CULTURAL TACTICAL ADVISOR FOR WARFIGHTERS IN THE URBAN BATTLESPACE

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1. ABSTRACT

We are developing a mobile handheld system that provides tactical and cultural advice to warfighters. The system fuses built-in knowledge of social factors and location specific information with dynamically entered situation descriptions to produce an assessment of the situation and recommend actions. The outcomes include the system's confidence in its recommendations, along with explanations of its reasoning. The result gives warfighters the information they need to make the critical decisions necessary to accomplish their mission, while minimizing the collateral damage that alienates the local populace.

2. INTRODUCTION

According to the Defense Advanced Research Projects Agency, the key to success in the urban battlespace is the development of an understanding of the relationships among the civilian population, military forces, and urban infrastructure that define the battle context. There are various systems in development that will effectively expose urban infrastructure to enable effective military tactical development. What these systems lack in establishing battlespace success is cultural awareness. The goal of the ACTAR system (Augmented Cultural Tactical Awareness and Response) is to establish the desired interrelationship between these progressive systems and the populace of the battlespace by enabling cultural tactical analysis.

The necessary management of an urban battlespace will depend on a soldier's ability to amalgamate and empathize with the resident culture. This requires awareness of the culture in question. Augmenting cultural awareness entails integrating a soldier's current tactical perspective with a resource for assessing various cultural aspects relevant to the scenario, such as

- Pentagon policies,
- local political exigencies,
- cultural norms, traditions, and expectations, and
- sociological, religious, legal, geographic, economical, and historical factors.

The urban model generated by this culturally enhanced perspective will incorporate an understanding of the area's populace, resulting in sensitivity to the inhabitants of the urban battlespace that is currently not considered by existing systems for devising tactical operations. Establishing sensitivity to the populace of an urban battlespace via the ACTAR system will enable a more predictable projection of urban activity.

There are two primary ways in which ACTAR will facilitate a predictable projection of urban activity.

1. Consideration for the concerns of the populace will enhance the relationship between soldiers and civilians. A good relationship will facilitate more predictable and constructive behavior by both parties.

2. Taking into account the normal, traditional, or expected behavior of a culture of people will enable a characterization of suspicious behavior with respect to the culture of interest.

As such, the key to success in the urban battlespace is knowledge—knowledge of the techniques and limitations of the opponents; knowledge of the current location of enemies, friends, and weapons; knowledge of the interrelationships among the opponents; and knowledge of the urban terrain. Before a soldier enters a building, he should know exactly whether he should expect to find opposing forces, civilians, or both, how to communicate with them, what their reaction to his presence will be, and what type of response to expect.

We believe that most of the technology for delivering and acquiring this information already exists, but what is needed is the distributed software that will bring together all the disparate sensing and communication technologies. We are thus developing software for handheld devices, which will record and aggregate the observations of the warfighters in the field and provide them with specific, time- and location-sensitive advice. Our handheld

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application will tell a soldier what he needs to know when he needs to know it, all the while minimizing the amount of interaction the soldier needs to have with our system so that he can be free to carry out his mission. The ultimate goal of our system is to give each soldier omniscience over the urban battlespace. This will be accomplished by *a priori* aggregation of cultural and command-and-control knowledge and *in situ* collaborative aggregation of state knowledge by the warfighters, sensors, and any other autonomous systems (e.g., UAVs and robots) available.

We are developing a mobile handheld system that provides tactical and cultural advice to warfighters. Our project consists of two major parts: (1) we are constructing a cultural and military adviser for warfighters that operates independently, without the need for communications with other handhelds, to provide warfighters with specific advice on what to expect given their current situation, the cultural imperatives of their opponents, and orders from command; and (2) we are utilizing the wireless capabilities of the handheld in order to let warfighters cooperate in creating an aggregate view of the urban battlespace. The system fuses built-in knowledge of social factors and location-specific information with dynamically entered situation descriptions to produce an assessment of the situation and recommend actions. The outcomes include the system's confidence in its recommendations, along with explanations of its reasoning. The result gives warfighters the information they need to make the critical decisions necessary to accomplish their mission, while minimizing the collateral damage that alienates the local populace.

3. A NEW APPROACH IN THE URBAN BATTLESPACE

Imagine a group of suspected terrorists has escaped into a religious building, such as a mosque, temple, church, or synagogue. Should they be pursued into such a building? If so, what are the social or political ramifications that might negatively affect the larger mission? Are there any other effective options available to capture the terrorists that may mitigate the negative consequences? What if the building in question is a different kind of public place, such as a school, marketplace, hospital, government office, or historic site? Do the implications of actions change if the context is more personal, such as a private home or a graveyard or mausoleum? Does the day of the week, such as a holy day when religious services are being held, affect the decision? Is the gender of the suspects relevant? Does their age matter?

These are complex questions requiring diverse and expert knowledge to support complex decision-making. A warfighter in an urban battlespace must consider all of these factors while making tactical decisions, and often under extreme duress and danger. To add to the difficulty, most of the factors are more qualitative than quantitative, and thus are difficult to assess, combine, and compare. There is no time to assemble and consult a team of experts, yet the decision must none-the-less be based on accurate and appropriate data that informs and minimizes the problem space.

The warfighters obviously need help with making decisions that take all of these factors into account, but no computational aids are available. Warfighters have C4I support systems that direct them in battlefield tactics, yet they are completely unequipped in effectively handling scenarios such as those described above. The available support systems are oriented around winning the battle. Effectively handling scenarios like those described above will lead to the mitigation of tensions and the fostering of relationships. These are acts of peace. What warfighters now require is a tool for winning peace.

4. THE NEED FOR CULTURAL AWARENESS: BRIDGING THE GAP

Culture is an evolved capacity of the human species. As with any evolution, there is a specific environmentally motivated justification for why we have evolved such a complicated characteristic such as culture. What does culture provide to human beings, and why is it increasingly important in today's world to facilitate the generation of cross-cultural relationships? In this section we will briefly define culture, and describe how it helps and hinders our ability to get along. We will also discuss how a computational system enabling cross-cultural integration can assist in significantly mitigating intercultural conflict.

Communities of people are able to establish common behaviors that are explicitly taught and indirectly shared with others within the community (Linton, 1945). Lederach (1995) agrees with Linton that culture is "shared knowledge and schemes created by a set of people," then he continues by specifying reason for creating such commonalities, namely "for perceiving, interpreting, expressing, and responding to the social realities around them." Thus, culture is a human response in which people establish common behaviors that are expected in certain social contexts. Kroeber and Kluckhohn (1952) declare that, "culture systems may, on the one hand, be considered as products of action, and on the other as conditioning elements of further action." If this cultural behavior is presented in appropriate contexts, it creates congruence between the actors generating predictable subsequent behaviors, which may be useful in establishing pro-social relationships such as trust or comfort. Imagine the following typical greeting in US culture: if someone approaches you with an outstretched hand and a smile on their face, there is common protocol as to the behavior that will ensue. The common protocol puts the one being greeted at ease, and this ease diffuses any tensions that may have existed. On the contrary, imagine if the greeter bluntly got to the point saying abrasively "Who are you?" Tensions would be raised as a result of this broken cultural protocol.

Just as culture generates pro-social opportunities, lack of cultural awareness may have anti-social consequences. Lederach (1995) describes the relationship between culture and conflict as one in which "social conflict emerges and develops on the basis of the meaning and interpretation people involved attach to action and events… From this starting point, conflict is connected to meaning, meaning to knowledge, and knowledge is rooted in culture." Culture is in essence at the root of conflict, generating conflict because culture is missing and so meaning is missing. Two groups of people that have no shared knowledge or mutual understanding will inevitably conflict as one group remains unaware of the social realities to which the other is sensitive.

Cross-cultural integration is essential for bridging the cultural divide and establishing genuine and effective understanding between cultures. Once cultural awareness is generated, unnecessary and unintentional conflicts resulting from ontological incongruence will be mitigated. Computer systems can be a useful means of establishing this understanding in a timely and accurate manner. The system will not simply convey cultural data; it will identify appropriate cultural actions the user should consider taking with detailed explanations delineating why such an action would be appropriate.

A computer system may be more aware of the details of the battlespace than the soldier. This is no surprise, as the system is able to store more information than the user, and hence allow the user the flexibility of focusing on a more immediate sub-context. The important factor to this is that the system must be aware of when certain information is pertinent to the user's localized battlespace. In this way, a computer system may suggest culturally motivated actions to the user that are based on apparently extraneous data such as where other troop members are located in the battlespace or the current suspect's recorded history. People have only a limited capacity to consider distant and seemingly unrelated consequences to an action, particularly when these actions have to do with a foreign culture of which the person has minimal understanding (Dorner, 1996). Computers can provide significant assistance in this regard. A culturally motivated decision-making computational assistant such as ACTAR can manage the cultural information as well as an awareness of the battlespace. In processing this data, the assistant could provide contextually and strategically appropriate suggestions to a warfighter.

5. IMPLEMENTATION

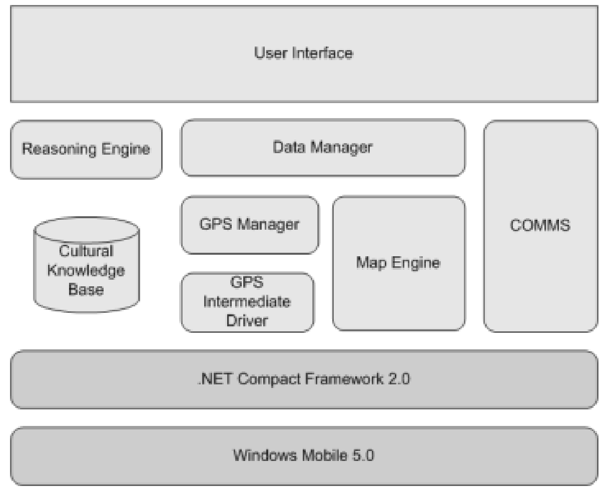

Fig. 1 ACTAR system's components

The ACTAR system is designed for Windows Mobile 5.0 powered handheld devices utilizing the .NET Compact Framework. Its architecture is conceptually composed of several subsystems or modules that provide services to each other. Figure 1 shows the components of the system and the communication links among them. Each subsystem is in charge of a particular task, as described next.

- **The GPS Manager (GPSM)** controls the handheld GPS hardware. It is responsible for retrieving GPS coordinates and providing GPS power management services.
- **The Map Engine (ME)** provides the mapping services for the ACTAR system. It is responsible for rendering GPS maps and keeping track of map landmarks, such as buildings and points of interest. It requests the services of the GPSM to calculate GPS coordinates.
- **The Communications module (COMMS)** manages handheld-to-handheld communication, interactions with a central command center, and control and data exchanges with sensors. The channels are provided by WiFi, BlueTooth, and USB.
- **The Cultural Knowledge Base (CKB)** contains Bayesian models of command and cultural domain knowledge encoded as cases. The models correspond to situations where cultural information is a key to success. Each case contains a set of attributes that describe the situation and a recommendation for that situation. Examples of these attributes are: Information about the *scenario* (building search, personal search, etc.), *who* is involved (males,

females, infants, children, etc.), *where* is the situation occurring or located (buildings, street, residence, etc.), *when* (prayer time, dinner time, day, night, etc.), and the perceived *threat* (suspected bomb making location, suspected terrorist/insurgent, suicide bomber, civil unrest, death of insurgent, etc.). Each attribute has a weight or probability associated with it. The CKB module can be changed according to the culture where the warfighter is carrying out a mission. For example, we can develop a CKB module for different cultures[1] (e.g., Middle East, Eastern Europe, Central Africa, and South America) and load the corresponding CKB in the ACTAR system before leaving for a mission, depending in the culture of the mission's location.

- **The Data Manager (DM)** aggregates sensed data, data from the warfighter, geographical information given by the ME and the GPSM, information about the military unit of the warfighter (including the number of its members, armaments and devices available, etc.), and mission details (target, goal, location, etc.).

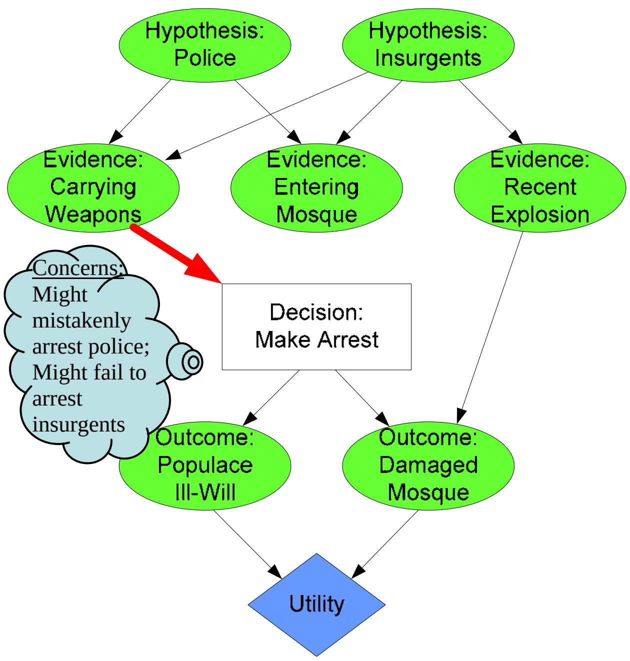

Fig. 2 The decision mechanism in ACTAR

- **The Reasoning Engine (RE)** provides recommendations to improve the decisions of the warfighters according to the cultural context of the situation. It executes case-based reasoning over influence diagrams, as shown in Figure 2, using the models in the CKB with the user's information and the aggregated data provided by the DM. When the RE finds the closest case to the current situation and some of the attributes of the case are missing, it asks the warfighter about the attributes using an intuitive data entry form in the UI. The answers improve the accuracy of the recommendation. The ultimate choice of decision is the one that maximizes the expected benefit of a decision (utility - cost), as given by

$$E[U(x,d_i)] = \left(\sum_x p(x \mid d_i) U(x,d_i) \right) - cost(d_i)$$

- **The User Interface (UI)** enables control and communication between the user and the other components of the system.

Figure 3 shows part of the UI of the ACTAR system. The yellow icon in the map represents the position of the warfighter or user of the system and the red icon represents a target the user has indicated on the map. Figure 4 shows an example of ACTAR's recommendations. In this case, the situation is a personal search of an adult male suspected of being a suicide bomber, while the suspect is in a mosque at prayer time.

Fig. 3 ACTAR system's user interface.

[1] Currently we have implemented only one CKB module for the Arab culture.

6. RESEARCH CHALLENGES

A cultural decision-making advisory system for military domains poses several significant research challenges on the path to attaining this vision. In this section we introduce and briefly describe each one.

Our design involves the integration and accommodation of various disparate representations of social information, reasoning methods, and abstractions for individual contextual factors. For example, if a soldier on patrol at night encounters a mother with a sick child breaking curfew, the advisor will begin integrating the contextual factors of the broken curfew, the sick child, and the known hours of operation of local hospitals with reasoning methods that will result in the assessment that the child needs to go to the nearest hospital. This information will instantly be reasoned with physical information, such as GPS coordinates of the nearest hospital in the area, as well as social information as to how to interact with the likely terrified mother as to assuage her fears and establish comfort or possibly trust in the soldier who is there to help her child. These various reasoning methods must work together to create a holistic understanding of the domain space based on the social, physical, and other contextual information being gathered.

Fig. 4 Example of recommendations provided by ACTAR.

Acquiring domain knowledge for each factor will be challenging. Some information poses little resistance, such as using Web services to extract Web-accessible data, such as GPS coordinate analysis or weather forecasts and traffic reports in certain areas. Other information will be significantly more difficult to gather and maintain. For example, social networks of people are often oral creations that are generated and maintained through common events and acquaintances. This kind of information is often difficult to digitize. For the particular example of social networks, notably, much work has been done in the domain of counterterrorism with respect to identifying and modeling dynamic social networks (Behrman and Kathleen, 2003).

The difficulty of extracting domain knowledge is coupled with the issue of having to represent this data within the appropriate time constraints. Outdated data is more than useless: it is wasteful. As complicated and resource intensive as it is to define a dynamic social network, if this network does not provide useful information, i.e., the right data at the right time, then the expense of calculation is to no avail. Specific situations will have to be represented fast enough and clearly enough for contextual decisions to be made and actions to be taken in a timely manner to ensure the validity of the data being acted upon. Generating this caliber of representation and managing its reliability is a challenge of this work.

Once the social information has been gathered and processed, the decision support system must then present its recommended courses of action to the warfighter, who will then use it to make decisions. This poses a research issue in the area of human-computer interfacing. The system will want to present the information concisely yet clearly, so the warfighter does not simply see a list of possible actions, but a description of the actions, their projected outcomes and explanations of the analysis, as well as comparisons among possible actions. In various scenarios, visual representations of the analysis will also be an effective means of relating information to the user.

7. DEPLOYMENT: IMPACT FOR THE WARFIGHTER

The mobile handheld cultural advisor will provide several new critical benefits to a warfighter. First, it will enable the integration of human-sensed information into consistent and concise aggregate views for commanders, as indicated in Figure 5. Second, it will provide situation-specific advice to a warfighter by leveraging the various sensors that are connected to the handheld, the soldier's own inputs to the handheld, and the Bayesian-encoded models we create of command and domain knowledge.

We envision having various knowledge modules, such as an Arab module, a Latin American module, and a Central African module. Each would incorporate different domain knowledge from experts in that particular culture. The results of our research are contributing to an improved understanding of representation and reasoning in complex social situations and will improve the decisions of warfighters by guiding their choice of the appropriate tactics in the appropriate context.

7.1 The Advisor

One of the major obstacles that we find in the urban battlespace comes from our warfighters' lack of knowledge about the specific cultural imperatives and guerrilla techniques of their host country. It is also hard for fresh soldiers to remember every single piece of advice from their training and apply it when needed. As such, we propose to develop software for handhelds that can be used by a soldier to get useful context-sensitive information on what to do or what response to expect given his actions. A key part of our proposal is that this information must be *situation specific* so as not to overload the soldier with needless information.

Of course, in order to provide situation specific information, our software will need to know the situation in which the soldier finds himself. Another key idea in our design is to maximize the use of passive sensing and a priori data entry, such that the soldier will need to input as little information as possible when he needs advice. For example, before going out on patrol, the soldier could tell our software the planned path, the number of warfighters in the patrol, their abilities, weapons, equipment, etc. For the passive sensors, we plan to use the handheld's clock to determine the time and its microphone to determine if the soldier is currently under fire. Its GPS sensor will tell our system the soldier's exact location. In future releases, we envision the addition of other simple sensors. For example, the soldier could carry a tiny digital camera that would automatically take pictures of what he sees and wirelessly deliver these to his handheld. The soldier could be outfitted with throwable disposable cameras that he could place in strategic locations so as to know what is happening there even after he leaves or he could throw them over walls, slide them under doors, throw them across open windows, etc. to see parts of the battlespace that would otherwise remain hidden to him. Similarly, there could be disposable motion sensors that the soldier places in strategic locations to alert him of nearby movement, thus acting as an electronic tripwire. Once GPS systems become more miniaturized we'll have disposable tracking devices that the soldier can place on suspect vehicles or persons in order to track their movement across the urban battlespace. These are just some of the possible passive sensors that already exist, even if their current size and pricing might be too large. We expect that even more creative sensors will be developed in the near future using research from micro-fabricated MEMS and nanotechnology.

All these sensors, however, are useless without a way for aggregating automatically the data they provide and making it available to the soldier using an intuitive interface. Our handheld adviser serves this role by becoming the local hub for all the data provided by the various sensors. It is easy to physically deliver the raw data to the handheld using encrypted Bluetooth or WiFi channels. However, aggregating data from various sensors into a coherent picture of the current state of the world and then offering advice to the soldier based on this state is a more challenging task. This is the task we propose to accomplish.

Our handheld software will examine the soldier's current state along with any specific query the soldier might pose, and deliver situation-specific advice based on deep *domain and command knowledge*. At its simplest, our software will tell the soldier, given his current situation, which actions will result in surprising consequences, under the assumption that the soldier is not familiar with the social mores of his host country. This advice could either pop up as alerts, if especially important, or remain hidden until requested by the solder. That is, the soldier can query our system on the expected results of a particular action. If the system’s uncertainty is high, it might give preliminary advice and ask the soldier for more information in order to increase the certainty. For example, given the current state, the system might conclude that it is somewhat likely that the seemingly non-threatening people the soldier observes are really armed opponents. The system could then give the soldier a question, in the local language, that he can ask the unidentified individuals. Their response to the question will determine, with high certainty, whether they are friend or foe. More generally, our system would provide advice on how to handle a wide variety of common situations, including confrontations with mixed crowds composed of women, children, and possible insurgents.

When the cultural and command knowledge is encoded into Bayesian networks that capture the set of possible states a soldier might be in, then the networks will give us probability estimates on hidden aspects of the state, that is, they will induce unobservable aspects of the world. We will also encode the expected outcomes of possible actions in every possible state. Once we have all this information encoded it is a simple matter to calculate the expected outcomes of every action available to the soldier given the evidence and tell him which actions are particularly good or bad. In other words, we are building a sophisticated Bayesian *model* of the complex interrelations among the various actors in an urban battlespace, taking into account their social, economic, political, and military attributes. This model can then be used to determine the expected outcome of a soldier's action.

Calculating the best action, or even just eliminating bad actions, also require us to use and expand techniques from applied *game theory*. Our model is both probabilistic and large. The soldier's state is rarely completely known and the immediate result of actions, both the soldier's and the opponents', can also be probabilistic. As such, our system will need to calculate equilibria for large non-deterministic extended-form games. These problems are generally intractable for everything but the smallest instances. We overcome this difficulty by developing algorithms that use our extensive domain knowledge to prune unlikely situations and actions. We also recognize that while there might be a large number of actors, each one has social relations with only a few others. Thus, we do not need to worry about how one agent's actions might affect everyone. This greatly reduces the dimensionality of the problem—it creates sparse payoff matrices and thinner extended-form trees that are easier to solve.

7.2 Collaborative Information Gathering and Analysis

Most handhelds on the market today come with WiFi and Bluetooth built-in. The moment that handhelds can communicate with neighboring handhelds we open a very large space of possible collaborative applications. Specifically, while it is impossible for the lone soldier to get a complete view of the state of the urban battlespace by himself, we believe that an army of warfighters with handhelds can collaboratively achieve omniscience over the urban battlespace. Each soldier can contribute what he or his sensors perceive. Furthermore, the system can request that the warfighters make observations that benefit the group as a whole, even if they might inconvenience an individual soldier. That is, the warfighters are not just passive sensors, they become *active information-gathering agents at the service of a command*. For example, the system might note that a unit might be in danger from possible sniper attack, determine their possible locations, determine which other warfighters in the area have visibility over those locations, and finally ask these warfighters to turn around and look at those locations to check for suspicious movement.

The global picture of the battlespace that is thus generated can also be relayed to central command where experts can make highly informed decisions about how to proceed. Their orders or suggestions are propagated back to the warfighters in the form of added certainty about some element, “that figure is definitely an insurgent,” or new knowledge about what action to take in certain situations, e.g., “zone X has been compromised, avoid it at all costs.”

The software developed for this aspect of the system includes a map-based interface, which will be especially useful as it can naturally limit a soldier’s view to only those things that are nearby. It enables a warfighter to enter information on a map using gestures. He can drag and drop icons that represent possible enemies, possible booby traps, possible allies, and any other point of interest or draw circles around areas he considers dangerous, areas where there are civilians, areas of strategic importance, etc. Each data point will be annotated with the time it was observed, the owner of that observation, and any other details pertinent to it.

The observations are then automatically distributed among the warfighters by the system, thus allowing a soldier to see everything everyone else is seeing. Furthermore, our system will reconcile conflicting evidence by using probability formulas and display these probabilistic states in an intuitive, graphical manner. For example, if there are conflicting reports on the possibility of a sniper at the top of a building then the icon will reflect this uncertainty, perhaps by using different shades of red. Our system will apply its acquired knowledge as represented by the icons to create personalized views. For example, if a soldier is walking, then the areas that are within gunshot of a reported sniper position will be highlighted as dangerous. Finally, the system will apply its knowledge about the icons to make useful representations at various zoom levels. For example, what appears as individual insurgents at a high zoom turns into a red zone as we zoom out, where the red zone indicates areas of unrest.

In effect, we view an army of warfighters with handhelds as a distributed sensor network where each soldier is an intelligent autonomous sensor. The fact that the warfighters are intelligent means that they can interpret raw sensor data, for example, they can tell the system if a loud noise was a gunshot or a car backfiring. The fact that the warfighters are autonomous means that our system will need to take into account the fact that it can only ask them to take certain actions, but ultimately the individual warfighter must decide what to do. Also, human limitations mean that there will be inconsistencies in the sensed information. One soldier might identify an enemy in the second floor of a building, while another soldier might claim that there is nobody there.

In the future, we envision warfighters using heads-up displays that provide them with an augmented reality view of the urban battlespace and a voice recognition interface to communicate with our system. Note, however, that while these input/output technologies are still not ready for use, the software we propose to develop should not need to change much as we transition from handhelds to heads-up displays. The problem of data aggregation is complex and it is one that we can and should start working on now, even if the current technologies for its use are sometimes cumbersome.

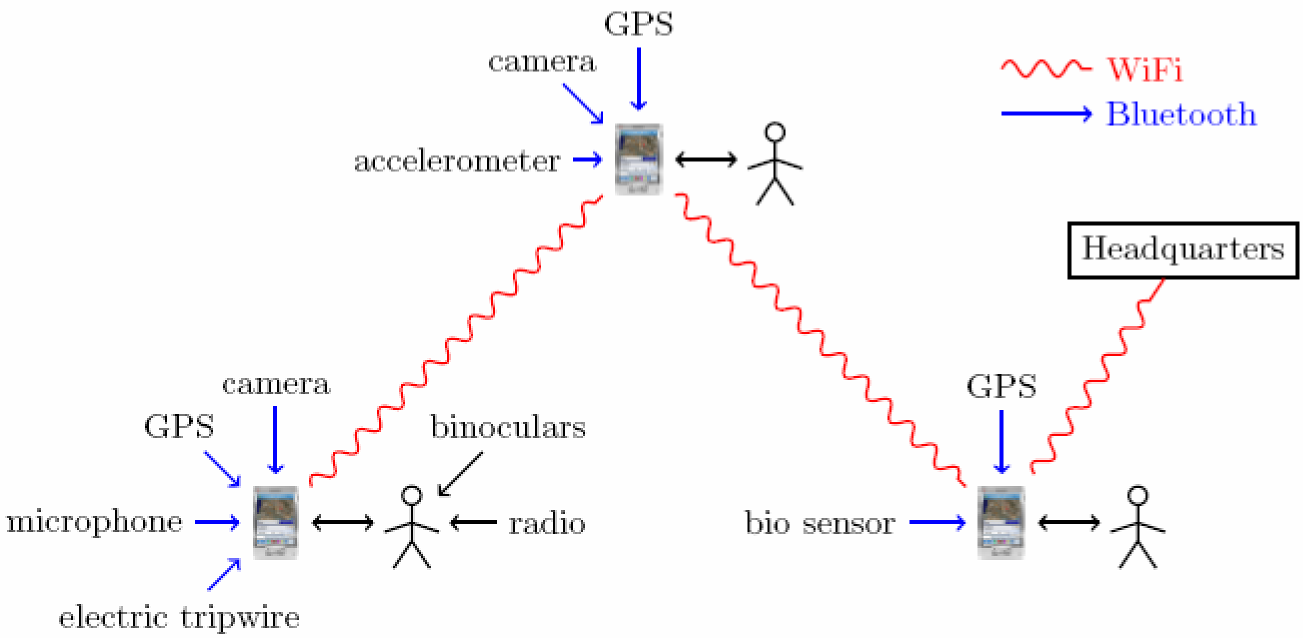

Fig. 5. Schematic view of handheld advisors' (ACTAR's) deployment

8. CONCLUSION

In summary, our handheld adviser can provide situation-specific advice to the warfighter by leveraging the various sensors that are connected to the handheld, the warfighter's own inputs to the handheld, and the Bayesian network models we create of command and domain knowledge. We envision having various knowledge "modules," such as an Arab module, a Latin American module, an urban battlespace module, and a suburban battlespace module. Each one would incorporate different domain knowledge from experts in that particular culture or battlespace. Warfighters would then be able to choose to install only the modules they need. The results of our development are contributing to an improved understanding of representation and reasoning in complex social situations and will have the practical benefits of improving the decisions of both commanders and warfighters that will guide their choice of the *appropriate tactics* in the *appropriate context*.

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