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Fuzzy Modeling Approach for Integrated Assessments Using Cultural Theory

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Abstract

It has already been noted that the accurate prediction of societal responses requires the use of a formal model based on some social or cultural taxonomy. One such taxonomic candidate is Cultural Theory (CT). CT argues that all societies, irrespective of time or place, are informed by their underlying worldviews, which must be more or less Hierarchic, more or less Individualistic, more or less Egalitarian, and more or less Fatalistic. This approach appears to have a potential for cross-temporal and spatial comparisons that makes it a particularly attractive instrument for a study of the human dimensions of global climate change. However, a significant difficulty in previous attempts to use CT in integrated assessment models (IAMs) has been inexactness or uncertainty inherent in both IAMs and CT. In this paper we introduce a fuzzy-based modeling approach using CT in integrated assessment approach to model social reactions to environmental policy decisions.

Key Words: *Decision making under uncertainty, Cultural Theory, Integrated assessments, Fuzzy logic*

1. Introduction

Integrated assessment models (IAMs) attempt to integrate information used to assess the climate change related to global warming by linking mathematical representations of different components of natural and social systems in a computer model [1]. That is, IAMs have the potential to provide meaningful input to global policies with regard to climate change. However, it has been pointed out that IAMs containing socio-economic models are lacking in the social component. One other effort [6] has found that Cultural Theory (CT) is effective in IAMs. A significant difficulty in this approach has been the inexactness or uncertainty inherent in IAMs and CT. CT is one of the theories that involve the classification of social groups into

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"cultural" groups. These groups are labeled Individualists, Egalitarians, Hierarchic, and Fatalists, according to Cultural (or Grid-Group) Theory [2].

An axiom of CT is that all societies and their underlying worldviews, irrespective of time or place, must be more or less Hierarchic, Individualistic, Egalitarian, or Fatalistic. These four cultural leanings are defined by the two dimensions of "Grid" and "Group", which respectively describe the number and strength of behavioral prescriptions and proscriptions imposed by living in a particular way, and the strength of people's attachment to the community that lives that way. CT's potential for cross-temporal and spatial comparisons makes it a particularly attractive instrument for a study of the human dimensions of global climate change. In fact, it has been shown in [3] that a person's cultural classification is a much better predictor of that person's attitude toward environmental questions than, for example, race, gender, education, economic situation, etc.

The problem then becomes: "how does one put this idea into an integrated assessment model?" It has already been pointed out that uncertainty plays a key role in assessment modeling [6]. We think that one possible solution to this problem is to use fuzzy set theory in modeling cultures, environmental policies, and the relationships among the policies and cultures. The fuzzy set theory can play an important role in integrated assessment modeling by identifying, representing, and modeling the uncertainties involved in the problem domain. Our proposed fuzzy-based modeling approach, which utilizes the extended cultural theory, can be used in integrated assessment of climate change with the identification of these groups and modeling the behavior of each. One may go further to predict the responses of the cultural groups of individuals to short-term climate fluctuations and to tailor the forecasting message to them by using our modeling approach presented here.

The rest of the paper is organized as follows: Section 2 first summarizes cultural theory. In the next section we discuss how CT is utilized in evaluation of policy decisions. Section 4 includes our fuzzy-based modeling approach utilizing CT in assessing policy decisions. We use the proposed model in a rather simple application, evaluation of a policy on deregulation of electric power production, and the results and related descriptions are presented in Section 5. Finally, Section 6 provides conclusions and future work.

2. Cultural Theory

The roots of CT [2] are in the philosophical/sociological work of Tocqueville, Nietzsche, Toennies, Simmel, Durkheim, and Fleck, all of whom recognized the divergent societal consequences of worldviews that might adequately be described as Egalitarian materialism, centralization, and anomic individualism. Other researchers, such Mary Douglas and Aaron Wildavsky, built on this foundational categorization, developing what is now known as CT. Numerous others have applied CT in analyses of perceptions of and attitudes toward environmental issues and policies. Among these scholars are Steve Rayner, Michael Thompson, and Richard Ellies.

Among other work, Pendergraft [3] suggests that using CT to classify survey respondents into clusters produces a stronger indicator of attitudes toward environmental threats than do such commonly used variables as political party, political philosophy, age, gender, income, or education. This result comes from a random survey of 762 persons in selected counties and parishes in Texas and Louisiana, USA.

What CT adds to the analytic arsenal is an enhanced ability to go beyond mere description toward verification and practical utility. A major virtue of CT is its universality of application to society: societies and the cultures that inform their institutions may be cross-temporally and spatially compared using this simple but powerful theory because any society, any culture must be simultaneously more or less Egalitarian, Hierarchic, Individualistic, and Apathetic. CT helps us link diverse levels of analysis from the individual level

to the global. If indeed people's perceptions of and reactions toward threats are shaped by the socio-cultural lenses through which they perceive reality, the very different implications of Egalitarianism, Hierarchy, Fatalism and Individualism can be illumined by CT. CT also equips us to consider adaptation at both individual and collective levels.

After a decade of research, Cultural Theorists are just now finding which types of questions are most effective and efficient in providing data that can be easily interpreted. As this discovery process progresses, studies increasingly suggest that social networks, which are united on the basis of "tacit knowledge", are the most important single influence on how information about environment hazards is perceived [4]. The principle was well-expressed three decades earlier by Michael Polanyi: "Our believing is conditioned at its source by our belonging" [5].

Even when drastic events overwhelm any rational possibility that their reality can be denied, the issue of what to do about the problems may still be shaped by cultural predisposition. Egalitarians will blame Individualists, and Hierarchs for creating an unjust society that forces many people into the hopeless status of exclusion from influence on policy, making them fatalists, made apathetic by their exclusion from power. Egalitarians will recommend and support recommending and supporting redistributive policies to restore the balance they long for. Individualists will blame Hierarchs for abusing undeserved power, Egalitarians for squelching actions that could allow the situation to be coped with. Hierarchs will blame unruly, selfish Individualists and impractical Egalitarians. Fatalists will just try to endure.

Cultural Theory provides a foundation for predicting what sorts of reactions are likely from which groups. Thus, it should also suggest which remedial policies have the best chance to achieve a critical mass of support for their successful formulation and implementation.

3. Cultural Theory in Evaluation of Policies

In general, there are several "policy characteristics" used in policy evaluation. These are sometimes summed up as the "3 E's and 3'P's:" Effectiveness, Efficiency, Equity, Participation, Predictability, Procedure.

Effectiveness means that the policy does what it was intended to do. It is the major concern of Hierarchs. Efficiency means that the benefits of the policy are cost-effective. This is a measure that individualists are especially concerned about. Equity is of particular concern to Egalitarians.

Participation is an interesting criterion. Egalitarians like the maximum, broadest range of public input, while hierarchs would prefer that experts have the most say, and individualists are concerned that stakeholders have influence.

Predictability is important for both hierarchs and individualists, who must plan around the administration of policy administrators to accomplish their goals. Egalitarians might more often wish that a policy could be administered on a case-by-case basis, to take account of "special needs."

Procedure refers mostly to "procedural fairness:" Egalitarians would be particularly sensitive here, and Individualists would usually press for less red tape and quicker decisions. Hierarchs want things done in an orderly manner.

The 3E's are largely susceptible to evaluation by economic measures (e.g., cost/benefit analyses) while the 3P's are more fuzzy, more apt to need evaluation by intuition (which is of course dependent on the cultural views of the evaluator – is the process fair?).

The term "public interest" seems almost to have been taken over by Egalitarians. If, for instance, you do an Internet search for the term, you will find that most of the web sites you find are said to be advocates for "consumers," "the environment" and "democracy" – strong indications that the group leans

to the Egalitarian side. Arguing that all policies should be evaluated on the basis of their effects on "the least advantaged members of society," is most congenial to the Egalitarian worldview. "Utilitarianism," on the other hand, argues that a good policy be one which maximizes overall social utility – a notion congenial to hierarchs. Individualists will be more interested in minimal regulation and protection of property rights.

An axiomatic concept among most policy analysts is "Pareto Optimality," which says that we should redistribute to the point that any further redistribution would make someone less well off. However, Egalitarians and Hierarchs may be quick to deny this economics-based criterion: for Egalitarians it is perfectly all right to disadvantage the "advantaged" to help the "disadvantaged." Hierarchs think that this may be all right if and when it enhances the general social welfare, but individualists tend to take a laissez faire approach, "blaming the victim," Egalitarians charge.

4. Fuzzy-Based Cultural Theory Model

Our model utilizes Fuzzy Set Theory [7] and CT [2] in the context of integrated assessment models. Fuzzy set theory provides a means for the representation of imprecision and vagueness. Each fuzzy set, A, is defined in terms of a relevant universal set U by a membership function, denoted as $\mu_A(u)$, where $u \in U$. This function assigns to each element u of U a number, in the closed interval [0,1], that characterizes the degree of membership of u in A. That is, the membership function can take all values between 0 (zero) and 1 (one) including the discrete values of 0 and 1. More formally, membership functions are the functions of the form $A: U \rightarrow [0,1]$. In defining a membership function, the universal set U is always assumed to be a classical set.

With respect to the computational model, the cultural groups can be thought of fuzzy sets since most individuals are not completely in one set, but may belong to a set with a degree in [0,1]. For example, many liberal politicians are first Egalitarians, but with a fairly strong bent toward Hierarchies. Conservatives can be highly Individualistic ("libertarian") or more Hierarchic ("socially conservative'). In addition possible uncertainties may be associated with subjective judgments, policies and disagreement among the experts and/or policy makers. Here we specifically aim to a model of the general characteristics of the cultural classifications and policies and how the cultural classes affect the policies on the global climate change by utilizing fuzzy set theory.

The general approach for modeling policy decisions and cultural groups to be used is shown in Figure 1. In this figure, the knowledge-based system includes a number of fuzzy if-then rules for capturing knowledge that basically represents the relationships among the policies and cultural groups. The relationships that exist in this application are usually imprecise and inexact by nature, therefore we use linguistic variables to describe the elastic conditions in the "if-part" of fuzzy rules [8]. The fuzzy knowledge-based system will have a capability to perform inference under partial matching.

More specifically, our modeling approach starts with fuzzy partitioning the input space of a population into the four cultural groups where each is modeled as a fuzzy set. A fuzzy partitioning allows a smooth transition from one subspace into a neighboring one as illustrated in Figure 2. The degree of overlap of any subspace is subject to further study; here we only illustrate that the transition between two sets may be gradual.

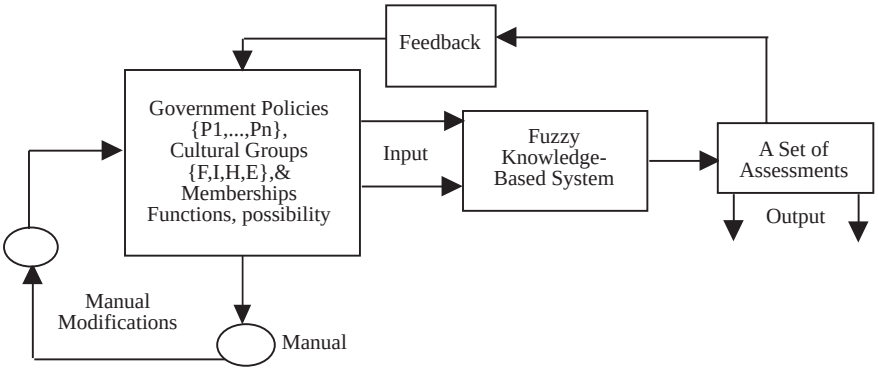

Figure 1. General Architecture of the Fuzzy Model

In Figure 2, the y-axis, grid, describes the strength of the behavioral prescriptions and proscriptions imposed by living in a particular way. The x-axis, group, describes the strength of people's attachment to the community that lives that way. As can be seen from the figure, cultural theory uses a group-grid typology to characterize individuals forming four cultural leanings defined by the two dimensions of grid and group. These dimensions respectively describe the number and strength of behavioral prescriptions and proscriptions imposed by living in a particular way, and the strength of people's attachment to the community that lives that way. The four classifications are termed Individualists (I), Egalitarians (E), Hierarchs (H) and Fatalists (F). For example, when a person's social environment is characterized by strong group boundaries and binding behavioral prescriptions, they are termed Hierarchs.

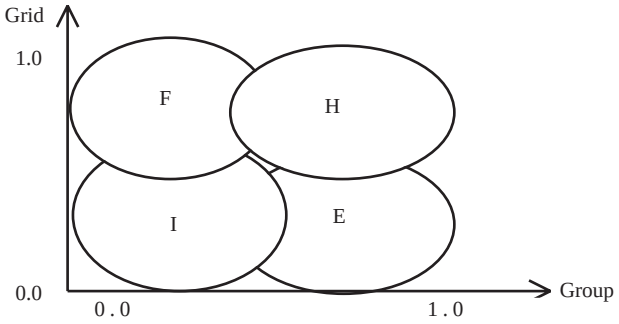

Figure 2. Taxonomy of Cultural Theory.

As mentioned before, the entire input space is partitioned which results in four fuzzy subspaces. The boundaries of these fuzzy subspaces may overlap and the union of these subspaces is the entire space. More formally, a fuzzy partition of a space U is a collection of fuzzy subspaces. For any element of the space, its membership degree in all subspaces always sums to 1.

$$\Sigma_i \mu_{Gi}(x_i) = 1, \forall x_i \in \mathrm{S} \text{ and } \mathrm{G}_i \in \{\mathrm{F,I,H,E}\} \text{ and} \cup_i \mathrm{G}_i = \mathrm{S}.$$

Each G_i is a fuzzy set and can be represented as $\mathrm{G}_i = \Sigma_i \mu_{Gi}(\mathrm{x}_i)/\mathrm{x}_i$.

For example, $\mathrm{E} = \{0.1/\mathrm{h}_1, \ldots, 1/\mathrm{h}_j, 1/\mathrm{h}_{j+1}, \ldots, 0.5/\mathrm{h}_i, \ldots, 0.1/\mathrm{h}_n\}$, where E stands for Egalitarian and each h_i is an individual or a cluster of individuals. This fuzzy set may be represented, for example, by

a trapezoidal membership function as shown in Figure 3. There could be other ways of representing these fuzzy sets. Instead of assigning a membership values in [0,1] for each individual or clusters of individuals, we could use some fuzzy terms (or sets) such as:

E = {weak/h_1,..., very-strong/h_j, very-strong/h_{j+1},..., moderate/h_i,..., weak/h_n}.

Which technique is better will be determined later after understanding more the details of the application domain. The membership functions for the other cultural groups can be generated in similar fashion.

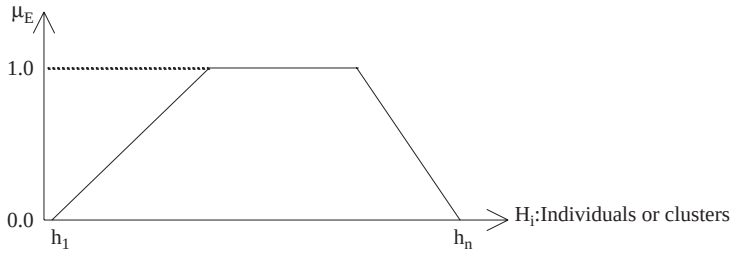

Figure 3. A Possible Membership Function for the Egalitarian Cultural Group

Each policy (or statement) may be agreed with or disagreed with by the cultural groups with a certain degree of confidence. Using the membership function of Figure 3, an example representing the degree of agreement of Egalitarians with each policy is illustrated in Figure 4. The membership functions for the other cultural groups can be defined similarly. It might be also necessary to fuzzily partition the domain of policies and establish fuzzy relationships among the policies. A possible fuzzy partitioning of the domain of the policies and representation of similarity relationships (with respect to grid and groups) of policies is given in Figure 5. The relationships among the policies and cultural groups can depend on the application, the form of data, etc., and especially the form of the fuzzy rules represented in the fuzzy knowledge-based system which will be used to capture these relationships.

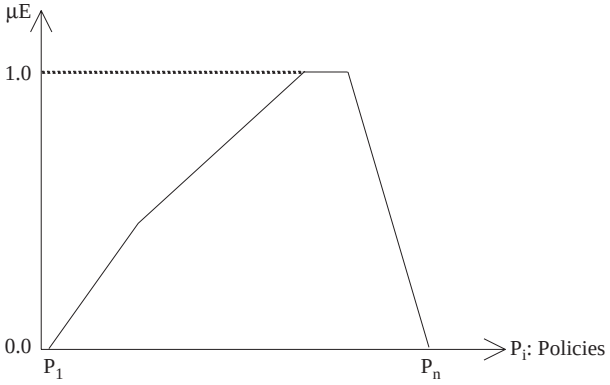

Figure 4. The Strength of Agreement of the Egalitarian Group with the Policies

So, our modeling approach involves identifying and defining a set of fuzzy rules which describe a functional mapping relationship between a set of input variables with attached strengths to a set of output variables with resulting strength from inference. In this specific application we identify our major input variables as a set of Cultural Groups (F,I,H,E) and as a set of policies (P_1,...,P_n). The output variables are a set of assessments (A_1,...,A_n) about the policy. A fuzzy mapping rule imposes an elastic constraint on possible

associations between input and output variables. The constraint is elastic because a fuzzy rule can describe input-output associations that are somewhat possible, i.e., the gray area between totally possible and totally impossible.

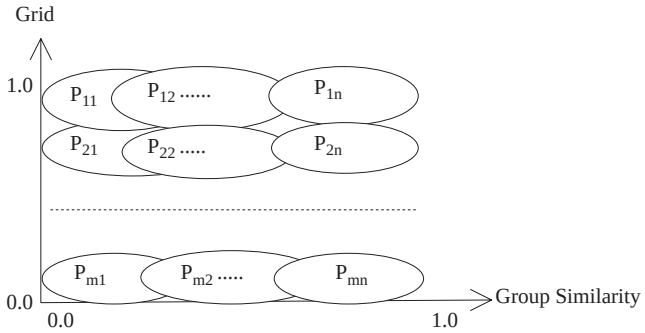

Figure 5. A Fuzzy Partition of Policies Used in the System

The degree of possibility of an input-output association imposed by a rule R can be expressed as a possibility distribution [9], denoted by Π_R. Since a fuzzy relation can be thought as a way for describing a possibility distribution, one can use the fuzzy relation to represent the possibility distribution imposed by a fuzzy rule. A fuzzy mapping rule is represented by the fuzzy relations formed by Cartesian product of the variables referred to in the rule's *If*-part and *Then*-part. For example, the mapping rule

$$\text{R: } If\ x \text{ is F, } Then \text{ y is P}$$

This rule can be mathematically represented as a fuzzy relation R defined as $\mu_R(x, y) = \mu_{FxP}(x, y)$. If we use the *min* operator for the Cartesian product, the fuzzy relation R becomes

$$\mu_R(x, y) = min\{\mu_F(x, y), \mu_P(x, y)\}.$$

The inference (i.e., interpolative reasoning) of such a fuzzy rule-based model is based on the compositional rule of inference. The composition is the result of three operations: (1) cylindrically extending each relation so that their dimensions are identical, (2) intersecting the two extended relations, and (3) projecting the intersection to the dimensions not shared by the two original relations. The net effect is a possibility distribution over the domain of definition of the output variable.

Among three types of fuzzy rule-based models for functional approximation, it seems that the Mamdani model [10] fits in our application the best. The Mamdani model utilizes rules whose consequent part is a fuzzy set. It consists of the following linguistic rules that describe a mapping from $\mathrm{U}_1 \times \ldots \times \mathrm{U}_r$ to W.

R_i: IF x_1 is A_{i1} and ... and x_r is A_{ir} THEN y is C_i

where i = 1,..., N and N is the number of rules and $\mathrm{x}_j \in \mathrm{U}_j$ (j = 1, ...,r) are input variables, y$\in$W is the output variable, and A_{ij} and C_i are fuzzy sets characterized by membership functions μ_{Aij} (x_j) and μ_{Ci}(y), respectively. Inputs in the Mamdani model are in the following form:

x_1 is A'_1 and ... and x_r is A'_r

where $\mathrm{A}'_1 \ldots \mathrm{A}'_r$ are fuzzy subsets of U_1,...,U_r (e.g., fuzzy numbers). The contribution of rule R_i to a Mamdani model's output is a fuzzy set whose membership function is computed by

$\mu_{C'i}(\mathrm{y}) = (\alpha_{i1} \wedge \ldots \wedge \alpha_{ir}) \wedge \mu_{Ci}(\mathrm{y})$

where α_i is the matching degree (i.e., firing strength) of rule R_i, and where α_{i1} is the matching degree between x_j and R_i's condition about x_j.

$$\alpha_{ij} = \sup_{xj} \left(\mu_{A'j}(\mathrm{x}_j) \wedge \mu_{Aij}(x_j)\right)$$

and $\wedge$ denotes the "min" operator, which is the clipping method [11].

The final output of the model is the aggregation of outputs from all rules using the "max" operator:

$$\mu_C(\mathrm{y}) = \max\left\{\mu_{C'1}(\mathrm{y}),\ \mu_{C'2}(\mathrm{y}),\ldots,\ \mu_{C'N}(\mathrm{y})\right\}$$

Notice that the output C is a fuzzy set. This fuzzy output can be defuzzified into a crisp output using one of the defuzzification technique [11].

The Mamdani model [10] is well known and presented in the literature in detail, so we do not include its detailed description here.

5. An Application: An Electric Power Deregulation Policy

The way we envision this application is that one takes a policy proposal: e.g., deregulation of electric power production, and then looks at the responses of various actors in the debate over the issues surrounding the policy, based on domain specific data provided.

One begins, perhaps, with a classification of actors by whether they are for, against, or neutral in regard to the policy proposed, then looks at the arguments they make, supporting their case or attacking the arguments of others. These arguments can be categorized in terms of CT. For instance, actors opposing deregulation of electric power production will say there is little or no need for it. A Colorado Public Utilities Commission (COPUC) questionnaire asked if the need for deregulation was strong, slight, or none. COPUC also asked if the competition engendered by such deregulation might hurt the environment. There exists a cross-tabulation of responses to these two questions: is there is a need for change? And, will the competition engendered by such a change threaten the environment?

We would hypothesize that Egalitarians would argue against deregulation, warning that a deregulated market would be unfair, penalizing the poor and rewarding the rich. Egalitarians tend to oppose most deregulatory policies since the inequitable effects of environmental degradation are an important concern for most Egalitarians, so we would suppose that those who deny there is a need for deregulation might also be worried about threats to the environment. We would expect individualists to favor deregulation on the ground that it won't hurt the environment, and expect Egalitarians to take the other position.

The cross-tabulation (collected data) shows that 21of 25 respondents say there is no need, or slight need, for structural change (i.e., deregulation), also say such change would threaten the environment. On the other hand, only 5 of the 19 who say that there is a strong need think that competition would threaten the environment.

Individualists tend more strongly to believe in the virtues of competition than do Egalitarians. We have here a clear division of respondents into two groups. At any rate, one can take responses to other questions asked in the COPUC questionnaire and see if the responses follow patterns similar to this one, and they do.

One can take this set of data (responses to the COPUC questionnaire), and assign respondents to the cultural categories. Then each category can be assigned a weight proportionate to the percentage of respondents who fit into it and predict the reaction to each policy proposal on the basis of its policy goal (i.e., whether it ought to be more or less appealing to each cultural type). The policy proposal may promote or threaten efficiency, equity, or order. These policy preferences are respectively those of individualism,

Egalitarianism, and hierarchies.

We would then inventory the actors who support or oppose, or are neutral about, the policy, and assign them to boxes, possibly, with a "power" weight corresponding to their number.

Suppose we find out that of 50 actors 25 seem to lean toward Egalitarianism, 20 toward individualism, and only 5 toward hierarchies. If these were the case, we could see that (assuming other power variables are roughly equal) those Egalitarians would be in a fairly good position to get their way, since they are a plurality and because hierarchies tend not to want to deregulate very badly.

Here, culture, of course, is only one of the inputs. Other inputs could be included such as economic interests, status interests, etc. Actors tend to use arguments that support their economic/status interests, but these arguments can often be seen as consistent or internally contradictory in terms of CT.

For this deregulation problem, we divided the society into several groups: (1) Producers of power (larger producers, small producers, and public-owned producers), (2) Consumers of power (large private consumers, large public consumers, and small consumers), (3) Regulators (federal, state, and local), and (4) Policy advocates (pro- or anti-deregulation, or neutral). An examination of the rationales of each group for their position would support the cultural classifications.

Policy advocates can only have opinions pro-deregulation, anti-deregulation or neutral about deregulation. So this group's membership function includes the following values (as example inputs):

$$policy\_advocates = \{strongly/pro\_deregulation, weakly/anti\_deregulation, weakly/neutral\} \quad (1)$$

All other groups have opinions about equity, efficiency, effectiveness, liberty, fairness and order of the deregulation. So their membership function consists of the following values:

$$\begin{aligned} Large\_producers \; = \; & \{medium/equity, small/efficiency, medium/effectiveness, small/liberty, \\ & small/fairness, medium/order\} \end{aligned} \quad (2)$$

Similar input values may be assigned to other social groups. We convert these groups including policy advocates to cultural classes such as

$$\begin{aligned} policy\_advocates \; &= \; \{0.8/H, 0.2/I, 0.3/E\} \\ large\_producers \; &= \; \{0.7/H, 0.4/I, 0.5/E\} \end{aligned}$$

by matching each group to cultural classes whose member functions consist of pro-deregulation, anti-deregulation and neutral about the deregulation and equity, efficiency, effectiveness, liberty, fairness and order of the deregulation like

$$\begin{aligned} Hierarchy \; = \; & \{mod\_pro/pro\_deregulation, mod\_anti/anti\_deregulation, \\ & mod\_neu/neutral, small/equity, small/efficiency, \\ & med/effectiveness, very/liberty, med/fairness, small/order\} \end{aligned} \quad (3)$$

$$Individualist \; = \; \{strong\_pro/pro\_deregulation,$$

$$weak\_anti/anti\_deregulation, weak\_neu/neutral,$$
$$very/equity, very/efficiency, very/effectiveness,$$
$$very/liberty, med/fairness, small/order\} \quad (4)$$

$$\begin{aligned} Egalitarian = \{&weak\_pro/pro\_deregulation,\\ &strong\_anti/anti\_deregulation, weak\_neu/neutral, small/equity,\\ &small/efficiency, small/effectiveness,\\ &med/liberty, small/fairness, small/order\} \end{aligned} \quad (5)$$

In detail the matching can be illustrated by the matching of policy advocates to cultural classes.

$$policy\_advocates = \{\mu_1/H, \mu_2/I, \mu_3/E\} \quad (6)$$

where μ_1, μ_2, and μ_3 are values in [0,1] to be calculated.

We calculate μ_1, μ_2 and μ_3 as shown below. Our basic interest here is not to calculate these values with the most efficient and accurate way possible, but only show a solution to this problem.

$$\begin{aligned} &module(strong\_pro - mod\_pro * \mu_1 - strong\_pro * \mu_2 - weak\_pro * \mu_3) +\\ &module(weak\_anti - mod\_anti * \mu_1 - weak\_anti * \mu_2 - strong\_anti * \mu_3) +\\ &module(weak\_neu - mod\_neu * \mu_1 - weak\_neu * \mu_2 - weak\_neu * \mu_3) \end{aligned} \quad (7)$$

where all these fuzzy words are from the pro-deregulation, anti-deregulation, neutral parameters of (1), (3), (4) and (5), is minimal.

Using the same method we can get all groups in terms of cultural classes. So now all groups are converted to cultural classes like

$$\begin{aligned} policy\_advocates &= \{0.8/H, 0.2/I, 0.3/E\}\\ large\_producers &= \{0.7/H, 0.4/I, 0.5/E\} \end{aligned} \quad (8)$$

Similarly, the conversions can be done for the other social groups.

According to the fuzzy model that was described in the previous section, we have the table in Figure 6showing how much Hierarchy, Individualist or Egalitarian cultural groups support, oppose and are neutral to the policy given.

	support	**oppose**	**neutral**
E	weak	strong	weak
H	mod	weak	strong
I	strong	weak	weak

Figure 6. The Opinions of the Cultural Groups on Electric Deregulation Policy

Using a mapping technique (i.e., composition) between groups and the table above, we can get each group's opinion of *support, oppose* and *neutral* even with a degree if necessary. For example,

$$policy\_advocates = \{mod/support, weak/oppose, strong/neutral\}$$
$$\text{and}$$
$$large\_producers = \{strong/support, weak/oppose, weak/neutral\}$$

Lastly, by taking the union all these opinions together, we can get the final result as follows: result for support: *strong,* result for oppose: *weak,* result for neutral: *moderate*

That is, the output is: { *strong/support, weak/oppose, moderate/neutral*}

6. Conclusion

In this paper we have described a computational model for integrated assessment based on Cultural Theory (CT). While utilizing CT in integrated assessment models (IAMs), we also used the fuzzy set theory to deal with the inexactness or uncertainty inherent in both CT and IAMs. Our fuzzy-based modeling approach provides a mechanism for understanding the reaction of a populace to environmental policy decisions. We modeled and implemented an application, namely deregulation of electric power production, by using our fuzzy-based computational model described here. Using this model for more complex applications is one of our on-going research efforts in the short term.

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