# SCARE: The Spatio-Cultural Abductive Reasoning Engine

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## Abstract

In this paper we introduce SCARE - the Spatio-Cultural Abductive Reasoning Engine which implements an algorithm that solves spatial abduction problems (Shakarian, Subrahmanian, and Sapino 2009). We review results of SCARE for activities by Iranian-sponsored "Special Groups" (Kagan, Kagan, and Pletka 2008) operating throughout the Baghdad urban area and compare these findings with experiments where we predict IED cache sites of the Special Groups in Sadr City. We find that by localizing the spatial abduction problem to a smaller area we obtain greater accuracy - predicting cache sites within 0.33 km as opposed to 0.72 km for all of Baghdad. We suspect that local factors of physical and cultural geography impact reasoning with spatial abduction for this problem.

## Introduction

The counterinsurgency environment provides a new set of challenges to the military commander, particularly at the tactical (Division, Brigade, Battalion, and lower) level. What von Clausewitz called the "fog of war" (von Clausewitz 1832) is certainly present, but deceptive. Although the enemy in these contemporary conflicts often do not wear uniforms or operate out in the open, their actions in these complex environments are not entirely random. The enemy, or enemies in a counterinsurgency typically have goals and strategies - not totally dissimilar to military units.

> *As with terrorist tactics, guerrilla tactics are neither mindless nor random.* (US Army 2006)

In the field of criminology, several theories exist that relate the geographic location of criminals with the locations of their crimes. *Pattern theory* (Brantingham and Brantingham 2008) and *geographic profiling* (Rossmo and Rombouts 2008) are extensively used. In the Army, intelligence professionals root their analysis in the process known as Intelligence Preparation of the Battlefield (IPB) (US Army 2004; 1994), which can also be extended to counter-insurgency operations (US Army 2006). However, traditionally, analysis of attacks in a counter-insurgency environment is to identify "hot spots" or places where attacks are likely to occur. In this paper, we extend such analysis by examining techniques to locate sites used for enemy weapons caches based on attack data. We use a new theory called *Spatial Abduction* (Shakarian, Subrahmanian, and Sapino 2009). This theory models a scenario where you have two sets of locations (observations and partners) in a space that are related to each other based on a set of constraints. In this paper, we examine improvised explosive device (IED) attacks attributed to certain groups. We attempt to locate weapons cache sites based on attacks and on the locations of arrested enemy personnel using SCARE - the Spatio-Cultural Abductive Reasoning Engine.

In this paper we review experiments done on SCARE for the entire Baghdad urban area and compare them to results for the Sadr City district. While we obtained an accuracy of within 0.72 km for predictions for the entire city, we obtained 0.35 km accuracy for only Sadr City. We believe that this improvement is due to local effects of spatial abduction constraints and intend to explore these effects further in future work.

## IED's in an Insurgency

From 2001-2009, IED's have emerged as a weapon of choice for the enemy in counter-insurgencies in Iraq and Afghanistan. Currently, there are two main approaches to dealing with the IED problem. One approach is to focus on the attack - where the blast occurred, what type of explosive, etc. A common practice of commanders with this approach is to clear routes where IED attacks frequently occur and target IED networks through intelligence (Brown 2007). Another approach - to emphasize the IED "network" is more intelligence focused and seeks to find bomb makers and emplacers (Moulton 2009). Our approach with SCARE is essentially a hybrid approach. We are using information about the attack to automatically create new intelligence about cache sites. If uncovered, these cache sites can be exploited to gain further intelligence on the IED network through forensics and document exploitation. This will help lead to more effective counter-insurgency operations, by impeding the ability of the insurgent to transport and emplace the IED's (Mansoor and Ulrich 2007).

In order to use attack information to identify caches, we

*The research in this paper was conducted with and under the supervision of Prof. V.S. Subrahmanian, University of Maryland, College Park, MD 20742, USA. Email: vs@cs.umd.edu and Prof. Maria Luisa Sapino, Universita di Torino, Torino, Italy. Email: mlsapino@di.unito.it make some simplifying assumptions on the behavior of the IED attack cells. We know that IED attacks are typically conducted by small teams (McFate 2005) whose members include the following:

- **IED manufacturers** who make the actual IED
- **IED emplacers** who place the IED in the designated attack area
- **IED triggermen** who are present during the IED attack. They may or may not arm or detonate the IED, but would at least conduct overwatch of the attack
- **IED logisticians** ensure that IED manufacturers obtain materials or otherwise transport IEDs to and from cache sites
- **Higher level support** such as financial support, leadership, intelligence gathering, etc.

Social network analysis (Reed 2007) is increasingly used to target IED networks. However, such analysis primarily focuses on higher-level support and IED manufacturers. On the other end of the spectrum - engagements with IED cell members at the location of attack - will primarily hit the emplacers and triggermen. SCARE will hit the logisticians and emplacers of the network as the caches are the key places where material is exchanged between the two. Further, it has the potential to reduce the enemy's capability by denying them forward cache areas used for attacks. Without such cache sites, the IED cell members will be forced to travel longer distances with IED materials before an attack - thereby increasing the chances of compromise. The full list of assumptions for our model follows below.

1. IED cell members do not store materials at home. Typically, materials were stored in a common area (cache site).
2. The cache site is accessed prior to the attack to obtain the necessary materials.
3. The cell members have some restrictions on where the cache sites can be - i.e. it cannot be in a body of water, on a coalition base etc.
4. The distance from the cache site to the attack is greater than a certain distance. If the cache site were too close, it would increase the chances of being found and destroyed following an engagement.
5. The distance from the cache site to the attack must also be less than a certain distance. Transporting munitions over too great a distance increases the chance of the cell members being compromised in transit (i.e. material may only be moved during hours of darkness.)

Having this model of IED cell behavior is a starting point to creating an accurate representation of their behavior. We shall add a further constraint in that the attacks and cache sites are affiliated with the same insurgent group (or family of groups). The line of thinking is that different groups may use different models. Fortunately, we have open source data for the Iranian-backed "Special Groups" which conducted numerous IED operations in Iraq during 2007-2008.

## Special Groups

"Special Groups" operating in Iraq are defined as Shia extremist elements funded, trained, and armed by Iran (Kagan, Kagan, and Pletka 2008; Cochrane 2008c). Although at the time of this writing (2009), their influence seems to be waning (Cochrane 2009), these groups leveraged significant insurgent military and political power during 2007-2008.

Perhaps the most widely known among these groups is Jaysh al-Mahdi (JAM), headed by the young firebrand Shi'ite cleric Muqtada al-Sadr (Nasr 2007), however differing ideologies and agendas have caused fragmentation in this group. Despite the primacy of the Iraqi (Arab) Shi'ite identity that these groups publicly state, they receive a great deal of support from Iran (Cochrane 2008c) as cited by several sources. Many of the off-shoot organizations of JAM also seem to retain the Iranian support as evidenced by their access to certain weapon systems.

The trademark weapon of these group is the explosively-formed penetrator (EFP). This weapon system is known to be imported from Iran (Kagan, Kagan, and Pletka 2008). This is a more advanced type of IED designed to penetrate armored vehicles. The signature of an EFP is sufficiently unique to the extent where it is easy to differentiate this type of attack from a typical IED in Iraq.

In Iraq, the Special Groups operate mainly in southern Iraq, the provinces of Diyala, Salah-al-Din, and Baghdad (Cochrane 2008c). In Baghdad, their safe-havens are traditionally in districts of Sadr City and Kadamiyah. However, in 2006-2007 they have attempted to exert their influence in other areas of Baghdad (IMC 2007). An open-source Google Earth map called *Map of Special Groups Activity in Iraq* available from the Institute for the Study of War (ISW 2008a). This map lists over 1000 insurgent activities attributed to Special Groups throughout Iraq. This data set contains events for the 21 months between February 2007 and November 2008, which is a period of high activity for these groups (Cochrane 2008b). The events are plotted are based on Multi National Forces - Iraq (MNF-I) press releases. According to the Institute for the Study of War, "efforts have been made to plot the data points with as much accuracy as possible." The map is available in KMZ format for Google Earth.

The incidents in the map are only those attributed to the Special Groups. However, due to the nature of EFP's and militia affiliation, these events were relatively easy to identify with Special Groups with a high degree of accuracy. The activity types include the following categories:

1. Attacks with probable links to Special Groups
2. Discoveries of caches containing weapons associated with Special Groups
3. Detainments of suspected Special Groups criminals
4. Precision strikes against Special Groups personnel

In our tests, we utilize this map of Special Group activities as our data set. Next, we shall briefly introduce the actual SCARE system.

## The SCARE System

SCARE is the Spatio-Cultural Abductive Reasoning Engine and is based on the idea of Spatial Abduction presented in (Shakarian, Subrahmanian, and Sapino 2009). Abduction (Peirce 1955) is a form of nonmonotonic reasoning extensively used in Artificial Intelligence, to generate explanations for observed manifestations. It has been applied in many different domains. Diagnosis is one of the first and more important applications of abduction, especially in the medical domain (Peng and Reggia 1990; Y. Peng 1986). Other important application scenarios for for abductive reasoning include fault diagnosis (Console, Portinale, and Dupré 1991), belief revision (Pagnucco 1996), database updates (Kakas and Mancarella 1990; Console, Sapino, and Dupré 1995) and automated planning (do Lago Pereira and de Barros 2004).

For our purposes, given two related phenomena, SCARE and Spatial Abduction determine the location of "partnered" phenomena derived from the location of observed phenomena based on certain constraints. In its current form, the constraints consist of the minimum and maximum distance between observations and their partners as well as a function that designates if a partner can be located at a certain point. For the prediction of IED cache site, we consider the attacks as the "observations" and the cache sites as the "partners." Hence, we are attempting to locate cache sites based on attack locations.

SCARE takes as inputs a geographic space with integer coordinates. In this way, SCARE can view the geographic space as a set of discrete points. The system uses historical data to determine minimum and maximum constraints. However, it also allows the user to input a threshold for the maximum distance between an observation and partner. In the SCARE tests in this paper, as well as previous tests we review here, this distance is set to 2.5 km.

The user can also supply an overlay in Google Earth format to designate the points in the geographic space that are infeasible for partners (caches). In our experiments, we utilize open-source religious information from the International Medical Corps for the 89 neighborhoods in Baghdad, as most of the "Special Groups" are Shi'ite, we can disregard predominantly Sunni neighborhoods as cache site locations. This religious data is current as of January, 2007 (IMC 2007). We will also augment this data with globalsecurity.org, open-source locations of MNF-I military facilities (globalsecurity.org 2009). SCARE allows us to input these restricted locations by simply importing a Google Earth file with polygons designating the restricted areas.

As implemented, SCARE attempts to find the *minimum* number of caches to support the attacks (based on our constraints). Therefore, our results will not accurately find all cache sites, although our results are encouraging. Locating additional sites will either require different constraints or a different type of algorithm. We will explore these aspects in future work.

SCARE employs greedy selection that utilizes a dynamic ranking system through a Fibonacci heap (Fredman and Tarjan 1987).

| Area | Number of Attacks Considered | $\alpha$ (km) | $\beta$ (km) | Sample Mean Run-Time (ms) |
|---|---|---|---|---|
| Baghdad $27 \times 25$ km | 73 | 0.60 km | 1.98 km | 201.4 ms |
| Sadr City $7 \times 7$ km | 40 | 0.00 km | 1.06 km | 24.6 ms |

Table 1: Parameters and Run-Times for SCARE

## Experiments

Our implementation of SCARE, runs on a Lenovo T400 ThinkPad laptop equipped with an Intel Core 2 Duo T9400 processor operating at 2.53 GHz and 4.0 GB of RAM. The computer was running the Windows Vista operating system, 64-bit Business edition with Service Pack 1 installed. We implemented SCARE in the Java programming language. Java Runtime Environment (JRE) Version 6 Update 14 was used. The software was developed with Eclipse version 3.4.0. We used the JGraphT library version 0.81 to implement the Fibonacci heap. The Fibonacci heap implementation was written by Nathan Fiedler (JGraphT 2009). No other external libraries (outside those included with Java) were used. We also added the capability to output KML files so that the results could be viewed in Google Earth - we used Google Earth 4.3.7284.3916 (beta) operating in DirectX mode. Experimental results were also collected in CSV-formatted spreadsheets.

We conducted two tests using the data from (ISW 2008a). In our first test, we employed SCARE on the entire Baghdad urban area, and in the second we used data for only the Sadr City district of Baghdad. SCARE sets two parameters from historical data - $\alpha$ and $\beta$ - the minimum and maximum distance between an attack and cache, respectively. For both tests, SCARE learned these parameters using the first 7 months of attack data ($\frac{1}{3}$ of the available months) and 14 months of cache data. When learning these parameters, SCARE was geographically restricted to the appropriate area (i.e. it learned the parameters for Sadr City using only Sadr City historical data).

For the prediction of actual cache sites, SCARE used Special Groups attack data from months 8 to 21 of the data. We compared the predicted cache sites to the nearest actual cache site (that could support the associated attacks based on time) as a measure of accuracy. We used actual cache sites from the same time period as the attacks. Therefore, our system could possibly have predicted cache sites not in the data set - i.e. sites found beyond month 21. However, we only consider accuracy *wrt* known cache sites in the data set. As SCARE has some non-determinism (random behavior) built-in, we ran each algorithm 100 times before analyzing the results. We summarize the parameters and run-times of SCARE in Table 1 and accuracy results in Table 2.

### The Baghdad Urban Area

As the relationship between attacks and cache sites may differ with terrain, we selected only events in the urban area of Baghdad. Not only are the events by the Special Groups in

| Area | Sample Mean Number of Predicted Caches | Sample Mean Average Distance to Actual Cache | Sample Mean Number of Caches Less than $0.5$ km to Actual Cache |
|---|---|---|---|
| Baghdad | $14$ | $0.72$ km | $7.353$ |
| Sadr City | $6$ | $0.35$ km | $5.280$ |

Table 2: Accuracy Results for SCARE

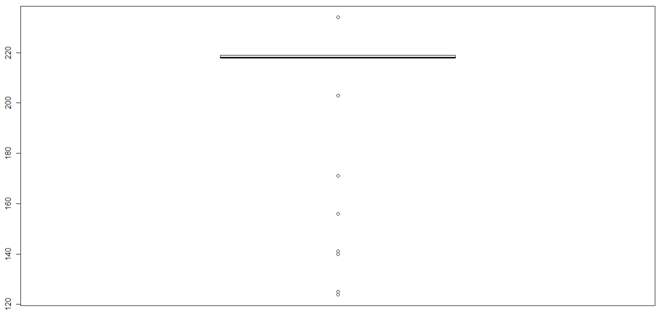


Figure 1: Box Plot of run-times of SCARE in Baghdad.

our data set primarily from this area, but geography outside of an urban area may indicate a different set of constraints. For example, the high population density of a city may limit movement between ethnic and religious enclaves, whereas this may not be an issue in more open countryside.

The tests of the SCARE algorithms were performed in a 27 x 24 km area covering Baghdad [1]. In our tests, the algorithms considered 73 attacks as the input set of observations. We used the feasibility overlay described earlier. The value $\alpha$ (minimum distance between cache and attack) was calculated to be $0.60$ km and the value for $\beta$ (maximum distance between cache and attack) was calculated to be $1.98$ km.

The run-times for reasoning about the 73 attacks in Baghdad were very reasonable. For Baghdad, SCARE predicted $14$ cache sites in each of the $100$ trials with an average run-time of $201.4$ ms. The box-plot in Figure 1 illustrates the variation in run-times for the SCARE trials for Baghdad. Figure 2 shows a screen-shot of a single run of SCARE for cache predictions in relation to the attacks for Baghdad.

As described earlier, for each prediction, we measured the distance to the nearest actual cache. For a single trial, we created the box-plot in Figure 3 in order to provide a feel of the accuracy for a set of predicted cache sites in Baghdad. Also, for a single trial, we plotted all cache sites found by coalition and Iraqi forces as well as the SCARE predictions in Figure 4. We found that, for our sample of $100$ trials, the mean of the average distance to an actual cache was $0.72$ km. We illustrate the distribution of average distances to actual cache sites in Figure 5. Further, for a given solution set, on

[1] More precisely, the 27 km east-west and 24 km north-south rectangle with a lower-left corner of $33.2°$ North latitude, $44.25°$ East longitude.

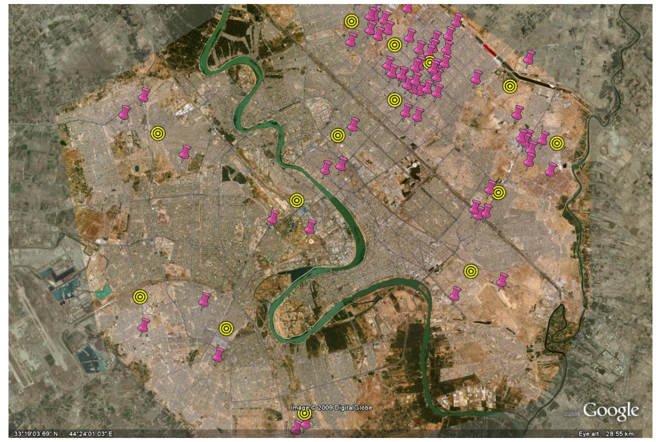


Figure 2: Screen shot of sample Google Earth output from SCARE compared with attack data for Baghdad. Predicted caches are yellow bulls-eyes, attacks are pink push-pins.

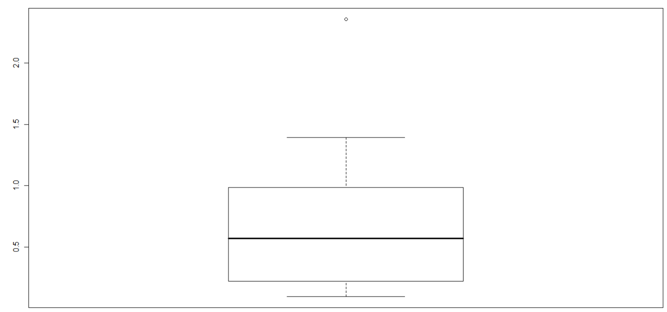


Figure 3: Box plot of a single run of SCARE in Baghdad showing the distances to the nearest cache site (in km) for all predicted cache sites. Notice that nearly half of the elements in the solution are less than $0.5$ km from an actual cache site.

average, over half the elements were $0.5$ km or less from an actual cache site. Figure 6 shows a box plot of number predictions less than $0.5$ km accuracy for all the trials.

However, it is arguable that even the city of Baghdad is too large of an area for such a model. It could be said that the constraints differ from neighborhood to neighborhood, even for the same group. Factors causing the constraints to change may include the average height of buildings, the types of streets in the district, the social-cultural or religious makeup, and the presence of other features such as open areas or palm groves - all common in Baghdad. All of these factors may affect the distance between caches and attacks - for example, neighborhoods with a lot of back alleys and a friendly local population may allow an emplacer to travel further between the cache site and the area of an attack. A neighborhood with a lot of open areas and a mixed population may force the attackers to launch their attacks closer to the cache site.

In order to do an experiment where such factors are miti-

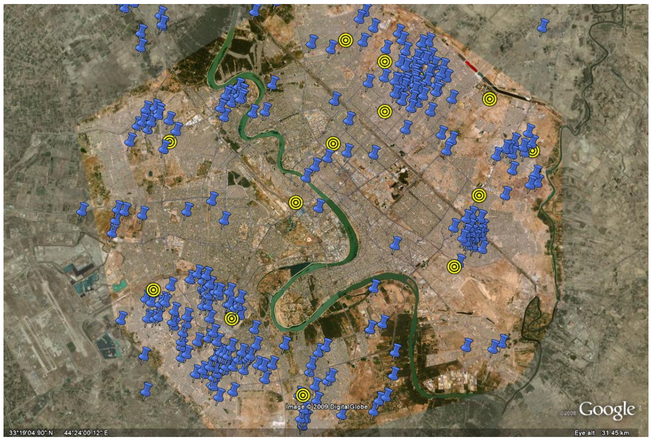


Figure 4: Screen shot of Google Earth output from SCARE compared with actual cache data for Baghdad. Predicted caches are yellow bulls-eyes, attacks are blue push-pins.

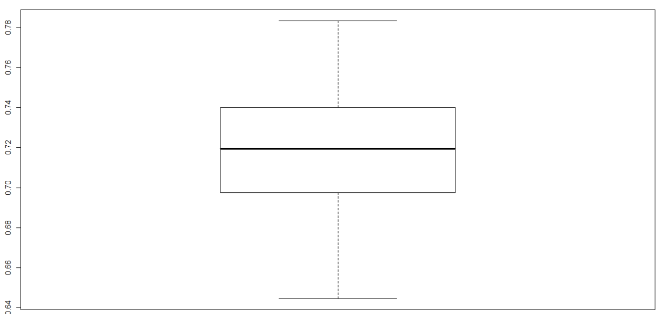


Figure 5: Box Plot of average distances to actual cache for SCARE in Baghdad

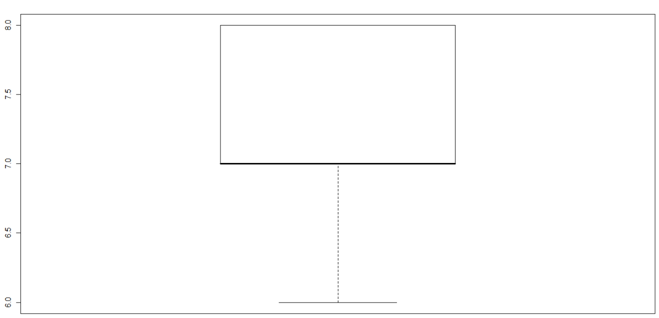


Figure 6: Box Plot of number of elements in a set of cache predictions in Baghdad less than $0.5$ km from an actual cache.

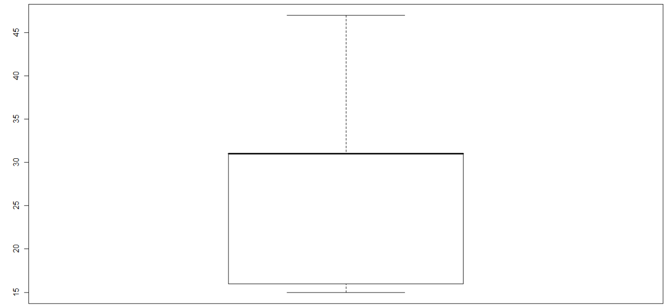


Figure 7: Box Plot of run-times of SCARE Performance results for Sadr City

gated, we selected the Baghdad district of Sadr City for our new tests.

## The District of Sadr City

In order to localize the effects, we decided to look at a smaller area. Sadr City was known to be a major stronghold for the special groups (Kagan, Kagan, and Pletka 2008; Cochrane 2008b). It has a strong Shi'ite population and the district is planned in a grid configuration (see Figures 8-10). By focusing on this smaller area, we hoped to mitigate some of the effects on constraints that may have been present when we considered the entire Baghdad urban area.

Over half of the attack activity in our Baghdad tests were in the district (we considered $40$ attacks for Sadr City, $73$ for the Baghdad urban area). Other than the change to the location [2], we set up the experiment with the same parameters as for the Baghdad tests. SCARE calculated $\alpha = 0.00$ km and $\beta = 1.06$ km based on historical data (of the same time intervals as for the Baghdad trials) for Sadr City, using the same maximum threshold for $\beta$ of $2.5$ km. Note that these values differ from those obtained for the entire Baghdad urban area - one indicator that there may be localized effects on the constraints.

The run-times for reasoning about the $40$ attacks in Sadr City were very fast. For Sadr City, SCARE predicted $6$ cache sites in each of the $100$ trials with an average run-time of $24.6$ ms. The box-plot in Figure 7 illustrates the variation in run-times for the SCARE trials for the district. Figure 8 shows a screen-shot of a single run of SCARE for cache predictions in relation to the attacks for Sadr City.

As we did for all of Baghdad, we measured the distance to the nearest actual cache as a means to determine accuracy. For a single trial, we created the box-plot in Figure 9, the associated plot of actual cache locations vs. prediction is shown in Figure 10. We found that, for our sample of $100$ trials, the mean of the average distance to an actual cache was $0.35$ km - a great improvement over the accuracy for all of Baghdad. We illustrate the distribution of average distances

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[2] For Sadr City we we used a 7 x 7 km area with a lower-left corner of $33.345°$ North latitude, $44.423°$ East longitude.


Figure 8: Screen shot of Google Earth output from SCARE compared with attack data for Sadr City. Predicted caches are yellow bulls-eyes, attacks are pink push-pins.

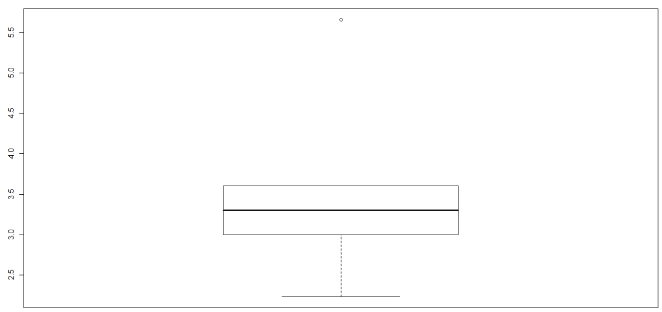


Figure 9: Box plot of a single run of SCARE in Sadr City showing the distances between the predicted caches and actual caches (in tenths of kilometers).

to actual cache sites in Figure 11. Further, for a given solution set most of the elements were within 0.5 km of an actual cache site. Figure 12 shows a box plot of number predictions less than 0.5 km accuracy for all the trials. Additionally, for Sadr City, all predictions returned by SCARE were within 0.6 km of an actual cache site. Figure 13 shows a box-plot considering the least accurate cache prediction for each trial.

## Discussion

The experiments with Sadr City possibly illustrate the localized effects of constraints in a spatial abduction problem when predicting IED cache sites. Although we intend to explore this further with other data sets, the following are several observations made in this study that we will consider in future versions of SCARE.

- SCARE shows viability as a system for predicting IED cache locations. Early tests for the Baghdad urban area and the Sadr City district have produced predicted caches closer to actual cache sites than expected - especially con-

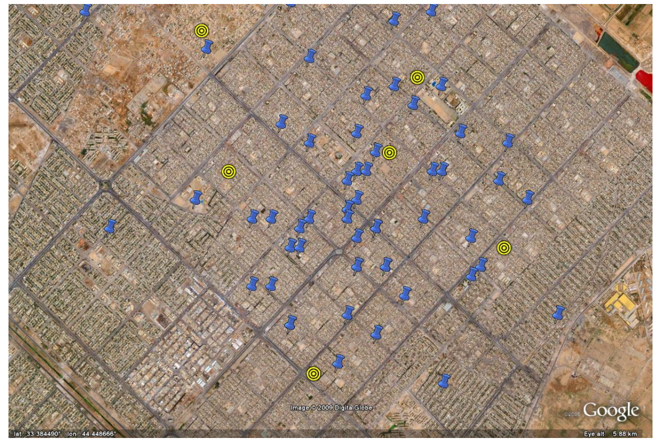


Figure 10: Screen shot of Google Earth output from SCARE compared with actual cache data for Sadr City. Predicted caches are yellow bulls-eyes, attacks are blue push-pins.

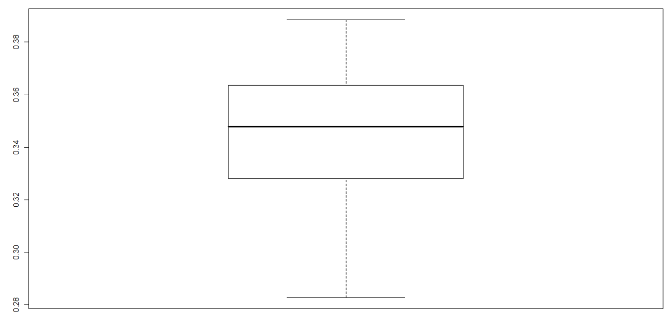


Figure 11: Box Plot of distance to nearest cache for SCARE based on attack-cache relationships for Sadr City.

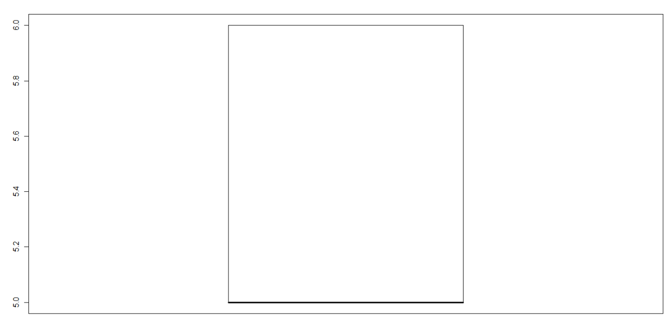


Figure 12: Box plot of the number of predictions in a given run that were less than 0.5 km from an actual cache. For the Sadr City trials, each run returned 6 predictions.

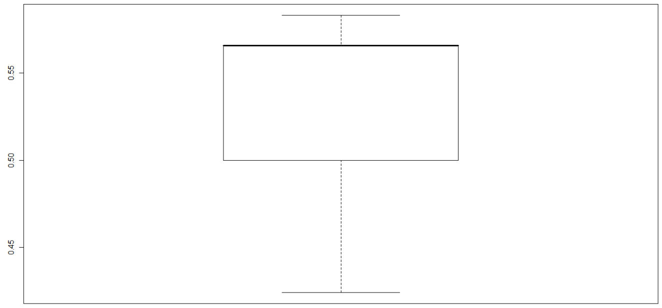


Figure 13: Box plot showing the furthest predicted partner from an actual partner for each Sadr City trial. Notice that SCARE always predicted a cache site within $600$ meters.

sidering the limited constraints and the minimality requirement.

- SCARE may need to consider different constraints for different areas based on physical and cultural geography.
- Our experimental results indicate that there is use in our model of IED cell behavior and that spatial abduction is a good formalism for this model.

## The Current Tactical Utility of SCARE

The results of SCARE for IED cache site prediction are not only promising for future work, but may even have current applicability. Consider the issues of planning reconnaissance and surveillance and collection management (US Army 1998). In our Sadr City tests, we found that on average, SCARE predicted caches within $0.35$ km of an actual cache. Military staff planners can use information in a number of ways, including the following:

- SCARE predictions can be used to help cue other assets. If we have a prediction, we can focus other collection assets in that area.
- SCARE predictions can be used to deny enemy operations. In Table 1 For example, for Sadr City, we found that attacks were near caches within $1.06$ km (the $\beta$ value based on historical data of $40$ previous attacks). However, the accuracy of a SCARE prediction averaged $0.35$ km. Hence, with SCARE, the commander can cover a smaller area to deny cache sites and this prevents attacks.

## Additional Analysis

In addition to our analysis with SCARE, we also learned some interesting facts based on when we input the data into the system. As we combined the religious, coalition facility with the Special Groups data from disparate sources, we noticed that some of the neighborhoods from (IMC 2007) labeled as "predominantly Sunni" had weapons caches (ISW 2008a) attributed to the Shi'ite Special Groups. The religious data was current as of February 2007 and the cache sites were discovered in August-October 2008. Despite noticing this discrepancy, we employed the data from (IMC 2007) "as-is" in order to maintain scientific integrity. However, we were curious why this occurred. What follows is a brief analysis of this finding. The two neighborhoods where we noticed this trend where southern Ghazaliya and south-eastern Dora.

*Southern Ghazaliya* can be viewed as a faultline - to the south is the Sunni district of Ameriya, to the east is the Baghdad suburb of Abu Ghuraib - which is a Sunni town that links Baghdad to the Sunni province of Al-Anbar. However, despite being nested in this location, Shi'ites from the nearby Shi'ite militants dominated district of Khadamiyah[3] moved into the area to conduct operations in 2008 (Anderson 2007; Roberts 2008; Lowry 2007).

There were four caches found in the fall of 2008 in this area that were attributed to "Special Groups." Despite being a faultline area, Ghazaliya was ultimately Sunni territory. Hence, what do these four cache sites in autumn of 2008 mean? The first hypothesis is that this is a mistake in the data set - that the caches are really Sunni cache sites. However, a closer look at the data reveals that copper plates were found at some of the sites (ISW 2008a) which is a main component in EFP's (which is indicative of the Shi'ite Special Groups, not Sunni insurgents). Another hypothesis is that the Shi'ite militants and Sunni insurgents were working together in this area. This is an interesting hypothesis, but due to the local dynamics of Ghazaliya, particularly the Sunni-Shi'ite infighting known to occur in that area, this hypothesis is doubtful as well. Our third hypothesis is that by the fall of 2008, the Shi'ite groups gained a significant foothold in southern Ghazaliya. This is possible as the caches were found over a year after the neighborhood was labeled as "predominantly Sunni" by the IMC.

*South-eastern Dora* is less of a faultline area. While the western portion of the Dora district borders the Jihad district, an area with a significant Shi'ite presence in 2007, the eastern portion is generally regarded as Sunni territory (Kingsbury 2008). Further, just to the south of the area where the cache sites were found is the suburb of Arab Jabour. Arab Jabour is a significant Sunni insurgent stronghold. Named for the al-Jabouri tribe - the largest Sunni tribe in Iraq - this neighborhood is dominated by Iraqis of Sunni belief. Numerous coalition operations directed against Al-Qaeda in Iraq have taken place in this area (ISW 2008b). Across the Tigris from Arab Jabour is a predominantly Shi'ite area around the suburb of Salman Pak. This makes the presence of Shi'ite Special Groups cache sites in the area puzzling.

There were 7 weapons caches attributed to Special Groups found in south-eastern Dora. We believe that it was not erroneous to label them as a Special Groups sites most of these caches contained known Iranian weapons. There are several hypotheses to consider. First, and perhaps most likely, is that the Sunni insurgency was weakened by the fall of 2008 that Shi'ite groups from Salman Pak and eastern Bagh-

[3] After Sadr City, Khadamiyah is probably the next most Shi'ite dominated district in Baghdad. Notably, it is home of the Khadamiyah Shrine - the burial place of the seventh Imam in the Shi'ite faith (Nasr 2007).

dad were able to penetrate into the southern Dora. Facing the pressure of the surge, where legitimate Iraqi security forces, with coalition soldiers, the Shi'ite Special Groups may have needed to push into new areas outside the city to store weapons. South-eastern Dora, although Sunni, lacked population density. Cache sites in this area would allow the Shi'ite militants to avoid coalition forces, strike at the Sunnis in Dora and Arab Jabour, and strike at coalition forces traveling along major routes to the south and east of Baghdad. However, due to the strong Sunni population in the area, the locals may have resented this move and reported the activity to the authorities, hence the cache sites being found.

There is another, although somewhat less likely hypothesis to consider. In 2007, the US Department of Defense made several public statements about the Iranian government supplying weapons to Sunni insurgents in both Iraq and Afghanistan (Cochrane 2008a). It is not impossible that these caches may be a case of this type of behavior, however more information about other materials found at the sites (i.e. documents, media, etc.) would be needed to substantiate such a claim.

## Conclusion

In this paper, we illustrated how spatial abduction can model the relationship between IED attacks and cache sites through the SCARE system, reviewed results for the prediction of cache sites by Special Groups in the Baghdad urban area and presented new results with the same data set specifically for the Sadr City district. While we obtained predictions 0.72 km away from actual cache sites when we considered the Baghdad urban area, we obtained better predictions (0.35 km from actual sites) when we only considered the Sadr City district. We found that SCARE set different distance constraints based on the historical data for this district and we conjecture that there are localized geographic and cultural effects that may influence this problem. In future versions of SCARE, we intend to explore these effects by extending our spatial abduction model as well as testing the system on data sets with different cultural and geographic configurations.

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