Patterns of Life in the Foreground and Background: Practical Approaches to Enhancing Simulation-Based Interaction Skills Training

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ABSTRACT: *Interaction skills training, using simulated environments, demands proper behaviors not only from the learner but also from the agents (here, central and background characters) the learner observes or contacts. In several projects we are developing scalable, flexible, and ultimately easily-authored methods to portray natural activity, influenced by sociocultural context, within situations designed for interaction skills training. To meet differing use cases, we are interested in some cases in a high-level perspective of agent activity (e.g., realistic crowd movements) and in other cases in a ground-level view of individual agents with social networks who demonstrate patterns of life. To do so, we use different tools to achieve agent realism, from fuzzy state models to simple behavior algorithms to more complex cognitive reasoning. This paper describes cultural modeling knowledge structures and methods appropriate to a selection of use cases. Recommendations are provided for incorporating realistic sociocultural material into skills training.*

1. Introduction

An ability to manage face-to-face social interactions is critical to achieving successful outcomes such as increased flow of actionable information, de-escalation of conflict, correction of errors and misperceptions, increased mutual perceptions of trust and respect, and enhanced cooperation. Understanding—or misunderstanding—of social and cultural influences on these interactions thus has consequences. Training on social interaction skills can be important in fields as different as clinical practice in medicine, community policing in law enforcement, and civil affairs in the military.

Traditional interaction skills training commonly relies on relatively passive videos of common situations, or on paper-based or live-action role plays where hired actors or other learners play the roles of supposed social partners in varying situations. Offshoots of these approaches include tactical decision games (Schmitt, 1994), cultural assimilation (Fiedler et al., 1970), interactive video (Roy et al., 2006), and authentic social interactions (Szulborski, 2005). These learning experiences have some drawbacks (Hubal & Frank, 2001), including limited variability in situations encountered and expense. Further, successful training requires sufficient fidelity of environments and realistic-enough behavior from the learners' perspective to assure transfer of training. One approach to managing these limitations is to use simulated environments to train. Though not a solution that satisfies all criteria, "virtual role plays" have some advantages including potential variability of situations portrayed and lower distribution costs (Hubal, 2008).

Of particular interest here is the fidelity of the behavior of synthetic characters acting in virtual role plays. Even more specifically, the focus is not only on the central characters with whom the learner interacts, but also on background characters who populate the virtual worlds in which interaction occurs. An important consideration of learning about conducting successful interactions involves presentation of an environment that is reflective of that which the learner will encounter. The point is to strive for realism in characters' behaviors because an important component of learning is to identify important cues or signals and distinguish them from background "noise". Interaction skills training, then, should take place in appropriately diverse worlds, rendering a clutter of different ages, genders, personalities, ethnicities, cultures, and accepted practices (Endrass et al., 2010; Johnson, 2010; Kim et al., 2009; Taylor & Sims, 2009). The challenge is how to adequately model characters at different scales so as to train learners to recognize not only culturally appropriate population behaviors but also identify what is normal and what is anomalous.

In a series of projects, the authors and colleagues have integrated and are integrating detailed models of cultural daily activities and patterns of life into simulations of synthetic characters inhabiting virtual environments. The design of realistic cultural models introduces hard problems. We have identified and developed (overlapping) prototypical solutions for three such problems:

Background at Scale. There is a need for simulation of many (thousands) of characters with intelligent profiles, that is, each character having a kind of life story that drives its behavior.

Variation. There is a need for variability in characters' behaviors based on facets underlying their intelligence such as culture, and a demand to avoid predetermined, scripted actions.

Anomaly and Normalcy. Central characters should have additional intelligence (e.g., to effect specific actions, as needed for training on anomalous activities), yet these characters must be able to blend into the general population, requiring not only models of their own behaviors but recognition of others' behaviors.

In essence, our approach is the interleaved representation of three classes of synthetic character patterns. First is a fuzzy state machine (FuSM) for low level "clutter" presentation of up to thousands of individuals. Second is algorithmic control over basic movements of background characters using sociocultural parameters to make the characters more realistic for training in specific use cases. Third is the use of sophisticated cognitive agents for emulating high-value individuals, that is, central characters that intermingle seamlessly with clutter (FM 3-60, 2010).

As will be discussed in examples, this work includes interaction at different scales. In some projects the focus is on gross movement, essentially culturally realistic group behavior observable from a thousand-foot perspective. In others the focus is on continuous assessment of a scene for expected and anomalous items and events as a learner moves through the world. In others still the learning includes ground-level interaction with individual characters.

2. Current Approaches and Limitations

Many researchers and developers have investigated techniques to incorporate cultural conditions into interactive characters (Allbeck & Badler, 2004; Huang et al., 2009; Kim et al., 2009; Nazir, Aylett, & Cawsey, 2008). Yet the need to achieve variation without hard-coding hundreds of examples demands a means to take high-level inputs and create a variety of scenarios that fit the patterns. When possible, population models or urban crowd movement models may be used. Such models are increasingly realistic, but involve limitations for both central and clutter characters that are relevant to the three problem areas just described.

Relating to the problem of scale, researchers have studied and impressively portrayed how crowds move (Braun et al., 2003; Kim et al., 2012; Pelechano et al., 2005), but where the individuals have come from and where they are going to does not typically matter; they lack underlying goals. Hence the crowds are not moving purposefully based on facets such as culture, neither during normal routine nor in response to chaotic events (Shendarkar et al., 2008; Zheng, Zhong, & Liu, 2009).

For the problem of variation, while researchers have investigated culture-specific characteristics such as pedestrian movement (Fridman & Kaminka, 2010), political identity (Lustick, 2000), and adversarial intent (Loscos, Marchal, & Meyer, 2003; Silverman et al., 2004), they have not fully considered a myriad of alternative factors that can influence behavior. For instance, in religious Islamic cultures, crowd movement potentially changes five times per day when men are instructed to pray. Meanwhile, commercial activity, weather, special events, even tendencies of denizens toward walking in streets versus on sidewalks can influence movement by affecting what paths are available to individuals, where individuals are tending to go, and how many individuals are out and about. Similarly, just as pedestrian activity is culture-dependent, so is vehicular activity. Aside from obvious cross-cultural differences such as traffic density (e.g., cars per person) or rights of way (e.g., drive on the left vs. right) there are culture-specific influences such as types of vehicles on the road (to include size of cars and trucks, and presence of motorbikes, bicycles, rickshaws, and other non-motorized vehicles), general hurriedness, respect for the law, and time-of-day or day-of-week factors (rush hour characteristics, Sabbath day restrictions) (Hood & Diaz, 2003; Zaidel, 1992). Current models of pedestrian movement and vehicular traffic do not take generally these cultural influences into account.

Last, regarding anomaly and normalcy, modelers have explored how characters are affected by elements of the situation (Hoey & Schröder, 2015; Prendinger & Ishizuka, 2001), and these approaches can be used to support variation in social behaviors generated by the FusM and cognitive models. But they have not always accounted for how key individuals within crowds can affect others' behavior and change their own behavior based on crowd characteristics. For instance, population models have not yet taken full advantage of findings derived from network activity such as the modeling of the emergence and spread of infectious disease through a community. Cultural models that take into account network phenomena have the ability to influence how crowds behave in response to central characters, and how central characters' behaviors can be influenced by other simulation agents. Similarly, few simulated populations are synthesized using census or geographic data to model households and individuals and account for schools, workplaces, restaurants, and other daily locations (Wheaton et al., 2009), but these data promise increased cultural realism.

3. Culturally Aware, POL-Savvy Synthetic Characters

An emerging discipline in intelligence analysis is the recognition that pattern of life (POL) anomalies are an excellent mechanism to identify potential threats (Schatz et al., 2012). Those who live in an area learn to recognize POL anomalies and react accordingly. For example, a quiet marketplace at a day and time when it is expected to be busy is an indicator to the local populace of potential danger, or at least the need for caution (a "time to watch out"; Batty, 2007). However, recognition of, and vigilance to, patterns of life and revealing deviations are important not only to threat detection but also to effective interactions, because every interaction is situated in a context that provides meaning and information (i.e., social affordances; Zebrowitz, Bronstad, & Montepare, 2011).

Perhaps the most complex behavior comes from those individuals who blend in with normal patterns for most of their activities, but who as central characters to the scene step out as required to execute some action, gesture, or dialog that is important to training. It is not only population-level pattern deviations from the norm (e.g., the empty marketplace on market day) that is of interest, but also individual-level behavior. The complexity of getting synthetic agents to behave both unobtrusively and anomalously depending on any current context suggests that pattern-deviating simulated agents must be "aware" of their surroundings—blending in with the realistic crowd, in the case of a pedestrian, or with other traffic, in the case of a vehicle.

Across several projects, our team has developed reasoning structures to improve models of the general population (and of vehicular clutter). For example, in an effort (Hubal, 2014) intended to model cultural daily activity and patterns of life in a constructive simulation, the output is a population of up to some ten thousand citizens, each built around a relatively simple FuSM. The existing models for this 'clutter' generate the logic to support dynamic visualization. We have extended the models by identifying parameters that control clutter agents' behavior that reflect differences between cultures. The approach scales down; even for applications where there is a need for only tens of background characters rather than thousands, hence the need for higher detail, we have developed a systematic specification of characters' social lives.

POL behavior specifications combine to drive an individual agent (e.g., a background pedestrian or vehicle) through a realistic yet adaptable routine. Behavior specification for an agent consists of a linear schedule of goals. For each time block, the schedule specifies activity type, location, and additional parameters to support getting to the location and engaging in the activity. We use a FuSM to efficiently plan route details and generate appropriate messages for the visualization engine to render the background agent's behaviors. The "fuzziness" in the fuzzy state machine refers to the manner in which agents' actions are not completely specified. For example, one schedule might tell a synthetic character to wake up at home around a certain time, travel to work at a certain place, move to a religious site and carry out prayers, and finally return home within a time range. These behaviors are mainly planned before each scenario begins, however, the system does contain repair mechanisms that let synthetic characters react to unplanned or unexpected inputs. For instance, when one character wants to meet with another, or they chance upon each other during routine activities, they may both rearrange their schedules to accommodate the meeting. Currently we are using a probability-based decision whether or not to change the schedule, and if it is changed the schedule is just shifted for some culturally-appropriate time to indicate the event taking place. The next step will be to make schedule change decisions culturally relevant to the scenario as a whole. Either way, these repairs driven by FuSMs represent an efficient approach that lets behaviors incorporate context-appropriate reactions but remain tractable in very large populations.

A second approach is the modeling of some dozen high-value individuals using a rule-based cognitive architecture (Soar; Laird, 2012) and fitting them within the crowd. It is these 'central' characters who are designed to understand patterns of life at the population level and reason about behaviors to fit in appropriately—or disguise their deviations from such patterns. Two such examples of training simulations that model cultural behavior are the Cultural Cognitive Architecture (Taylor et al., 2007) and high fidelity characters for small-unit training in game environments (Stensrud et al., 2012).

For both types of agents—clutter and central—the precise scheduling of their actions is determined dynamically at runtime. In this design, central characters reason about the world, such as determining when and where to engage in interactive behaviors with the learner and how to best commingle with clutter agents. Meanwhile, there are two types of formats for background characters. The high-level representations for the thousands of crowd-forming clutter agents specify probability distribution functions for various types of demographics, as well as partially instantiated schedules for clusters of clutter agents. In contrast, when there are tens of background characters who must be more socially adept (e.g., to be portrayed in a first-person environment rather than viewed from a thousand-foot perspective) there are more detailed parameter values associated with them.

4. Parameters for Cultural Awareness

Culturally aware agents are those that exhibit behaviors that reflect locally meaningful customs or that change based on local preferences or demands. Making them so requires identifying culturally relevant daily activities such as shopping, driving, dining, use of sidewalks, use of cellphones, setting up meetings, and religious observance; defining influences of weather, air quality, time of day, religious holidays, or a city's age or makeup on population-level activities; and modeling street-level interactions such as greetings and vehicular configurations that influence larger crowd behaviors (Hubal, 2014). For implementation, we have added a set of parameters to the schedule representation, allowing values within the schedules to be replaced by parameters. This method improves the ability to write reusable schedules that can be instantiated to different parameter settings.

We have begun to tap several sources to improve synthetic characters behavior models. One resource is a series of country-specific videoclips that show normal urban behavior—culturally-related crowd phenomena such as the passing side, family formations, and proxemics (Fridman & Kaminka, 2010). Other sources are publicly available movies and YouTube videos, as well as scientific literature that addresses cultural or societal differences in movement (e.g., Hershey & McKeown, 2012; Kaup et al., 2008; Mateo-Babiano & Ieda, 2007).

Table 1 shows a list of representative parameters that are applicable to the FuSM, behavior algorithms, and cognitive models, as they can influence characters' behavior whether viewed from a high-level or ground-level perspective. To control agent behaviors, we employ rules that reference parameter values and guide the flow of activity. Individual-level behaviors are influenced, as well as how individuals' behaviors affect group behaviors. Thus in one city a greeting between two persons may normally occur on the sidewalk and cause other people to move around the participants (unless and until they move to the side) but not step off the sidewalk, whereas in another city a greeting can occur anywhere in the street and not affect pedestrian flow in the same way. To handle this cultural variation we implemented a "conversation location" parameter. Similarly, in one city a preponderance of commercial activity might take place in open-air markets where a sudden rainstorm could cause a general clearing of shoppers, whereas in another city most shoppers may enter covered stores. This variation suggests a "marketplace exposure" parameter. We have found that a dozen or so such parameters, while not accounting for all possible cultural characteristics, still considerably change characters' activity patterns.

Table 1. POL/Cultural Parameters

Parameter	Values
Air quality	Poor, acceptable
Conversation location	Anywhere, move-to-side
Day/night activity	Difference-in-amount-and-kind, steady
Family life	Cross-generational-and-extended, home-centered, non-centralized
Marketplace exposure	Outdoor, indoor
Passing	On-left, on-right
Pedestrian, vehicular speed	Fast-moving, moderate, slow-moving
Personality/engagement	Busybody, normal, reserved
Religious observance	Traditional, modern, secular
Street crossing	At-designated-crosswalks, between-sidewalks, walk-in-street
Vehicular traffic	Congested, moderate, light
Vehicular type	Animal-pulled, man-pulled, small-motorized, large-motorized

4.1 POL and Cultural Awareness within Clutter Agent Models

Additional, statistically-relevant 'personal' parameters are associated with background agents and refer to aspects of the agents such as "home", "workplace", "father", "driver", or "coworker". Production rules define how these different agents behave in different contexts, taking into account how parameters interact (e.g., how does "traditional religious" mix with "busybody" to form a unique daily schedule that is reflective of an individual). Further, agents' schedules are allowed to contain branches with probabilistic selection, and individual actions can have a specified probability of occurring. Basic behaviors include walking from place to place or via a route as a single agent or as part of a group; driving as a single agent or as part of a spontaneously setup carpool; conversations as part of scheduled actions or to set up other scheduled actions (like group movement or carpooling); conducting meetings with other agents; and picking up and dropping off objects. It is also possible to include parameters that define interactions between clutter agents and the environment, such as information flow between agents to indicate activity or events (e.g., transmitting knowledge of other agents' locations) and reactions to natural (e.g., rain) and manmade (explosions) environmental events.

We have used two techniques can help make clutter characters' behavior realistic. One method is to create a detailed database of characters and their parameters. For each character, we specify a name, a family, a house at a particular location, an occupation, age, gender, ethnicity, personality type, health, wealth, social network, religion, relatives, friends, and attitudes towards others. To lessen the authoring burden, we developed an initial generation algorithm for background characters, taking into consideration gender, age levels, prevalent cultural groups, occupations, and social networks. For example, it is possible to enable the training system to determine the level of religious observance of individual agents at the family level, assigning families at random to nearby religious buildings of the appropriate religious sect, then causing the individuals to attend religious events in accordance.

Another method has been to implement activity algorithms. These are essentially small subroutines relevant to certain characters that guide what (walk, play, work, pray), where (anywhere, residence, workplace, religious building), and with whom activities occur. The ‘when’ is determined in concert with the flexible scheduling and POL constraints defined by other parameters, while the ‘how’ is reliant on whatever animations and visualization methods the simulation environment provides.

We have implemented simple and more complex algorithms. As an example of simpler activity, during a study to evaluate social decision-making (Paschall et al., 2005), we developed two versions of a school hallway scenario, one in which routine background activity took place behind the central synthetic character (**Figure 1**). Similarly, for studies of vigilance and stress control, we devised a number of potential background distractors involving real-world sights and sounds (Hourani et al., 2011; Hubal et al., 2010). As an example of more complex activity, for a project integrating POL into an Army simulated in-country operational environment, we enabled detailed behaviors such as guiding visits to the marketplace, religious sites, teahouses, and the like, initiating actions such as taking breaks and heading home from work, and directing friends to meet up (youtu.be/CitevFwa3TE; **Figure 2**).

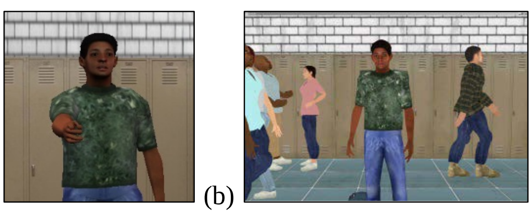
(a) (b)


Figure 1. Virtual environment (a) without and (b) with background activity

(a) (b) (c)


Figure 2. Daily activities: (a) smoke break at marketplace, (b) chance encounter, (c) visit to teahouse

4.2 POL and Cultural Awareness within Central Agent Models

Culturally-aware foreground agents are those that also exhibit behaviors that reflect locally meaningful customs, but not as a general population member—instead, as an individual who blends with the general population but at times purposefully violate cultural norms to accomplish predefined goals within the simulation.

Central character agents follow schedules similar to clutter agents until specific times when, for reasons of training anomaly and normalcy, goal-based reasoning takes over; then control is handed back (e.g., to the FuSM) when goals are achieved. We have demonstrated high-fidelity central character prototypes that can perform urban POL use cases autonomously based on partially specified behavior definitions, ultimately allowing the generation of a large number of different central character behaviors in a single scenario. As one example, we developed a robust, reusable set of goal-based human behavior models for virtual, small-unit training exercises (Stensrud et al., 2012). In this work, an infantry squad arrives in town, fire teams separate as planned and walk in formation, and soldiers run for cover when a team member is hit by a sniper. In this environment we also modeled local civilian agents who mimic activity within the town, walking around the main road, conversing with other agents, and walking in and out of local markets, and respond to unusual activity such as gunfire or the presence of outside forces.

Central character behaviors need to be adaptive and varied, and this is the advantage of modeling them using a cognitive architecture. For example, central characters might walk faster than clutter agents or take purposefully evasive routes. Thus, an agent may have the goal of implanting an improvised explosive device in a public space. The agent may plan to take a circuitous route to reach the location at a specific time, but may change its route in the presence of fighting forces or abandon the plans altogether if its reasoning suggests the goal will not be achieved.

We augment central character behaviors by incorporating cultural parameters to affect production rules. Hence in the explosive device example, while clutter and central character agents essentially work from the same low-level pool of physical behaviors (they have the same visual representation of movement via animations), a central character might need to walk or drive taking that circuitous path. In essence, central character activities should fall within the distribution of clutter behaviors, except when (e.g., for training purposes) they should be forced into distinguishable behavior patterns. The goal is to create a system where culturally appropriate central character behaviors are not obviously different, while still allowing a training system to set up cases where they can be distinguished from each other for educational reasons.

5. Findings

There is reason to suspect that realistic background activity influences central interactions. In the school hallway scenarios, presence or absence of other characters and movement in the background appeared to have a slight but meaningful effect on participants' performance. When there was background activity there were marginally more ambivalent statements (8% of statements vs. 3%), fewer pieces of information sought (10% vs. 16%), more provocative statements (6% vs. 3%), and instances of acquiescence to accommodate risky decisions (4% vs. 2%). These preliminary data did not reach significance, but are suggestive that participants were paying attention to what was happening in the background. Data that we collected from a stress control study (Hourani et al., 2011) seem to show that having a lot to respond to in a simulated environment led some participants to miss some cues. The same was true of participants interacting with a driving simulation having increasing levels of foreground and background activity (Mills & Hubal, 2001). One consideration these studies bring up is how to introduce the complexity of culturally-relevant behaviors, even whether or not to do so, during training; a systematic approach such as that described in Hubal & Frank (2001) may guide such decisions. Further work is needed to help clarify when and how background activity representing patterns of life influences users' behaviors, especially during training, as they engage with central agents.

6. Future Work on Character Behavior Modification

The background agents developed for these environments demonstrate considerable range in realistic behaviors and are flexible and dynamic, as was intended for them to portray appropriate POL. The agents appear to add considerably to the realism of the training scenarios, but there are some improvements, modifications, and tests that might further enrich the POL behaviors. These challenges, especially in visually rich simulations, require socioculturally-relevant, manipulable data.

In some ground-level visualization environments, background characters are observed to stand in awkward or unrealistic positions. It is rare, for instance, in the real world, for a person to stand idle alone in the middle of a path for any extended period of time, or for multiple characters to stand idle within a small range. Instead, a person would typically find an alcove in which to wait or side wall on which to lean, or engage in conversation with another person nearby, or vary the idling pattern (in more urban contexts, perhaps window shop or check cellphone messages), or enter a building. Further, we have noticed characters, on occasion, stop in the middle of a route from one location to another, and idle with actions such as taking a smoke break. The characters are supposed to look for a convenient spot as marked on the map by an author. While the appearance of the actions themselves is not unrealistic, it is somewhat implausible for a person to stop in the middle of a path to do so. Instead a person would move to the side, or, more likely, engage in the desired behavior at the destination.

This observed unrealistic behavior can have multiple causes. One reason is better animation, the fidelity of which has been shown to influence how users interpret the scene (Hayes-Roth, 2004; Lane et al., 2013). Another source is a possible delay in our implementation of a plan, or of a goal not including positioning information. To improve characters behavioral realism here would require the coding of additional subgoals or constraints on goals. Indeed, we propose adding and studying culture appropriate proxemics, including the culturally normal space left between persons engaged in discussion or walking past and aware of each other, as well as the distance among disparate groups of people and how that distance affects local behavior.

Relatedly, when passing a duo engaged in conversation on an otherwise empty path, a central character should at least acknowledge the ongoing discussion, by waving, nodding, or simply looking that way, if not joining in. When the character does not acknowledge the discussion, then the background activity may be unnecessary. The same is not necessarily true at a more crowded space, such as a marketplace, where pairs and trios of conversationalists are the norm. We realize there is a whole class of "group interaction" problems that needs further exploration; the logistics of how pairs and trios intersect with individuals walking around or standing in line has implications of politeness, personality, and intensity in achieving goals. Implementing this feature should also involve mainly adding rules to character behavior planning, and parameters to suggest better and worse locations for the actions that lessen the need for authoring specifics.

A potential advance in cultural awareness involves social network characteristics. For instance, the friendship paradox is a theorem that the average number of friends of friends is always greater than the average number of friends of individuals (Feld, 1991). Practically, this paradox implies that certain nodes (friends) in a network contribute disproportionately to an average of activity across the network. There are other networking phenomena of interest, including centrality, mixing, and interdependence (Newman, 2010). Building on computational models of infectious disease and geospatial data for synthesized populations (Cooley et al., 2008), we would like to study how these phenomena have cultural implications and incorporate them as appropriate into the synthetic character models. One consideration is to enhance cultural models based on lessons learned creating synthetic populations, based on models used by health agencies to track the spread of disease and drug-related emergency-room visits in the U.S., and on previously-developed synthetic populations for Mexico, Pakistan, India, and other countries (Wheaton, 2011). A further advance is to incorporate social network structures to model crowd movement (Wakamiya, Lee, & Sumiya, 2012).

7. Conclusions

Using fuzzy state logic, algorithms, and agent-based planning we have devised culturally appropriate pattern-of-life behaviors for both background and central agents to augment interaction skills training environments. Our intent is to address three design considerations for training simulation, background at scale, variation, and anomaly and normalcy. A series of parameters is used to make agents' behavior reflect specific cultures. The systems described have been implemented in a number of virtual environments for training and other simulation purposes. Early tests of these culturally aware POL capabilities are promising, but more experimentation is warranted to determine their effectiveness in improving simulation training.

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