Paper accepted for presentation at MABS 2010, Toronto, 11 May 2010

Computational Modeling of Culture's Consequences

Gert Jan Hofstede[1,2] , Catholijn M. Jonker[2], Tim Verwaart[3]

[1] Wageningen University, Postbus 9109, 6700 HB Wageningen, The Netherlands
gertjan.hofstede@wur.nl
[2] Delft University of Technology, Mekelweg 4, 2628 CD Delft, The Netherlands
c.m.jonker@tudelft.nl
[3] LEI Wageningen UR, Postbus 29703, 2502 LS Den Haag, The Netherlands
tim.verwaart@wur.nl

Abstract. This paper presents an approach to formalize the influence of culture on the decision functions of agents in social simulations. The key components are (a) a definition of the domain of study in the form of a decision model, (b) knowledge acquisition based on a dimensional theory of culture, resulting in expert validated computational models of the influence of single dimensions (c) a technique for integrating the knowledge about individual dimensions. The approach is developed in a line of research, studying the influence of culture on trade processes. Trade is an excellent subject for this study because it is ubiquitous, relevant both socially and economically, and often cross-cultural in a globalized world.

Keywords: dimensions of culture, computational model, social simulation

1 Introduction

Being competent in trading depends on more than economic rationality. To model trade as it actually happens, creating agents that compute the most profitable deal is therefore not enough. The agents' incentives could be modeled using Williamson's framework [1] in which four time scales are used: resource allocation (for instance: trade) happens continuously, and it is subject to governance rules that may change on a time scale of 1 to 10 years. These rules are themselves subject to institutional changes, e.g. new legislation, at a time scale of 10 to 100 years. Institutions in their turn are based on and attuned to the hidden rules of the game (culture) that are embedded in society and change on a time scale of 100 to 1000 years. So this model states that people involved in trade use governance rules, institutions and cultural values to guide their behavior, albeit unconsciously. The present article takes this position as a basis for modeling the culture's effects on agent-based social simulations.

Societies around the world differ greatly with respect to the value systems and ideas that govern patterns of human interaction.. Hofstede [2], p.9, defines culture as "*the collective programming of the mind that distinguishes the members of one group of people from another*". The behavior of people and their interpretation of the behavior of others are based on their norms for appropriate behavior. These norms vary from culture to culture.

In different cultures, different norms may prevail for behavior in trade; e.g., trade partner selection, bargaining style, trust that has to be shown, favor that is given to in-group relations or high-ranked society members, and opportunistic advantage that may be taken from partners. Different systems may be viable in different societies. For example, [3] used multi-agent simulations to show that economic systems based on trust and systems based on opportunism may both be viable.

When traders operate in foreign cultures, the programming of their minds may not be efficient. This explains the existence of practical guides for business behavior in different countries, e.g. [4] and [5], and the extensive body of scientific literature that has been developed. The scientific literature ranges from business oriented studies, e.g. Kumar [6], and cross-cultural surveys, e.g., Kersten et al. [7], to economic models, e.g., Guo [8] and Kónya [9].

The approach proposed in this paper aims to model culture at the mid-range level according to the classification by Gilbert [10], p.42. Mid-range models depend on a rich description of processes, but do not in facsimile model a particular situation. For mid-range models, observed trends should be similar to those observed in reality. This is important for our long-term research goal of improving the understanding of human decision-making in international supply chains with asymmetric information, see, for instance, [11]. The research method proposed in [11] combines multi-agent models with gaming simulation, but a general multi-agent-based model as proposed in [11] does not explain the cultural difference observed in the gaming simulations. Therefore, it is important to develop an approach to culturally adapt the models.

For the modeling of culture, one must lean on social sciences literature. Two main streams of research can be distinguished. First, there is the anthropological approach of rich description, in which specific cultures are studied by detailed and close observation of behaviors during an extensive time-span. Examples are the works of Lévi-Strauss [12] and Geertz [13]. Second, there is the comparative approach that tries to identify dimensions on which different cultures can be ordered, aiming to develop a classification system in which cultures can be typed by a small number of qualifications. Examples are the models of culture by G. Hofstede [2], Schwarz [14], and Trompenaars and Hampden-Turner [15]. The approach of that type of research research is to characterize cultures by their indices on a limited number of dimensions. The dimensions and the indices of cultures are typically created by factor analyzing massive surveys with standardized questionnaires in many countries. The value of such dimensions largely depends on the questionnaires used in combination with the sets of respondents that are required. Questionnaire studies will be more reliable predictors of behavior if they are about the desired (for self) than if they are about the desirable (for everyone), and also if they are asked to a broad range of types of respondents as opposed to just one type (e.g., students or managers). The resulting models provide a linear ordering of cultures along each dimension, where particular values and practices are hypothesized (based on empirical evidence) to be stronger or weaker or occur more frequently or less frequently according to the index on the dimension. For instance, in cultures on one extreme of a particular dimension concerned with asymmetry of power relations, the implicit norm is for parents to treat children as equals, while in cultures on the other end parents are supposed to teach children obedience. As authors of dimensional models stress, these same implicit norms carry over to all relationships in society that involve potential power differences, whether in school, in politics or in trade. In all social situations, they act as filters on perception and on action range. This means that there are no specific values for activity x, e.g. 'trade values', in a dimensional model. It also means that a dimensional model is suited for modeling any process that involves social intercourse, including trade and its sub-activities.

Cultural descriptions of the first type provide rich details about values, norms, symbols, beliefs, rituals, social structure, behavioral patterns etc. in a particular culture. These will prove very useful for facsimile modeling of specific social systems. The model proposed in the present paper aims to compare the influence of a great diversity of cultures in the standardized environment of a gaming simulation which is by itself an abstraction of social life. For that purpose we need to posit the model at an impartial distance from any single culture. A dimensional model of culture is more suited than a collection of incommensurable rich descriptions. Dimensional models are culture-level abstractions. They do not depict individuals, but average group characteristics, and therefore the agents in our simulation will be iconic for a culture (mid-range, in our term), not specific for any individual (facsimile, in our term).

Of the well-known dimensional models, the most widely used is Hofstede [2]. His work is accessible, sparse, and based on a very large, very well stratified sample of questions on the desirable for self, asked of people in all professions that continues to give it great explanatory value. No other model matches society-level variables so well to date [18].

The hypothesis of this research is that computational models of culturally differentiated agents can be deduced from social scientific theories that differentiate cultures, including the way members of such a culture interact with other people, along a limited number of dimensions. An agent-based model can be developed to incorporate behavior and agent interactions which are realistically differentiated along each of the cultural dimensions. Note that the model based on the cultural indices may reliably reproduce general trends, but will not differentiate up to the detail of actual individuals. For the long term, a computational model based on a dimensional theory of culture in multi-agent-based simulations can provide insights into the functioning of social systems and institutions in different cultural contexts.

To develop computational models of culturally differentiated agents in a specific domain of application a general agent-based model for that domain of application can be taken as a point of departure. That general model should be based on either a task, process, or activity analysis of the domain of application. A dimensional theory of culture can be used to determine the required adaptations to the model to reflect the way culture influences behavior trends. Such adaptations also pertain to the way the agents perceive their environment and the behavior of other agents. For instance, if the theory describes that in some cultures favor is to be shown to in-group customers, while in other cultures the norm is to treat all customers equally, the agents need a cognitive model in which they can be aware of what group they belong to and maintain models of other agents in which they maintain beliefs about other agents' group memberships (e.g., "I belong to group x and he/she does/does not belong to that group"). For each of the processes of the general model, an adaptation must be developed that models the adaptation of decisions by culture. This paper describes an approach to develop computational adaptations of the processes within the agent that are based on a dimensional model of culture, and expert knowledge about cultural effects on decisions and interpretation of behaviors.

The case for which the approach described in this paper has been developed is a simulation game of trade under asymmetric information [17]. A multi-agent-based simulation of this game has been developed [11], with two purposes: to test hypotheses about players' decision making and to design optimal configurations for human games. When playing the game with human participants, differences in outcomes were observed that were attributed to differences in cultural background [17]. The latter was the rationale for modeling culture into the artificial agents.

The process model for trading agents acting in the game is given in Fig. 1. The plans that the agents execute for process fulfillment are based on validated models taken from literature on social sciences and artificial intelligence.

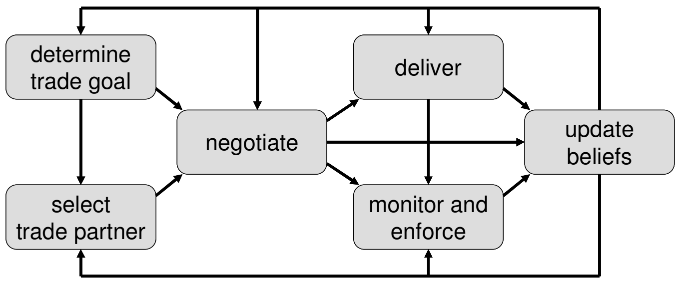


Fig. 1. Processes and internal information flows of trading agents (adapted from [18])

The agent's decision models implemented in the plans for process fulfillment were adapted to include effects of culture, based on Hofstede's [2] dimensional model. The present paper describes the approach taken to incorporate the dimensional model of culture into the decision functions. The paper is organized as follows. Section 2 presents an overview of the method that was followed in knowledge acquisition and model formulation. Section 3 formulates the computational model. A discussion of results concludes the paper.

2 Modeling Method

The exercise of modeling culture in trading agents could be carried out in a multitude of ways, using a variety of theories. The present article describes one such attempt. It also presents the choices and the line of reasoning behind this method. This could enable other researchers to choose which of the principles, choices and practices of this approach to adopt and from which ones to deviate.

In order to model cultural differentiation in agents the following steps were taken, once the domain to be modeled had been defined. Agent roles and network, agent communications, the environment and entities in it, their observable properties and possible actions of agents were defined. For the agents, a process model had been established. Throughout this paper, specific examples are taken from the domain of trading agents, see Fig. 1 for a process model.

In each process the agents take decisions based on decision rules. For these rules, models were preferred that had in empirical research been validated to simulate actual human behavior. For instance, in the model of culture implemented by the authors, the ABMP negotiation architecture is applied. It has been validated in experiments with Dutch adolescents and adults [19]. If no validated model can be found in literature, a dedicated model has to be formulated based on empirical data or research; see, for instance, [20].

The decision models taken from literature can be implemented as a set of rules (the agent's knowledge base. Typically, the decision rules are parameterized. For instance, parameters in the rules of the ABMP negotiation strategy have names like *concession factor*, *negotiation speed*, *impatience*. So, the decision model can be formulated as a set of parameterized rules, and the labels of the parameters can be listed. We refer to this modeling activity as "decision function analysis". The results are the decision rule base and a list of parameter labels (see Fig.2).

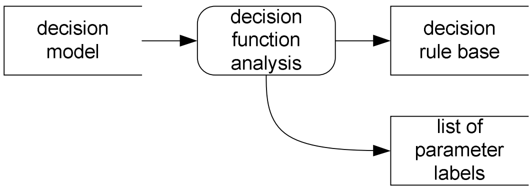
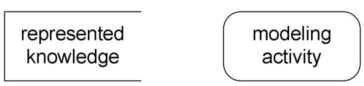


Fig. 2. Decision function analysis[1]

The decision rule parameters are the point of application for cultural differentiation. It is important to start from process models that allow for such adaptation. Validations of behavior with subjects from one culture are no guarantee for the occurrence of similar behavior in other cultures. This is amply shown by a multitude of experimental studies published in journals such as the Journal of Cross-Cultural Psychology, and in review volumes such as [21]. This fact implies that ideally, only models shown to be valid across cultures should be used. This condition could not be met for all the models used in this paper. The Hofstede dimensions of culture were derived using a sample of people in a broad range of professions from over 70 countries on all continents, and explicitly aiming to compare these countries. They qualify. For the ABMP negotiation architecture, however, we had to be content with validation in only one culture. Further validations in other countries of ABMP could yield results that necessitate revisions of our agent models.

For the cultural differentiation a dimensional model of culture was selected, in this case Hofstede's five-dimensional model [2]. Two criteria were important in the selection. First, the model had to be applicable for the social processes to be simulated, based on the contexts in which it has been developed and validated, and the availability of research results that provide rules for decision parameter

[1] Legend of Fig. 2…5:



adaptation. As argued in section 1, this condition holds for the Hofstede framework. Second, the modelers had to have access to expertise on the cultural model to be applied, for knowledge acquisition and expert validation of results.

Knowledge about the influence of individual dimensions of culture on the decision functions of the process model was acquired, using the concept of Synthetic Cultures [22] complemented by an expert systems approach. Synthetic Cultures are scripts, created by experts on cross-cultural communication, that catch a single extreme of a single dimension of culture in rules of behavior. They have been created for use in training counselors [22] and later adapted for use in simulation gaming for a multitude of applications [23]. Synthetic Cultures lead to believable behavior by simulation participants, and to realistic cross-cultural miscommunication, even though the synthetic cultures themselves are obviously unrealistic. Since their publication, a number of simulations based on synthetic cultures were created, the synthetic cultures were refined based on experience [24] and they have become adopted by cross-cultural trainers around the world.

Literature and expert knowledge are mostly based on differentiation along the dimensions. It is feasible to acquire knowledge on the differentiation along a single dimension, whereas it proved to be impossible in practice to interpret the joint influence of multiple dimensions on general rules. A classical knowledge acquisition approach was followed for each dimension: interview experts on the cultural theory, read literature, write narratives of expected system behavior, have experts validate the narratives, correct until the experts have confidence in the narratives. In addition to the narratives, the knowledge acquisition resulted in a list of relevant cultural factors[2] for each dimension. On the basis of the knowledge gained, the influence of the relevant factors for a single dimension on each parameterized decision rule can be formalized as a set of rules that modify the parameter values. See Fig. 3 for an overview of these steps.

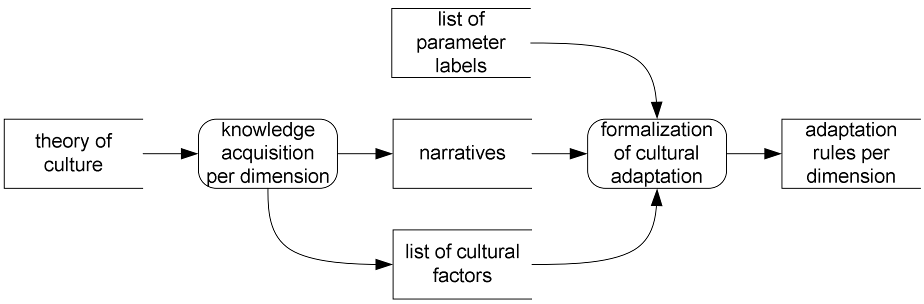


Fig. 3. Knowledge acquisition and formalization

[2] Some dimensions adapt the perceived relevance of certain relational attributes. For instance, the salience of common group membership (in-group versus out-group) is adapted by the dimension of individualism versus collectivism. Other such relational attributes are status difference and trust. 'Cultural factors' combine dimension scores and relational attributes.

The next activity in the modeling was to implement the rules in multi-agent-based models for each single dimension Fig. 4. The step of the modeling per dimension is described for each of Hofstede's dimensions in [25], [26], [27], [28], and [29]. The results of these models can only be validated by expert validation. In reality, cultures are composites of all dimensions and interactions with other dimensions distort the effect being modeled.

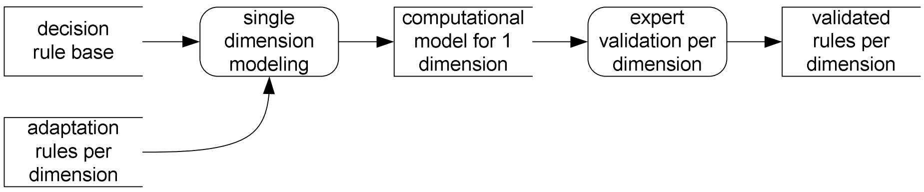


Fig. 4. Computational modeling and validation for a single dimension

Finally, the parameter adaptation rules of the individual dimensions were combined into an integrated set of rules, as the basis for a computational model of the simultaneous influence of all dimensions (Fig. 5). The integration technique used to integrate the adaptation rules is the subject of the present paper. This technique has been applied in models for the agent's processes of partner selection [30], negotiation [31], and delivery, monitoring and enforcing, and belief update [20].

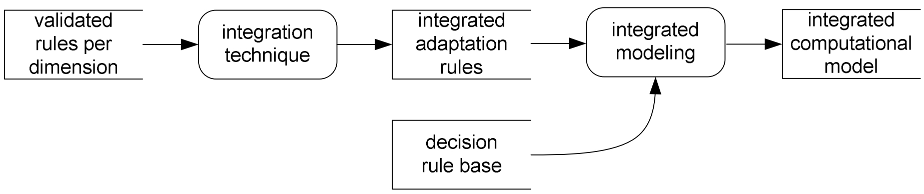


Fig. 5. Integration and computational modeling of joint dimensions

3 Integrated Computational Model

This section describes the approach taken to integrate the parameter adaptation rules for the single dimensions into an agent model that simulates an complete cultural "Gestalt". The approach has been applied to differentiate trading agents in a simulation game according to Hofstede's dimensions, but it is described in a more general way. The approach might also be applied for other dimensional models or to other processes where the decisions can be described by parameterized rules and data or expertise is available to assess the effects of culture on the parameter values. From this general perspective, we formulate the approach as follows.

Assume for some domain of application that a set of adapted decision rules per dimension and accompanying sets of parameters and cultural factors are given (see Fig. 2 and Fig. 3). This section discusses an approach to integrating all this knowledge into one integrated computational model that reflects the influence of culture on decision making in the domain. The key concepts used in our approach are described as follows (see Table 1 for an overview).

Table 1. An overview of the key concepts

Dimensions	*Cultural factors*		*Parameters ranging over 1≤ i≤ m*			
ranging over 1≤ j≤ n	Factor label set L	Factor value set F	Label set P: default value: adjusted value:	p_1 x_1 x_1'	… … …	p_m x_m x_m'
1	l_{11} … l_{1q_1}	f_{11} … f_{1q_1}		r_{111} … r_{11q_1}		r_{m11} … r_{m1q_1}
…						
n	l_{n1} … l_{nq_n}	f_{n1} … f_{nq_n}		r_{1n1} … r_{1nq_n}		r_{mn1} … r_{mnq_n}

The m parameters used in the domain model are labeled p_1 through p_m, with associated default values x_1 through x_m, for some reference culture, and values adjusted for culture x_1' through x_m'. For instance, in the ABMP negotiation model applied in the trading agents simulation, a parameter k is has label p_k="negotiation_speed"; it has a global default value x_k for a particular context, equal for all agents; for each individual agent, the value is modified to its cultural adjusted value x_k', so x_k' will probably be different for agents having different cultural profiles.

For each culture dimension j, there is a range of q_j cultural factor labels l_{j1} through l_{jq_j} with associated values f_{j1} through f_{jq_j}. Variable i is consistently used in this paper to range over parameters (values or labels), whereas j ranges over dimensions, and k over cultural factors per dimension j. For each factor label l_{jk} and each parameter p_i, there is a function r_{ijk} that maps factor value f_{jk} and default value x_i to adjusted parameter value x_i'. Table 1 presents an overview of these key concepts.

The integrated effect of culture on agent behavior can be modeled as a function h that maps a vector of cultural factors $\vec{f}$ and a vector of default values of model parameters $\vec{x}$ to a vector of culturally adjusted parameters $\vec{x}'$:

$$h(\vec{f}, \vec{x}) = \vec{x}' \ . \qquad (1)$$

The hypothesis of this work entails that, given the set of decision functions, a dimensional theory of culture can be used (a) to identify the cultural factors to be taken into account and (b) to define the mapping h. If this is possible, the agent modeling can benefit from vast bodies of social sciences literature that describe the differentiation of many behaviors along the dimensions of the cultural model. This literature can be used to define h for the wide range of behaviors described in it, assuming that we can formulate parameterized decision functions governing the behaviors. The literature is the basis for finding the attributes of agents and their relations which are relevant for moderation of the model parameters. This approach to integration of effects of cultural dimensions has been applied in [20], [30], [31]. In expert-systems based knowledge acquisition the effect of culture can be formulated in statements like: "*In hierarchical societies there are differences in selected trade strategy. The higher ranked prefer to trade high quality valuable commodities to underline their status that fits their position in life. They will not avoid deals where less powerful opponents technically have the opportunity to defect, because the higher ranked rely on their power to enforce cooperation*." [25].

This example refers to the effect of Hofstede's power distance dimension. It refers to multiple decision processes: partner selection, delivery, and monitoring and enforcing. It illustrates that research and experts can explain the differentiation of behaviors along a single dimension on the basis of dimensional theory. It also illustrates that it is hard to acquire knowledge about the processes in isolation. Therefore, the approach is taken to first model individual dimensions and then integrate the models process-by-process.

Table 2. Relevant factors with respect to trust and deceit, adapted from [20]; PDI^*, UAI^*, IDV^*, MAS^*, and LTO^* represent Hofstede's indices of culture, s_a the agent's own status, s_b partner's status, and d_b group distance between the agent and its partner; all variables were normalized to the interval [0,1]; + indicates an increasing effect on the parameter; – indicates a decreasing effect

Dim-ension index	Culture and relational characteristics	Cultural factor	Effect on			
			deceit threshold	inclination to trace	negative update factor	positive update factor
PDI	Large power distance	PDI^*				
	- with higher ranked partn.	$\max\{0, PDI^*(s_b-s_a)\}$	+	–		
	- with lower ranked partn.	$\max\{0, PDI^*(s_a-s_b)\}$		–		
	Small power distance	$1- PDI^*$				
UAI	Uncertainty avoiding	UAI^*			+	–
	- with stranger	$UAI^*\cdot d_b$	–	+		
	Uncertainty tolerant	$1- UAI^*$				
IDV	Individualistic	IDV^*				
	Collectivistic	$(1-IDV^*)$			+	
	- with in-group partner	$(1-IDV^*)(1-d_b)$		–		
	- with out-group partner	$(1-IDV^*)d_b$	–			
MAS	Masculine (competitive)	MAS^*	–	+	–	
	Feminine (cooperative)	$1- MAS^*$		–		
LTO	Long-term oriented	LTO^*	+	–	+	
	Short-term oriented	$(1-LTO^*)$				
	- with well-respected part.	$(1-LTO^*)s_b$	+	–		
	- with other partners	$(1-LTO^*)(1-s_b)$	–			

The example also illustrates that not just the values of the dimensional indices are relevant for modeling the effect of culture. Relational attributes are relevant as well. In this example Hofstede's power distance index (PDI) is relevant. It orders countries on a scale with the most hierarchical culture at the high end and the most egalitarian country at the low end. Conditional upon the value of PDI, the status of the agent and its partner are relevant: "*The higher ranked*" refers to agents that have a high status s_a in society; "*less powerful opponents*" refers to opponents with which the status difference $s_a – s_b$, where s_b refers to opponent's status, is high. So, in order to model cultural effects on decisions, not just the indices on the dimensions have to be taken into account as factors, but also relational attributes if their effect is differentiated across cultures. Based upon the example given, one can identify PDI$\cdot s_a$ and PDI$(s_a – s_b)$ as relevant factors in addition to PDI.

Based on the knowledge acquired for all individual dimensions, all relevant cultural, relational and situational factors can be identified. In the example of trade the following have been identified as relevant relational attributes: status, in-group versus out-group membership, and the trust relation between partners. For instance, the vector of cultural factors influencing the decisions to deceive and to trust identified by Jonker et al. [20] can be taken from the column labeled "Cultural factor" in Table 2. Such a table is constructed for each process or group of processes, in this case the trade processes of delivery, monitoring and enforcing, and belief update. It contains the expert knowledge for cultural adaptation of the agents' decision making. It contains the relevant cultural factors (on the rows) and the parameters to be adapted (in the columns). The cells describe the effect of culture on the parameters.

Having identified $\vec{f}$ for a particular set of processes, and assuming that the vector of parameter values $\vec{x}$ follows from the chosen decision functions, it comes to the definition of the function *h*. *h* can be decomposed into a vector of functions g_i , i.e., one per parameter, that map *h*'s arguments to the individual culturally adjusted parameter values x_i':

$$h\left(\vec{f},\vec{x}\right)=\left(g_1\left(\vec{f},\vec{x}\right),\ldots,g_m\left(\vec{f},\vec{x}\right)\right)=\left(g_1,\ldots,g_m\right)\left(\vec{f},\vec{x}\right)=\vec{g}\left(\vec{f},\vec{x}\right)\ , \qquad \mathbf{(2)}$$

so that

$$\begin{aligned} x_1' &= g_1\left(\vec{f},\vec{x}\right) \\ &\ldots \\ x_m' &= g_m\left(\vec{f},\vec{x}\right) \end{aligned}\ . \qquad \mathbf{(3)}$$

The problem now is to find the functions g_i for i=1,…,m. For this purpose the following hypothesis can be formulated: given that dimensional models of culture aim to provide for each dimension a linear ordering of the strength or frequency of occurrence of phenomena associated with that dimension, the effect of each cultural factor may be modeled as a strictly monotonic function r_{ijk} that adapts the *i*-th parameter to the *k*-th factor associated with the *j*-th dimension. r_{ijk} can be seen as a member of a set of functions *r* that can be indexed by the labels of cultural factors and parameters as arguments. r_{ijk} maps the value f_{jk} of the cultural factor with label l_{jk} into an effect e_{ijk} on the parameter with label p_i:

$$r_{ijk} : f_{jk} \times x_i \rightarrow e_{ijk} \ , \qquad (4)$$

$$r_{ijk} \equiv r(p_i, l_{jk}) \ , \qquad (5)$$

and

$$e_{ijk} = r_{ijk}(f_{jk}, x_i) = r(p_i, l_{jk})(f_{jk}, x_i) \ , \qquad (6)$$

where $p_i \in P$, the set of parameter labels, and $l_{jk} \in L$, the set of factor labels.

As the r_{ijk} are strictly monotonic, they can be classified as either increasing or decreasing. For each parameter label p_i its set of factors L_i^+ that have an increasing effect and its set of factors L_i^- that have a decreasing effect can be defined:

$$\forall p_i \in P: \quad L_i^+ \equiv \{ l_{jk} \mid r_{ijk} \text{ is increasing} \} \ , \qquad (7)$$

$$\forall p_i \in P: \quad L_i^- \equiv \{ l_{jk} \mid r_{ijk} \text{ is decreasing} \} \ . \qquad (8)$$

By the knowledge acquisition process taken, the increasing and decreasing effects of the cultural factors can be identified, as illustrated in Table 2 [20]: L_i^+ is the set of factor labels that have a + sign in the column associated with the parameter labeled p_i; L_i^- is the set of factor labels that have a minus sign in the column associated with p_i.

The next problem to solve is the combination of these influences into a single effect on each parameter, i.e. to identify the functions g_i that moderate the effect of culture on the parameters. On the basis of expert knowledge the following rules can be formulated as hypotheses:

1. In g_i there is no interaction between the factors $\vec{f}$ and other parameters than x_i. This assumes that any decision model can be formulated in such a way that any parameter can be modified for culture without taking the values of the other parameters into account. For the models we have implemented so far ([20], [30], [31]) this assumption is valid.
2. The joint decreasing and the joint increasing effect can compensate for each other. This expertise is confirmed by expert statements, e.g. (in cultures with high power distance) "*The powerful dictate the conditions. The less powerful have to accept. In feminine or collectivist cultures the powerful may exercise restraint, …*" [25].
3. For the increasing and for the decreasing effects, the effect with the maximal influence is dominant: influences in the same direction do not reinforce each other. According to expert knowledge, if several factors influence a parameter in the same direction, it is sufficient for one to be maximal in order to sort maximal effect (disjunctive factor influence, see e.g. "*feminine or collectivist*") under 2 above.

4. Cultural factors working in the same direction do not reinforce each other. This means that, for instance, in Table 2 three factors are identified to have increasing effect on deceit threshold. If two of the factors have effect 0.5 and one has effect 0.2, their joint effect is 0.5; not 0.4 (the average) or another linear combination (see 3 above); not 0.8 (probabilistic) or another product combination.

The first of these three hypotheses implies that the integration can be performed column-by-column using factor tables like Table 2, and we can write the functions as:

$$g_i\left(\vec{f},\vec{x}\right)=g_i\left(\vec{f},x_i\right) \ . \qquad \textbf{(9)}$$

The second hypothesis implies that the functions g_i can each be defined as the sum of x_i and a function $g_i^+ \geq 0$ that combines the increasing effects and a function $g_i^- \leq 0$ that combines the decreasing effects:

$$g_i\left(\vec{f},x_i\right)\equiv x_i+g_i^+\left(\left\{r_{ijk}\left(f_{jk},x_i\right)\mid l_{jk}\in L_i^+\right\}\right)+g_i^-\left(\left\{r_{ijk}\left(f_{jk},x_i\right)\mid l_{jk}\in L_i^-\right\}\right) \ . \qquad \textbf{(10)}$$

For the functions g_i^+ and g_i^- a range of function types were experimented with (probabilistic and linear combinations, to name the most obvious). However, under the third and fourth hypotheses all except weak disjunction proved to be untenable[3]. We found that both g_i^+ and g_i^- can be written as a weak disjunction:

$$g_i^+\left(\left\{r_{ijk}\left(f_{jk},x_i\right)\mid l_{jk}\in L_i^+\right\}\right)=\max\left\{r_{ijk}\left(f_{jk},x_i\right)\mid l_{jk}\in L_i^+\right\} \ , \qquad \textbf{(11)}$$

$$g_i^-\left(\left\{r_{ijk}\left(f_{jk},x_i\right)\mid l_{jk}\in L_i^-\right\}\right)=\min\left\{r_{ijk}\left(f_{jk},x_i\right)\mid l_{jk}\in L_i^-\right\} \ . \qquad \textbf{(12)}$$

Equations (11) and (12) enable the integration of the computational models constructed for the single dimensions. For this the form of the functions $r_{ijk}\left(f_{jk},x_i\right)=r\left(p_i,l_{jk}\right)\left(f_{jk},x_i\right)$ has to be defined. All that is known so far about these functions is that they are strictly monotonic. As long as there is no further evidence, a first order approach can be taken, i.e., let r_{ijk} adjust x_i proportionally to f_{jk} from its default value in the direction of the extreme values $\varepsilon_{ijk}^+ > x_i$ and $\varepsilon_{ijk}^- < x_i$:

$$\forall i\mid p_i\in P: \quad \forall j\forall k\mid l_{jk}\in L_i^+: \quad r_{ijk}\left(f_{jk},x_i\right)=\left(\varepsilon_{ijk}^+-x_i\right)f_{jk} \ , \qquad \textbf{(13)}$$

$$\forall i\mid p_i\in P: \quad \forall j\forall k\mid l_{jk}\in L_i^-: \quad r_{ijk}\left(f_{jk},x_i\right)=\left(\varepsilon_{ijk}^--x_i\right)f_{jk} \ . \qquad \textbf{(14)}$$

Under this first order approach, using (11) and (12), (10) becomes:

---

[3] Weak disjunction is consistent with the hypotheses 3 and 4 above. Any linear or product combination of cultural factor is not.

$$g_i\left(\vec{f}, x_i\right) = x_i + \max\left\{\left(\varepsilon_{ijk}^{+} - x_i\right) f_{jk} \mid l_{jk} \in L_i^{+}\right\} + \min\left\{\left(\varepsilon_{ijk}^{-} - x_i\right) f_{jk} \mid l_{jk} \in L_i^{-}\right\} . \qquad \textbf{(15)}$$

In practice, the values of ε_{ijk}^{+} and ε_{ijk}^{-} are unknown. However, minimal and maximal values can be assumed not to depend on the cultural dimension j, and estimates $\hat{\varepsilon}_i^{-}$ and $\hat{\varepsilon}_i^{+}$ can be determined per model parameter. Under the assumptions

$$\forall i \mid p_i \in P: \quad \forall j \forall k \mid l_{jk} \in L_i^{+}: \quad \varepsilon_{ijk}^{+} = \hat{\varepsilon}_i^{+} \ , \qquad \textbf{(16)}$$

$$\forall i \mid p_i \in P: \quad \forall j \forall k \mid l_{jk} \in L_i^{-}: \quad \varepsilon_{ijk}^{-} = \hat{\varepsilon}_i^{-} \ , \qquad \textbf{(17)}$$

(15) can be written (N.B.: $\hat{\varepsilon}_i^{+} - x_i > 0$ and $\hat{\varepsilon}_i^{-} - x_i < 0$):

$$g_i\left(\vec{f}, x_i\right) = x_i + \left(\hat{\varepsilon}_i^{+} - x_i\right)\max\left\{f_{jk} \mid l_{jk} \in L_i^{+}\right\} + \left(\hat{\varepsilon}_i^{-} - x_i\right)\max\left\{f_{jk} \mid l_{jk} \in L_i^{-}\right\} . \qquad \textbf{(18)}$$

Concluding, given default values for a specific context, e.g. trade in biologically grown vegetables or trade in second hand cars, and realistic minimal and maximal values for each parameter, using knowledge represented as in Table 2, the function in equation (18) can be used to estimate parameter values x_i' that are adjusted for culture.

4 Conclusion

This paper presents an approach to the modeling of cultural differentiation in multi-agent based simulations. It argues that a dimensional theory of culture is a good basis for middle-range agent-based models that simulate differentiation over a broad range of cultures. The decomposition of cultural phenomena into a set of linear orderings on a limited number of dimensions enables dimension-by-dimension modeling of cultural effects. The concept of Synthetic Cultures, well tested in practice, shows that dimension-by-dimension scripts give rise to believable, if unrealistic, behavior. As the dimensions provide a linear ordering, it is reasonable to assume that each dimension (and relational attributes relevant for differentiation of behavior associated with it) has a strictly monotonic effect on decision rule parameters, if all other factors are kept constant.

The integration of effects of all dimensions is based on (1) a division of effects in a subset of increasing and a subset of decreasing effects per parameter, (2) the use of a weak disjunction of the effects per cultural factor, and (3) compensation of increasing effects for decreasing effects and vice versa. The approach has been applied in several simulations of trade processes and has been validated to produce realistic tendencies across cultures in expert-validations.

An approach as followed in this paper aims to reproduce general tendencies of behavioral differentiations across cultures at an aggregated level. It can be used as a research instrument to generate hypotheses about behavioral differentiation that can be validated in experiments, or to validate theories induced from experimental results. As a mid-range model, it cannot be used to predict effects of culture in actual situations or at the individual level.

The approach was applied to simulations of trade processes, on the basis of Hofstede's five-dimensional theory of culture (e.g. [23]), but it is not specific for this domain and this theory of culture. It could also be applied to other domains, or other theories of culture, provided that parameterized decision models are available that may be expected to have general validity across cultures, and that sufficient knowledge for cultural adaptation can be acquired from social sciences literature and experts.

References

1. Williamson, O.E.: The New Institutional Economics: Taking Stock, Looking Ahead. Journal of Economic Literature 38: 595--613 (2000)
2. Hofstede, G.: Culture’s Consequences, Second Edition. Sage Publications, Thousand Oaks (2001)
3. Gorobets, A., Nooteboom, B.: Agent Based modeling of Trust Between Firms in Markets. In: Advances in Artificial Economics, LNEMS 584, 121--132, Springer, Heidelberg (2006)
4. Acuff, F.L.: How to negotiate anything with anyone anywhere around the world. Amacom, New York (1997)
5. Olofsson, G.: When in Rome or Rio or Riyadh: Cultural Q&A’s for successful business behavior around the world. Intercultural Press, Yarmouth Maine (2004)
6. Kumar, R.: Brahmanical Idealism, Anarchical Individualism, and the Dynamics of Indian Negotiation Behavior. International Journal of Cross Cultural Management 4(1), 39--58 (2004)
7. Kersten, G.E., Köszegi, S.T., Vetschera, R.: The Effects of Culture in Anonymous Negotiations: Experiment in Four Countries. In: Procs. of the 35th HICSS, 418--427 (2002)
8. Guo, R.: How culture influences foreign trade: evidence from the U.S. and China. Journal of Socio-Economics 33, 785--812 (2004)
9. Kónya, I.: Modeling Cultural Barriers in International Trade. Review of International Economics 14(3), 494--507 (2006)
10. Gilbert, N.: Agent-Based Models. Sage Publications, Los Angeles (2008)
11. Tykhonov, D., Jonker, C., Meijer, S., Verwaart, T.: Agent-Based Simulation of the Trust and Tracing Game for Supply Chains and Networks. Journal of Artificial Societies and Social Simulation 11(3), 1 (2008) http://jasss.soc.surrey.ac.uk/11/3/1.html
12. Lévi-Strauss, C.: Tristes Tropiques (originally in French, 1955). Penguin Books, New York (1992)
13. Geertz C.: The interpretation of cultures. Basic Books, New York (1973)
14. Schwarz, S.H.: Culture Matters: National value cultures, Sources, and Consequences. In: Wyer, R.S., Chiu, C.Y., Hong, Y.Y. (eds.) Understanding Culture. Psychology Press, New York (2009)
15. Trompenaars, F., Hampden-Turner, C.: Riding the waves of culture: understanding cultural diversity in business, 2nd edition. Economist Books, London (1993)
16. Smith, P.: Nations, Cultures, and Individuals: New Perspectives and Old Dilemmas. J. of Cross-cultural Psychology 35(1), 50--61 (2004)

17. Meijer, S., Hofstede, G.J., Beers, G., Omta, S.W.F.: Trust and Tracing game: learning about transactions and embeddedness in a trade network. Production Planning and Control 17, 569--583 (2006)
18. Meijer, S., Verwaart, T.: Feasibility of Multi-agent Simulation for the Trust and Tracing Game. In: Ali, M., Esposito, F. (eds.) IEA/AIE 2005. LNCS, vol. 3533, pp. 14--154. Springer, Heidelberg (2005)
19. Bosse, T., Jonker, C.M., Treur, J.: Experiments in Human Multi-Issue Negotiation: Analysis and Support. In: Proceedings of the Third International Joint Conference on Autonomous Agents and Multi-Agent Systems, pp 672--679 (2004)
20. Hofstede, G.J., Jonker, C.M., Verwaart, T.: A Multi-agent Model of Deceit and Trust in Intercultural Trade. In: Nguyen, N.T., Kowalczyk, R., Chen S.-M. (eds.) ICCCI 2009. LNCS, vol. 5796, pp. 205--216. Springer, Heidelberg (2009)
21. Smith, P., Bond, M.H., Kagitçibasi, C.: Understanding Social Psychology across Cultures. Sage Publications, Thousand Oaks (2006)
22. Pedersen, P.B., Ivey, A.E.: Culture-Centered Counseling and Interviewing Skills: A Practical Guide. Greenwood Press, Westport (1993)
23. Hofstede, G.J., Pedersen, P.B.: Synthetic Cultures: Intercultural Learning Through Simulation Gaming. Simulation & Gaming 30, 415--440 (1999)
24. Hofstede, G.J., Pedersen, P.B., Hofstede, G.,: Exploring Culture: Exercise, Stories and Synthetic Cultures. Intercultural Press, Yarmouth (2002)
25. Hofstede, G.J., Jonker, C.M., Verwaart, T.: Modeling Power Distance in Trade. In: David, N., Sichmann, J.S. (eds.) MABS 2008. LNCS, vol. 5269, pp. 1--16. Springer, Heidelberg (2009)
26. Hofstede, G.J., Jonker, C.M., Verwaart, T.: Modeling Culture in Trade: Uncertainty Avoidance. In: 2008 Agent-Directed Simulation Symposium (ADSS 2008), Spring Simulation Multiconference 2008, pp. 143--150. SCS, San Diego (2008)
27. Hofstede, G.J., Jonker, C.M., Verwaart, T.: Individualism and Collectivism in Trade Agents. In: Nguyen, N.T., Borzemski, L., Grzech, A., Ali, M. (eds.) IEA/AIE 2008. LNCS, vol. 5027, pp. 492--501. Springer, Heidelberg (2008)
28. Hofstede, G.J., Jonker, C.M., Meijer, S., Verwaart, T.: Modeling Trade and Trust across Cultures. In: Stølen, K., Winsborough, W.H., Martinelli, F., Massacci, F. (eds.) iTrust 2006. LNCS, vol. 3986, pp. 120--134. Springer, Heidelberg (2006)
29. Hofstede, G.J., Jonker, C.M., Verwaart, T.: Long-term Orientation in Trade. In: Schredelseker, K., Hauser, F. (eds.) Complexity and Artificial Markets, pp. 107--118. Springer, Heidelberg (2008)
30. Hofstede, G.J., Jonker, C.M., Verwaart, T.: Simulation of Effects of Culture on Trade Partner Selection. In: Hernández, C. et al. (eds) Artificial Economics: The Generative Method in Economics, pp. 257--268. Springer, Heidelberg (2009)
31. Hofstede, G.J., Jonker, C.M., Verwaart, T.: Cultural Differentiation of Negotiating Agents. Group Decis Negot, doi: 10.1007/s10726-010-9190-x (2010)