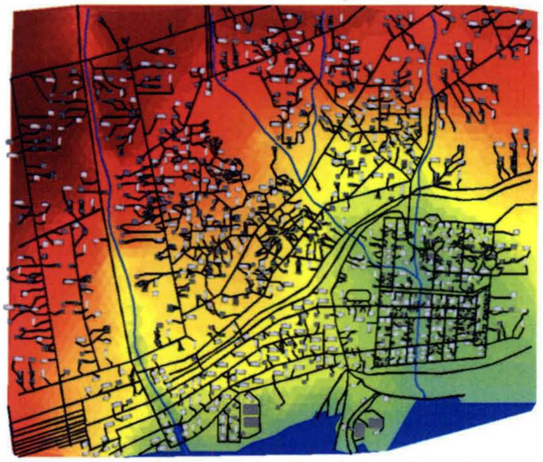

Figure 1. Example City Game Board

To better understand the order of magnitude of this city model, Figure 1 shows a top-down picture of the terrain model used. The model is a small city of approximately 4 km x 5 km. More specifically, there are 3649 buildings with over 12,000 floor locations. There were over 31,000 waypoints generated for this terrain model.

Step 2: Major Game Players

There are five major players in the election situation in Iran, where the people are protesting against the election results, which appear to be drastically different than prior polls indicate. The five major players in this conflict are: the supreme leader Ayatollah Ali Khamenei who backs the government declared incumbent President Mahmoud Ahmadinejad, the leading challenger Mir Hossein Mousavi, the general in charge of Iran's Revolutionary Guard Mohammad Ali Jafari, the religious hierarchy, and the people.

The supreme leader is a 70-year-old cleric. He reigns over Iran's Islamic system as part pope, part commander in chief and as a one-man supreme court. President Mahmoud Ahmadinejad was the winner of the June 12, 2009 election. He is an ultra-conservative who has isolated Iran from the rest of the world through condemnations of the United States, Israel, and United Nations. The president is backed by the supreme leader and is a puppet, so he is not considered a player here. Mohammad Ali Jafari oversees the 125,000 members of Iran's military. This revolutionary guard (RG) takes direct orders and is considered the strong arm of the supreme leader. The religious hierarchy is under direction of the supreme leader as well, but some clerics are asking for reform and a recount of the election. Thus, we have broken this group into two groups, a clerical reform player and a clerical conservative player. The people are by far the largest player in this conflict. This group can be divided into three camps: the conservatives that side with the incumbent, the reformists that side with the reform party, and the people that want to remain neutral.

As an assumption, some players are considered as single agent planners, such as the supreme leader, the reform leader, and the religious clerics. The remaining two planners are the revolutionary guard and the people. These planners require many agents in order to show the escalation of the conflict. The proper ratio is not known but there are over 7 million people living in Tehran and only 125 thousand guards in the entire country. However, the guards are well trained and armed. There are more players in the Iranian election situation than the ones described here, but these eight should be enough to sufficiently simulate the conflict.

Players\Metrics	Intrinsic Utility	Expressive Utility	Reputation Utility
Supreme Leader	Suppress Protests	Zero Tolerance/ Block Some Media	Treated As God/ Can Do Little Wrong
Reform Party	Ignite Protests/ Avoid Violence	Keep Reform Movement Alive	Adjust to People's Needs
Revolutionary Guard	Take Orders	Use Force	Never Show Fear
Religious Hierarchy Conservatives	Make People Subservient	Teach Religious Obedience	Back Religious Beliefs
Religious Hierarchy Reformists	Gain Power	Demand Recount/ Reject Violence	Empathize/Gain People's Favor
People Conservatives	Follow Religion Verbatim	Demand Others to Follow	Hard Working/ Poorer Class
People Neutral	Follow leader and keep low profile	Avoid areas of conflict/ Be Safe	Maintain Respect/ Peace
People Reformists	Believe Reform Will Help Economy	Instigate Protests/ Free Speech	Defend Women/ Debate/ Dialogue

Table 1. Players and Their Utility Metrics

Step 3: Utility

To appreciate the escalation of the conflict in Iran three measures of utility can be used for each player: intrinsic, expressive, and reputational utility. Intrinsic utility is the measure of what that player thinks is important and wants to accomplish. Expressive utility is the measure of how a player will deliver their message. Reputational utility is how the player perceives other players' opinion of their actions.

These players' metrics are shown in Table 1. This table is a qualitative description of the utility metrics. In an implementation, these metrics must be translated into some quantitative form that is reflected in their agents' actuators and sensors. For instance, the revolutionary guard's reputational utility is not to show fear, so they will never retreat when confronted to maintain fear in the people.

Step 4: Interactions

Player interactions are too many to build a real model of the Iranian election conflict. However, a simplified interactive model can be created if assumptions are made. Figure 2 shows such a simplified representation. The interactions are labeled one to thirteen with interactions six and seven expanded for the multiple religious hierarchy players and people players, respectively.

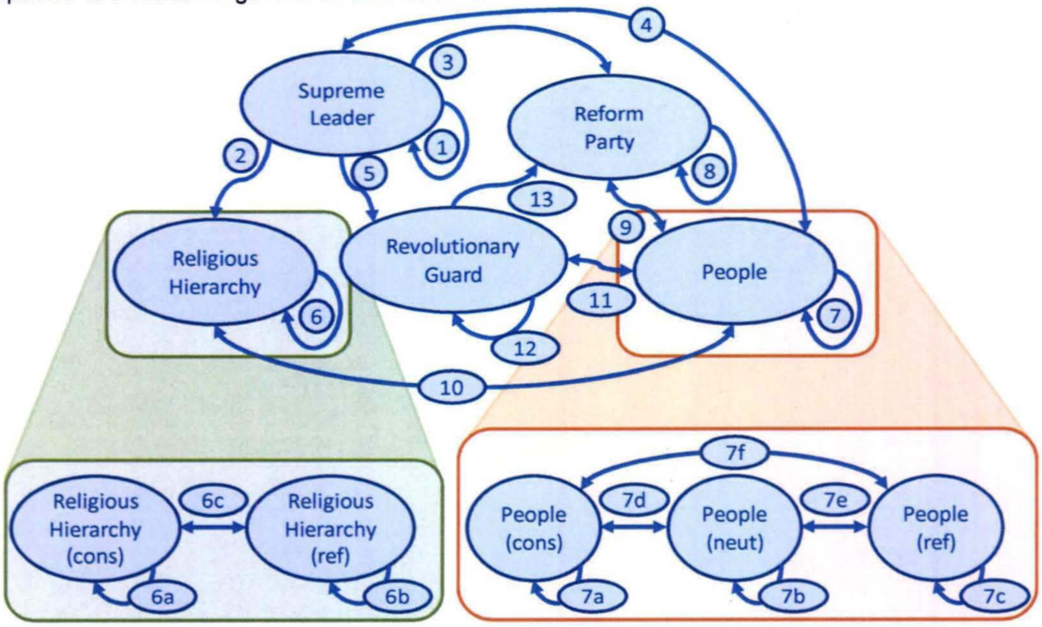

Figure 2. Players' Interactions

Connection 1 in Figure 2 is the supreme commander contemplating plans to suppress the protests, his intrinsic utility goal. Connection 2 is the supreme leader giving direction to the religious hierarchy, especially Ayatollah Ahmad Jannati Massah who heads Iran's 12-member Guardian Council, which certifies election results and is closely allied with Khamenei. Connection 3 is the limitations imposed on the reform party by the supreme leader. Many times these directions are ignored, such as not attending a religious rally to honor the dead. Connection 4 is the interaction between the people and the supreme leader. The supreme leader demands no protests and many people defy him by attending rallies. Connection 5 is the supreme leader's use of the revolutionary guard (RG) to forcibly take to the streets and break up protests. Also, the RG acts as an agent, which attempts to cut communication by confiscating cell phones and detaining people. Connections 6a-c are the religious hierarchy contemplating plans to either gain power (reformist group) or maintain allegiance to the supreme leader (conservative group). Connections 7a-f are the interactions among the people. The conflict among the people escalated into violence in first few days of protests. Connection 8 is the reform party contemplating plans as things unfold. For instance, the reform party decided to have large events centered on honoring the dead, which appealed to many people and created large crowds. Connection 9 was the interaction between the people and the reform party. They worked together to create large peaceful protests that further aggravated the supreme leader. Connection 10 is the mixed messages received from the clerics, some sided with the supreme leader while others demanded a vote recount or void election. Connection 11 exemplifies the conflict between the protesters and the RG. Many people have been killed and arrested in this conflict and is triggered by their unwillingness to back down on both sides. Connection 12 represents the RG contemplating maneuvers to break up protests, raid reformists homes, confiscate communication devices, and detain uncooperative people. Finally, connection 13 is the RG's attempt to subdue the reform party, such as detaining them from going to rallies.

Step 5: ADP&E System

The proven approach used here has five tiers, from the inner cycle of dynamic planning, executing, and assessing plans for players and agents, through the highest level, adapting players' strategies using tournament play through multiple games. Figure 3 illustrates this ADP&E implementation framework.

This system concept was built from the ground up to be an efficient and modular approach. This approach has been already applied for two applications, the game RISK [7], and an urban search and rescue operation [8].

- First, the core cycle was developed as an action and response system, where individual action sequences are planned, executed, and assessed in various model environments, with varying projected expectations, over many cycles, and for all agents in the correct time sequence.
- At the second level, agents execute a particular plan, and each agent's action set is stored separately for modularity.
- Third, the player is the conceiver and conductor of a plan that encompasses all agent activities. A player has a set of parameters that determine its choice of planned actions, and how often to re-plan those actions.
- Fourth, a game is the domain where action sequences are executed in the model environments, which will always lead to a final goal state. The final goal state must be achievable, because human intervention is prohibited in this framework and a game only completes when the final goal is achieved.
- Fifth, tournaments of games are arranged, so that players can improve their parameter settings over the course of many tournaments. Through evaluating each player's progress, and modifying the best players' parameters, players can improve their play.

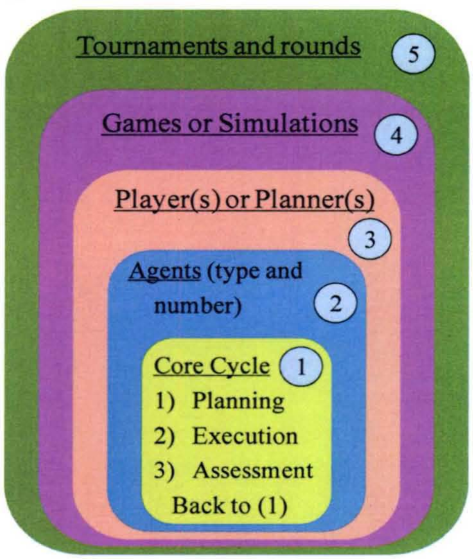

Figure 3. ADP&E Framework

At the heart of this approach is a core planning cycle for each of the eight players of the game. Figure 3 shows an illustration of this cycle. The core cycle has three components: (1) plan-generator (PG); (2) plan-executor (PE); and (3) plan-assessor (PA). The *plan-generator* is considered the search engine for contemplating plans for each player. PG strings together individual actions to form plans for each agent based on current perception of situation. The utility metrics described above can be used to evaluate plans and choose the better ones. Formulations as to how to generate and choose plans have been examined on two very large planning problems and are described in two previous papers [7] [8]. The *Plan-Executor* executes the plans in time sequential order. The *plan-assessor* estimates how well the remaining plan will execute given new observed information acquired from the environment while executing the plan. This cycle can be run after each executed action.

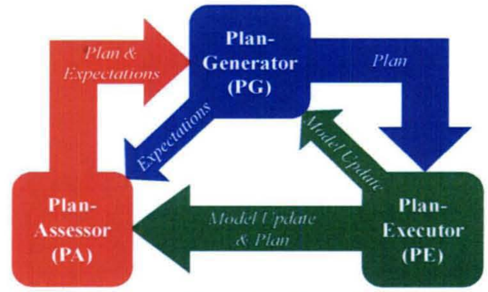

Figure 4. Planning Core Cycle

The three components use three objects that are manipulated and shared among the components. These three objects are the (1) *plans*, (2) *models*, and (3) *expectations*. *Plans* are generated by PG, executed by PE and assessed by PA. All players can be run in separate threads and execute independently. City *Models* are used in PG to predict future states, are used in PE to observe the real states, and are used in PA to observe whether expectations will be met. The models used in PG and PA are virtual-state city models, which are approximate to the real-state model used in PE. The real-state model is a real-world model, where a plan is executed. Virtual-state models do not know the real states until observed and are initialized to reasonable expectations. Thus, there are nine perceptions of the city model based on which planner is under consideration. There is one virtual model for each planner and a real-world model where all planners can execute their actions. *Expectations* are the measure of how well a plan achieves a desired goal (utility metrics), such as breaking up a protest. Expectations are projected both by the generated plan in PG and by the plan used in PA. The two expectations are compared to see if the expectations projected in PA still meet or exceed the originally generated plan expectations projected in PG. Each agent has an expectation for its plan. If expectations are met to a prescribed degree, a plan is retained; otherwise a plan is reformulated in PG.

If implemented, such a simulation tool can provide three major advantages. First, tuning parameters is crucial to matching historical records. The versatility in choosing alternative actions under uncertainty (e.g., reformist people were younger and more educated, using high tech devices for communications, something the leaders did not consider in initial plans), the timing of actions/ responses (e.g., the government lost credibility when saying the election was true when they did not use any time to investigate), the amount of reassessment and replanning (e.g., people switched to alternative forms of communication when services were cut, such as twitter, and cell phones) of each the eight players is critical. These are just three instances where agile planning is used in real world social events, and there are many other areas to investigate. Thus, tuning planner parameters in key aspects is essential to matching real world scenarios. The tuning of parameters can be learned via developed techniques already established for two other applications [7] [8].

The second advantage is the use of an ADP&E system to predict how real-time events will unfold. When a model has been developed that accurately predicts the evolution of historical events for a culture as described above, it can be tuned to follow the course of current events and could predict their future development with less uncertainty. These predictions can be further fine tuned to account for shifting alliances and priorities. Once a baseline of activity has been established, the ability to identify underlying causes such as those that lead to unexpected results is valuable information in itself.

The third advantage of such a simulation tool is to inject possible outside influences into the model and see if and how they alter the course of events. Models such as these could self train to produce the most desirable effects with the smallest perturbations. Further, trained models may be examined to determine that observations of the evolving environment are most useful to determine that plan expectations are being met.

Summary

This paper has proposed the application of ADP&E to modeling social influence in a combined centralized and distributed context. Individual agents have partial allegiances to one or more, potentially conflicting, central authorities, as well as their own internal goals and principles. Agents are not simply reactive, but proactively plan and execute action sequences in these contexts. ADP&E can provide a means of modeling the social forces at work within an individual agent, as well as the shifting allegiances and conflicts among agents. Into this complex, dynamic hierarchy, various PSYOP interventions can be injected, and the micro and macro reactions of the system observed.

The unrest surrounding the Iranian elections in the summer of 2009 have been used as an illustrative example of ADP&E modeling. The defining elements of that situation have been deconstructed into items and relationships prerequisite for the formation of a model. Application of ADP&E to that model has served to explain the features of ADP&E, and describe its benefits for such social influence models.

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