Modeling the Interaction between Mixed Teams of Humans and Robots and Local Population for a Market Patrol Task

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Abstract

We consider a cross-cultural interaction scenario where a group of soldiers assisted by robots interact with local vendors in a market place. We develop a model to quantify, analyze and predict the perception of the actions of the soldiers and the robot by the local population. The model assumes that humans are considering collections of concrete and intangible values which are not, in general, directly and linearly convertible into each other. We argue that satisfactory modeling accuracy can be achieved by restricting the considered intangibles to a small set of *culture sanctioned social values*. For these values, the culture provides a name, calculation methods, as well as associated rules of conduct. We validate our model by comparing the predicted values with the judgment of a large group of human observers cognizant of the modeled culture. We use the model to evaluate the tradeoffs between several long term strategies to maintain security as well as to increase the trust and goodwill of the local population.

Introduction

The objectives of soldiers in peacekeeping scenarios include maintaining the security of the local population, maintaining their own personal security and maintaining the general goodwill of the local population. The peacekeepers and the local population frequently belong to different cultures, opening the possibility of either misunderstandings, or, more subtly, to different judgements of the implications of certain behavior. Agent models which optimize a straightforward single metric such as financial worth or security have difficulty predicting the behavior of the participants in such scenarios. Peacekeeping soldiers might loose the goodwill of the population even through actions which benefit their security and financial well-being.

In this paper we describe a model which quantifies the way in which the interaction of the soldiers and their robotic teammates on one side and the local population on the other side is interpreted through their respective social and cultural values. We are also evaluating the way the long term perceptions are formed, evaluated and propagated. Some of the challenges we are facing in this endevour are:

- The difficulty to establish metrics of social values, as well as the impacts of actions in the case of interaction between different cultures.
- To difficulty to observe and model the diffusion of the resulting perceptions in the social environment through one-to-one interaction.
- The challenge to estimate the evolution of social values such as trust over extended periods of time. These values are affected by the actions of the interacting agents, but they also evolve in time in the absence of interactions.

The reminder of this paper is organized as follows. First, we informally describe the Market Patrol scenario which will be the running example in the remainder of this paper, followed by the modeling of the scenario using the culture sanctioned social value model. We validate some elements of the model using the results of a survey. We conclude the paper with the results of several experiments using the model.

Informal description of the Market Patrol scenario

Let us start by informally introducing our running example, the Market Patrol scenario.

The location of our scenario is an open air market in a generic Middle Eastern setting (with its implied cultural and social values). A number of vendors $V_1 \cdots V_n$ are selling their wares in the market. We assume that the scenario evolves over the course of several weeks, with the same vendors returning to the market every day. A group of soldiers, members of a peacekeeping operation are in charge of maintaining the security of the market, by preventing disruptive or terrorist activity. We consider the group to be formed by a sergeant (S), a private (P) and an autonomous robot (R). The group is patrolling the market, occasionally interacting with the vendors.

To understand the dynamics of the actions and the social motivations of this scenario, let us consider it from the point of view of the two main involved parties: the patrol and the vendors.

For the soldiers in the patrol, the primary task is to maintain security in the market and identify possible threats. To achieve this, they can initiate a search of the wares of the merchants. As we will describe in detail later, the search can be more or less thorough, can be performed with a public display or discreetly, and it can be associated with various levels of mitigating speech and behavior. Depending on

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these factors, the act of searching has more or less impact on the business and social values (dignity, face, public embarrassment) of the vendor.

The soldiers also have the objective to maintain friendly relations with the vendors. They are encouraged to participate in social interaction and conform to the local norms of polite behavior.

From the point of view of the vendors, the primary goal is to have an undisturbed and profitable business. Naturally, the vendors are interested in the security of the marketplace; however, the search of their *own* personal wares do not contribute to security and negatively affect other values. A search can result in public embarrasment, loss of face and personal dignity, and it can be associated with a financial loss, by the confiscation of contraband items. It is in the interest of the vendors to maintain friendly personal relations with the patrol in order to avoid or minimize the number of searches, or at least to ensure that they are conducted in a way which mitigates the loss of social values. The means through which the vendors can achieve this is by the local social norms of friendly interaction: casual conversation, gestures of hospitality, exchange of small gifts.

Analysis the Market Patrol scenario

To analyze the Market Patrol scenario, we will use the culture sanctioned social value (CSSV) model. In this model, the participants of the social interaction are evaluating a vector of values which are affected by their own and other agents' actions. Some of these values are *tangible*, such as financial worth or time. The intangible values are restricted to the values for which the culture: (a) provides a name (b) provides an evaluation method and (c) associates rules of behavior.

For the analysis of the Market Patrol scenario we will consider the following CSSVs (in parenthesis adding the actors who consider them).

- **Perceived security level (S, P, R):** is the level of threat as perceived by the members of the patrol. It is affected by factors such as the density of crowd in market, the general alarm level and the cooperation of the vendors during search.
- **Dignity (S, P, V):** The perception of the personal dignity by the soldiers and the vendor. While both the middle eastern and the western culture sanctions dignity as a social value, the associated evaluation algorithms differ. The soldiers use a generic western cultural model adapted to their status as soldiers: for instance, being defied on an open order offends dignity. The vendors use their own cultural model adapted to their status. Some of the evaluation algorithms are similar to the western one (being "ordered around" decreases dignity), while other ones are more culture specific (refusal of an offered gift is an offense to dignity).
- **Politeness (S, P, V)** The perceived politeness metric is evaluated according to culture specific algorithms by the vendor and the soldiers.

Beliefs and public perceptions

Besides the CSSVs of the agents, the social actions also affect their *individual beliefs* and *public perceptions*. Both of these play an important role in the actions chosen by the agents. In contrast to values, beliefs can be correct or incorrect. Even when incorrect, beliefs are important, because the agents will act and calculate CSSVs according to the beliefs, whether they are correct or not. If an agent considers another one a friend, it will act accordingly and judge the actions of the other agent in this context, irregardless if the friendship is mutual or not.

In the agent literature, the beliefs of the agent are frequently considered to be a "model of the world". Creating such a model, for human players, is clearly impossible. We argue, however, that the careful choice of a small number of numerical belief values are sufficient to model the influence of beliefs on the values and as a determinant on action choice.

Beliefs are higher level conscious judgments, and we posit that they are less subjected to the phenomena of *psychological adaptation* (Brickman and Campbell 1971) than the values. For instance values such as politeness or dignity perception will tend to return to their average values over timespans of days. Beliefs, however, evolve more slowly, and they do not have natural trends towards average values. This does not mean, however, that beliefs are not affected by timespans – for instance, the perception of friendship might diminish in the presence of long spans of time without actions reconfirming this friendship.

We model the agent's beliefs using the Dempster-Shafer theory of evidence (Shafer 1976; Yager 1987) in the following way:

- The agent's current beliefs are fully encoded in the mass function - no previous evidences are remembered.
- Incoming evidence can be weighted by significance.
- At every incoming evidence, the belief is updated using the standard Dempster's rule of combination (conjunctive merge).
- The value for the positive belief is used as the indicator of the belief.

Although, in general, the semantics of the Dempster-Shafer model are controversial, the results obtained with this model represent a good match to our intuitive understanding of the scene.

We will use the following beliefs in the modeling of the Market Patrol scenario:

B^{SPR}_{threat} is the soldier's belief that the vendor represents a threat. The threat would depend upon the resistance that the vendor exhibits while the search order is carried out. Generally, the passing of time and human interactions decrease this belief. This belief affects the soldier's judgement of the security level.

$B^{V \to x}_{\text{friend}}$ the vendor's belief that the soldier x is a friend. Friendly actions (casual conversation, exchange of gifts, requests delivered with high mitigation level, lenience in accepting reactions to commands) increase the friendship

Table 1: Possible actions for the participants in the Market Patrol scenario (with specific possibilities for actor and target)

	Action	Actors	Targets	Param.
A1	moves	V		Location
A2	declines-to-search	V		Offensiveness
A3	offers-gift	V	S, P	
A4	initiates-conversation	V,S,P	V,S,P	
A5	accepts-conversation	V,S,P		
A6	orders-to-search	S,P,R	V	Offensiveness
A7	passes-order	S,P	P, R	
A8	accepts-gift	S, P	V	
A9	declines-gift	S, P	V	Offensiveness
A10	order-to-move	S, P, R	V	Loudness
A11	overnight	S,P,R,V		

belief. Actions which are considered rude (unmitigated commands, refusal of gifts) decrease the belief of friendship. The belief also decreases (albeit more slowly) in the absence of friendship maintenance actions (eg. casual conversation).

Action repertoire

Let us now consider the actions which can be taken by the participants and their impact on the values of the actor and (if applicable) the recipient. Our modeling approach here is to define a relatively small number of actions, but to characterize them with *detail variables* which describe, for instance, the verbal style in which a request or command is delivered. These actions are listed in Table 1.

Action parametrization of A6 using mitigated speech

Let us consider the `order-to-search` action, and its impact on the dignity of the vendor and the perceived politeness of the soldier. In general, this action has negative connotations for the vendor. It offends his dignity through several mechanisms: it is personally offensive to take orders, it is a bigger offense when being ordered around by somebody considered a friend, it can be humiliating if it happens in front of peers (other vendors) or the general public. The action can also lead to financial losses by revealing possible contraband items.

While this action has a complex model, to be expanded upon in future papers, in this paper we will concentrate upon one aspect, the influence of the language with which the search order / request had been made. To attach a numerical metric of the politeness level of a request, we will use the *mitigation level* of the order - according to the classification recently popularized by Malcolm Gladwell (Gladwell 2008)[1]. To the 6 mitigation levels discussed by Gladwell, which culminate in "command", we add three more levels which model the threat of and actual physical actions, respectively.

[1]Note however, that similar ideas are present in the literature for a long time - e.g. in Brown and Levinson's politeness model(Brown and Levinson 1987)

Table 2: The impact of action A6 on the politeness of soldiers S or P and the dignity of the vendor using various levels of mitigated speech

Name	Example	$P^{S/P}$	D^V
L1: Hint	Seems like you have got new stuff in your bag to sell in market today.	1.0	1.0
L2: Preference	I like the stuff you sell, and would love to share my opinion about your new items (in the bag)	0.81	1.0
L3: Query	Won't you show me the new stuff that you're going to sell today?	0.68	1.0
L4: Suggestion	I would suggest that you let me search the bag, as the security alert is high today	0.56	0.91
L5: Obligation statement	I'm sorry i need to do this, but my boss insists that you show me your bag	0.44	0.73
L6: Command	Show me your bag!	0.36	0.63
L7: Threat of physical action	Show me your bag or i'll have to arrest you!	0.22	0.49
L8: Minor physical action	Pushing and snatching the bag, afterwards going through bag without consent of vendor	0.11	0.28
L9: Major physical action	taking the vendor in custody	0	0

Note that the values in the table are calculated from a Middle Eastern perspective. Certain cultures such as Korean or Japanese, would put a significantly higher penalty on unmitigated speech. On the other hand, Northern European cultures would put no penalty on direct speech and high levels of mitigation would lead to misunderstandings.

The values in the table can also be modeled in an equation form using a combination of signum, heaviside, exponential and other simple mathematical functions:

$$F(s5, a6)_{s,p} = sgn(5-x)\left[|5-x| + \frac{sgn(5-x)}{y+z}\right] \quad (1)$$

$$F(s3, a6)_v = -H(x-4)\cdot e^{x/3}$$

where, *x* is the level of mitigated speech, *y* and *z* are the loudness and offensiveness respectively. In Equation 1, the function *sgn* is the signum function, whereas *H(x)* is the Heaviside's function.

Survey-based calibration of the model

Assigning numbers to social values is an inherently inexact science. However, the working assumption is that the culture enforces a more or less uniform method to calculate the sanctioned social values. This means that we can validate (and, if necessary, calibrate) the CSSV model by performing a survey in which persons cognizant with the respective culture will judge the impact on the social values.

Representativeness of the survey

One of the important considerations is the representativeness of the survey: are the results of the survey representative of the CSSVs of the target population? It is well known that many academic surveys suffer from the problem of using respondents who are in many ways divergent from the general population and are, in certain ways, "weird"(Henrich, Heine, and Norenzayan 2010).

In the following we will discuss some of the obstacles we perceive in the representativeness of our results.

- The culture of the survey takers (Pakistan) might not be an exact match of the target culture. This is an unavoidable bias - for a perfect localization, one would need to use respondents from the exact geographical location we model.
- There might be a possible misunderstanding between the culture sanctioned values covered by the specific names. Our modeling target was a hypothetical, Arabic speaking Middle-Eastern environment. Our respondents have been primarily Urdu speaking, with a good knowledge of English, and many with at least some level of Arabic.
- The distorting factor of social class: the survey subjects have been drawn from a significantly higher social strata (students, engineers, doctors) than the average composition of the market. It is to be determined whether the social class affects the calculations of CSSVs. Our conjecture is that it has only a minimal effect, through secondary implications, which we will outline below.
- The impact of persons cognizant of multiple cultures. Many of the respondents have received some level of Western or Western-style education. It is to be determined whether this impacts their evaluation of the CSSVs. Our conjecture is that is at most a minimal impact. We assumed that people cognizant of multiple cultures are able to evaluate separate CSSVs according to multiple cultures (naturally, within the limit of the cognitive load they can handle). Then, they decide which CSSV dependent rules of conduct apply in the current situation (which might be a combination of rules), then plan their actions in function of (not necessarily in obeisance to) these rules. This behavior model implies that even people who do not follow rules according to these CSSV settings, will still be able to calculate them.

Survey results

The methodology of the survey was as follows:

- the participants are presented the scenario in a story-board style, with screenshots and explanation of the ongoing action.

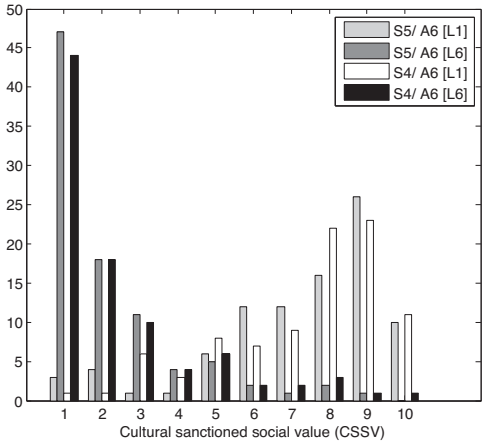


Figure 1: The survey histogram for public politeness [S4] and peer politeness [S5] in view of the vendor when the sergeant performs action [A6] (order to move)

- the participants score the value of the perceived social value from the point of view of the seller (answering of questions of the type: rate the perceived politeness of the X on a scale of 0 to 10).

The participants were 91 persons from various regions in Pakistan.

While space limits us from analyzing the full output of the survey here, Figure 1 shows a representative case. The figure shows the histogram of answers for the public and peer politeness values for action A(6, 5) - order to move using mitigation level 6 and moderate voice level and A(1, 5) using maximally mitigated speech (L1). The graph shows that there is a remarkable consistency in the estimated CSSV values, but also some level of distribution around mean values.

Experimental study

The proposed model has been implemented using the YAES environment (Bölöni and Turgut 2005), and a collection of third party visualization tools and the OpenWonderLand 3D virtual environment (Kaplan and Yankelovich 2011).

For the experimental study, we made the assumption that the patrol operates over the course of two weeks, with the same patrol composition and the same group of vendors. There are also external factors beyond the control of the patrol and the vendors: we assume that a medium (orange) alert happens on day 8 and high (red) alert on day 12.

The objective of this simulation experiment is to study different behavioral strategies the members of the patrol can adapt. For each behavioral strategy, we study the impact on the values, beliefs and public perceptions. To explore the full space of possible behaviors some of these strategies are intentionally extreme. Human behavior is, of course, more nuanced.

1. *Rigidly impersonal behavior*

   In this scenario, the members of the patrol act in a rigidly impersonal way, avoid social interaction, reject gifts and use unmitigated speech to perform searches (action A6

at mitigation level L7). With this behavior, the security level remains consistently high. However the overall public perception of the soldiers will be negative. Figure 2 shows the evolution of the social values S3 (dignity), S4 (public politeness) and S5 (peer politeness).

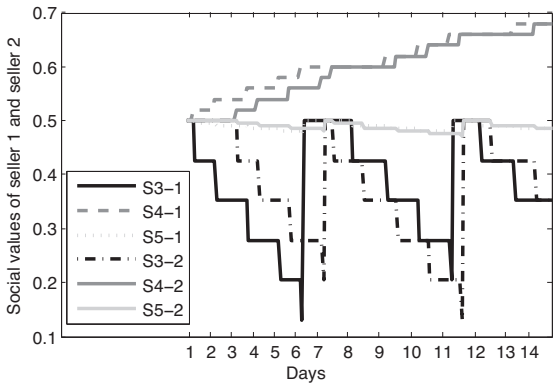


Figure 2: Scenario 1 - Dignity S3 (1) of seller 1 and S3 (2) of seller 2 gradually decreases with time.

2. *Maximally social behavior*

   In this scenario, the members of the patrol will behave in a maximally sociable way, responding positively to all suggested social interactions, and using maximally mitigated speech when performing searches (A6 with mitigation level L1). This extreme indirectness of speech allows the vendors to decline or delay the search operation. As expected, this strategy results in high trust and positive perception of friendliness, but low security. Figure 3 shows the evolution of the dignity, public politeness and peer politeness.

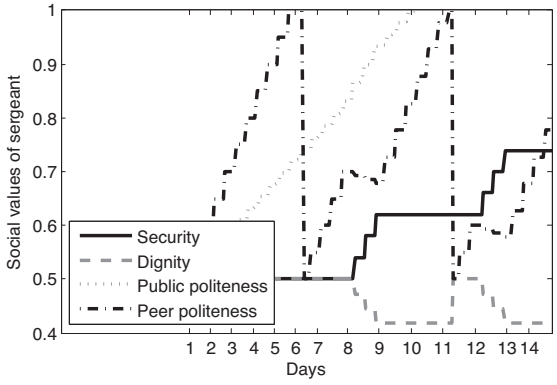


Figure 3: Scenario 2 - Vendors are non-cooperative during search task, but are friendly otherwise

3. *Threat level adaptive behavior*

   In this scenario, the members of the patrol are enacting a maximally social behavior in days with low alert, and rigidly impersonal behavior on high alert days. The intuitive justification of such a strategy is to restrict the perceived offensiveness to the situations when a higher security threat requires it.

   One of the observed conclusions of this scenario is that the overall impression is still negative, because the perceived offense to dignity is more damaging from a person previously considered a friend than from a stranger.

   Figure 4 shows the evolution of the dignity, public politeness and peer politeness for this scenario.

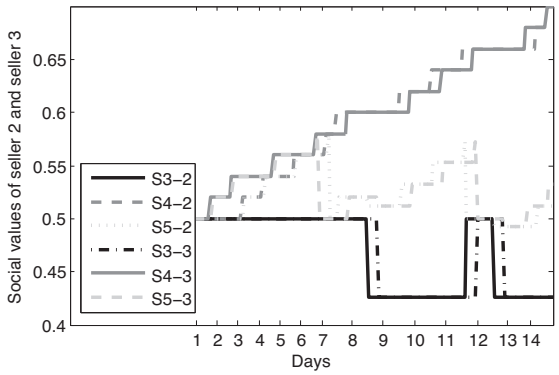


Figure 4: Scenario3 - Two negative falls can be observed in dignity (S3) of vendors on high alert days (day 8, 12).

4. *Relationship adaptive behavior*

   In this model, the members of the patrol maintain sociable behavior outside the searches, and adapt the mitigation level of search request in function of the personal relationship with the vendor. They start by using unmitigated speech at the beginning of the modeled period. Once the member of the patrol and the vendors develop a relationship, the request for search will be delivered in a more and more mitigated way. If the request will be declined, the members of the patrol will repeat the request with a lower mitigation, until it reaches a point where it is accepted.

   Figure 5 shows the evolution of the dignity, public politeness, peer politeness and perceived security level for this scenario (from the point of view of the sergeant S).

5. *Social humans / impersonal robot*

   In this scenario, the members of the patrol act in a sociable way and use highly mitigated speech to initiate search. However, when taking actions with high impact on the dignity of the vendor (for instance, escalating the request for search after several refusals), the members of the patrol *delegate the task to the robot*. The rationale behind this strategy is that the robot does not establish interpersonal relationships, and its behavior is not judged similarly to the one of a human. Figure 6, shows that although the seller feels offended when the robot escalates the request, still the loss of dignity is remarkably low when compared to Figure 4.

Related work

Famously, general Petreaus said that the american soldiers have to “drink a lot of tea” with local Afghan leaders, to

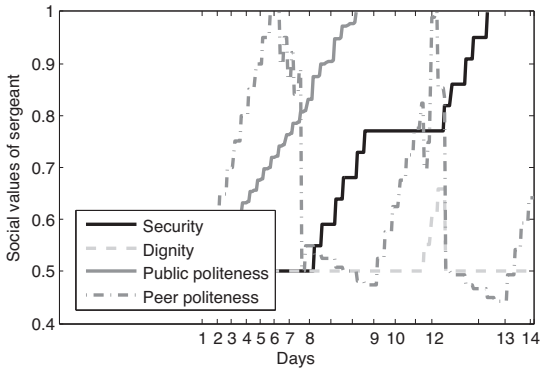


Figure 5: Scenario4 - The security (S2) risk increases on Day 8 and Day 12 during the search operation as the vendors show resistance. The soldiers persuade the seller by varying mitigated level of speech (L1, L3, L7)

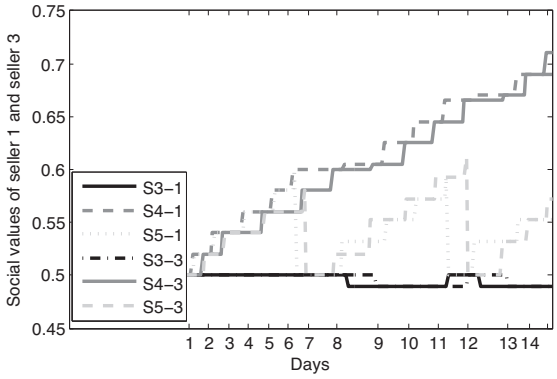


Figure 6: Scenario 5: Delegating unpleasant tasks to the robot

establish normal relations.

There is an extensive body of work which analyzes population sentiment in reaction to the presence of foreign military forces. Many of these body of work assumes general, high level policies, involving overall directives, and had been done in the context of policy decisions, sociology and integrative simulations.

Our work involves a direction which had been much less thoroughly investigated, which involves the action of individual soldiers, over the course of several weeks. In recent years, a number of approaches, similar in spirit to ours, are working towards modeling individual interactions.

Miller et al. (Miller, Wu, and Funk 2008) propose to operationalize the Brown and Levinson politeness model (Brown and Levinson 1987). The implementation, the Etiquette Engine, is used to assess the politeness of a number of custom crafted social-interaction vignettes involving common culture but different rank (the interaction between a corporal and a mayor). The values were compared against the evaluation by human observers (unfamiliar with the Brown and Levinson model).

In a follow-up work (Miller et al. 2009) they create a more complex model which investigates the relationship between culture (as examplified by Hofstede's cultural factors (Hofstede, Hofstede, and Minkov 2010)) as well as politeness levels affect directive compliance. Directive compliance - the way in which people react to instructions, commands or requests, represent a very large proportion of human interactions in work and military settings.

Conclusions

In this paper we described an approach for modeling the evolution of cultural values, beliefs and public perceptions for a scenario where a group of peacekeeping soldiers assisted by robots interact with local vendors in a market place. Future work includes improving the realism of the model, extending it to more general scenarios, and more extensive model of the role of robots as participants in the social interaction.

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