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ISR in the Urban Environment

Pretend you're one of our Soldiers on patrol in Baghdad. At night. In a storm. There are people out there who want to kill you. What do you want to know?

At the very least, you want to know "Where am I?" But surely not as a latitude and longitude. How about a street name? Or address?

Even more, though, you want to know "What's around the corner?" Again, surely not as latitudes and longitudes. Is there a park or a cluster of buildings? Is there a crowded market or a deserted avenue? Is there a mosque or an empty warehouse?

We are looking for ideas to translate numbers, like latitudes and longitudes, into symbols, names, and addresses. Of course, we already have a good technology to do this: maps. But maps don't do it very well; they are flat, outdated, and incomplete.

Shakespeare said "All the world is a stage, and all the men and women merely players." Let's use this metaphor to answer the question, "What's around the corner?"

The Stage

First, the stage. You'd like to know where the buildings are, because they limit your line of sight and provide locations where snipers can wait to kill you. You'd like to know where the roads and alleys are because they provide ways for you to maneuver. You'd like to know where barricades and hedges are because they can get you trapped.

Let me capture all of these things in the term "shape and materials." Buildings have shapes—complex, 3D shapes, not just flat outlines on a map. Windows allow bad guys to see you; walls don't. Wooden doors can be kicked in; steel doors can't. Bullets penetrate plywood walls, but

not cinder block. The shape and composition of buildings clearly affect the options available, both to you and to the bad guys.

You don't want just a map. You want a full 3D model – shape – and what things are made of – materials.

The Actors

Second, the actors. In vehicles and out. Where they are and where they came from. Did the beat-up car come from a residence or a chop shop? Did a pedestrian come from a home or from a car that sped away? Did the fire engine come from a firehouse or a warehouse?

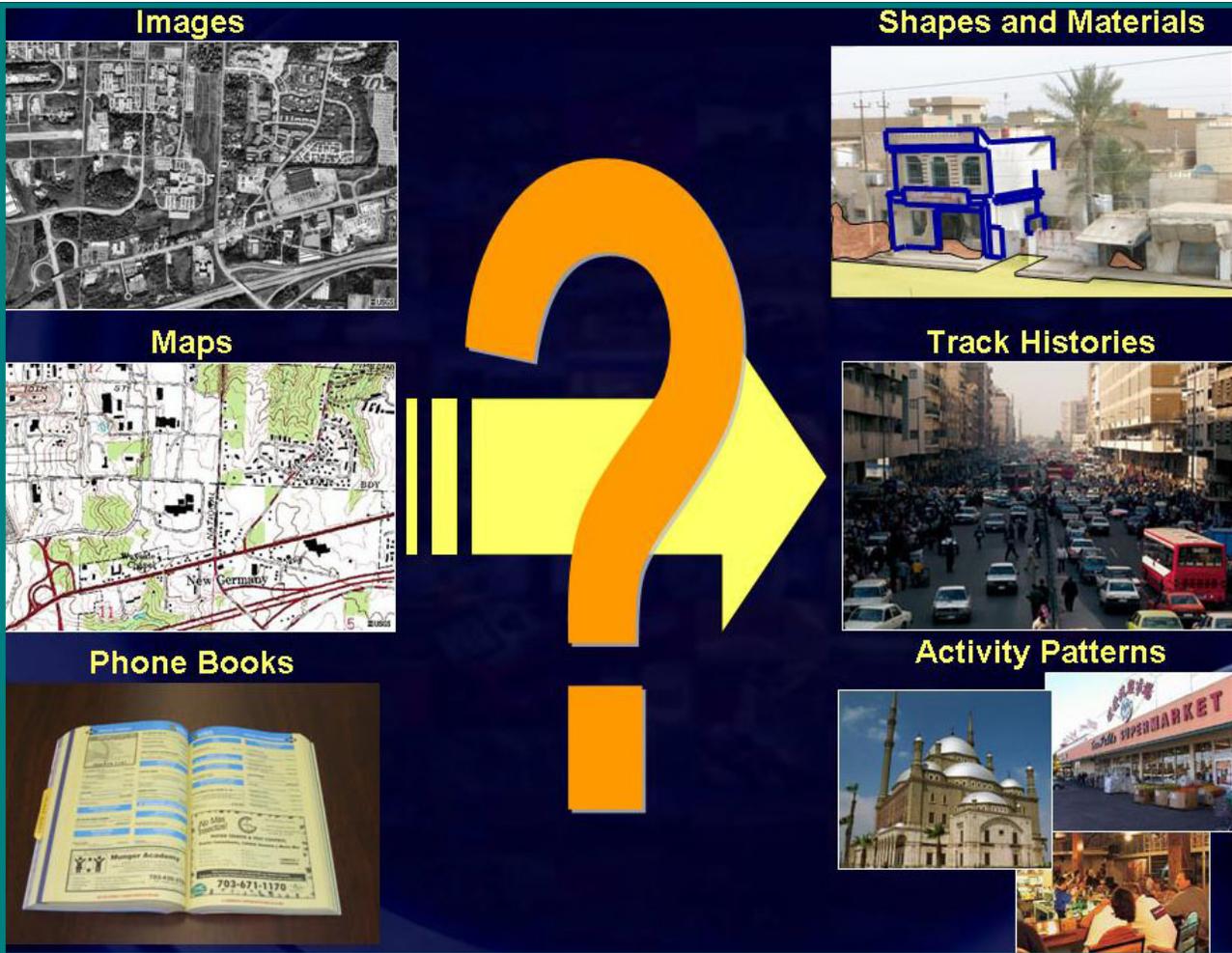
Let's call these things "track history." In the urban world, it's good to know where a truck came from. It's good to know with whom it interacted along the way. Because this historical information can help distinguish the guy who's just picking up the trash, from the guy who's about to die—along with you, and many others.

You don't want just a map. You want as much historical information as possible about the vehicles and people that have moved around in the structures shown on a map.

The Script

Finally, the script. No one's suggesting people in cities go around reciting Shakespeare, but they do have habits. They go to mosques at prayer time. They go to market when the market's open. A meeting at a mosque or market outside normal hours may be perfectly benign, but it's not part of most normal scripts and, therefore, might influence your course of action.

Let's call these "activity patterns." They may be expressed as densities: more people will be in the



market during morning and afternoon on weekdays, than at night, at noontime, or on holy days. They may be expressed as travel patterns: garbage trucks have more-or-less normal routes. They may be expressed as social or business activities: neighborhood soccer games happen in the evening. All these normal behaviors, when filtered out, leave indications of abnormal behavior. Warned of abnormal behavior, you can choose to watch, to intervene, or to leave—but you have the initiative.

You don't want just a map. You want timely indications of abnormal behavior occurring in the area covered by a map so you can intervene early and effectively.

Surface and materials. Track histories. Activity patterns. These are three crucial components of situation awareness in cities that go way beyond old-fashioned maps. We know that the traditional

product, maps, are extremely difficult to keep up to date. How can we do better? For one thing, we have amazing sources of information, some old, some new.

First, imagery. We can collect lots of images, from lots of vantage points, in lots of different parts of the electromagnetic spectrum. Images are useful, particularly to help determine shape and materials, and we don't want to lose them.

However, images are not our only source of information. While a lot of great work has been done to identify what's in an image (e.g., to find roads in an aerial photograph), this is a hard problem. It's actually harder than the problem we really face.

That's because, second, we have those maps – however old. Maps are very good symbolic representations of the world, especially things in its

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cities. They're usually out of date, inaccurate, or ambiguous, but they provide considerable context: outlines of buildings, roads, and more important things that are never observable in imagery such as political boundaries, names, and addresses.

We don't have to process images in a vacuum. Rather, we can use existing symbolic information (maps) to provide context for image exploitation. Perhaps we can use the results to update the maps. But maps do not only supply names; they provide something even richer: relationships. Maps indicate many kinds of spatial relationships—adjacency of buildings, connectivity of roads, traversibility of waterways—all of which are important to urban operations.

There's an even richer source of relational information that I urge you to consider: an ordinary telephone book.

Our Soldier in Baghdad knows where she is; GPS solves that problem, at least in terms of lat/long. Maps, perhaps updated with images, give her an address and that of the street around the corner. The telephone book tells her what's on that street around the corner: a gas station, a mosque, a firehouse, a factory, whatever.

Images tell us what things look like. Symbols tell us their names. Relationships suggest what they do. We have ingredients for situation awareness at all three levels of abstraction. The real question is how do we convert images, maps, and telephone books into shapes and materials, track histories, and activity patterns?

Thinking Outside the Box

These are the boundaries of the urban surveillance problem. IXO needs you to suggest ways to fill the space inside these boundaries with DARPA-class technology. Here are three suggestions:

First, change analysis. Not change detection, change analysis.

It was suggested that our image-processing problem is not posed as "here's an image, tell me what's in it?" Rather, it's "here's an image and a map, where

does the map need to be updated?" Adding the map—or rather, the complete model of 3D shape and materials—to the problem makes a big difference. Some of you are doing great things in image change detection: taking images at different times that look at the same thing and finding differences. Our problem is that many of the differences you find are inconsequential. An hour passes, the earth rotates, shadows move. So what? The wind blows, dust settles, colors change. So what? Our challenge is not to detect change; it's to figure out which of the thousands of apparent changes indicate significant, operational changes—things our Soldier in Baghdad cares about.

The hope is that, by assembling a unified representation of an urban situation (those shapes, tracks, and activities), we can aspire to predict some changes. Like shadow movement. Predictable changes are unlikely to be operationally significant. Perhaps we can filter out predictable changes and focus our attention on anomalies, things that are at odds with our current understanding of the situation.

Second, symbolic correlation. Not report-to-track correlation, symbolic correlation.

Suppose you have a map and phone directory for Baghdad. How do you combine them? There are some elements in common: street names, perhaps even addresses. There are some things unique to each: lat/long data from the maps, telephone numbers from the directory. Combine the two, and we could associate lat/longs with phone numbers, and vice versa.

The problem becomes more interesting when we include nontraditional maps. These often sacrifice geospatial fidelity for interpretability: roads still have the same connectivity, but are stretched to make room for other information. Like names, functions, addresses, even site-specific addressing schemes like building numbers.

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Third, collection cueing. Not sensor scheduling, collection cueing.

You have been misled up to this point by only reading only examples of structured data—images, maps, and phone books. Our best sensors in Baghdad are our Soldiers. They can ask questions. They can carry on conversations. They can be extremely effective if they have context for those conversations.

We can figure out where to put a Predator to collect video on a suspicious alleyway. We can ask people to pick up maps or phone books when they find them. But the only way we can find out “what’s the name of that building?” or “when is the garbage usually collected?” or “is anything still going on in that body shop?” is to ask someone. And only our Soldiers, on the ground, can ask questions.

Visualizing

We’ve come full circle. We started by claiming that the answer to “what’s around the corner?” is

the most important product of urban surveillance. We’ve ended by claiming that a critical element of that answer comes from that same Soldier or her comrades through a process that allows her to ask pointed, precise questions of people on the street.

Between these two questions lies a mass of information needed to connect them. Information that’s been stitched from images, maps, and telephone books into a consistent, up-to-date description of the situation expressed as shapes and materials, track histories, and activity patterns.

Why is this so important? Visualization. We have incredible technology to provide exquisite insight into fictional environments, even fictional urban environments. Let’s figure out how to give our Soldiers the same kind of insight into real urban environments.