Independence of Functions of Verbal Hedges from Modificands

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Abstract: *Independence of functions of verbal hedges from modificands is important issue to implement hedges to computers as fuzzy sets. In this paper, we aim to discuss the independence experimentally. First, we confirm that the differences of the modificands do not affect the functions of the hedges, based on the membership functions for the hedges obtained from 72 subjects. Then, we describe treatment of context dependability of hedges comparing the Zimmer's model and the model proposed in this paper.*

Keywords: *verbal hedge, context dependability*

1. Introduction

Back ground of this work: Verbal hedges, for example, "*very*" or "*slightly*," have been used to modify extent of a modificand, that is, a membership function for a fuzzy set, in many applications that include vagueness, such as control rules in fuzzy control systems, extent that users in fuzzy expert systems describe and so on [1-2]. So expressing the function of the verbal hedge is one of the important topics on the fuzzy set theory. As you know, *Zadeh* has already picked it up in his first paper on the fuzzy set theory [3]. Actually, many researchers studied shape of the membership function, that is, how to formulate the shape, in the view of using the verbal hedges on computers or analyzing psychological aspects of them [4-7].

Especially, we have to formulate the hedges to use them for many applications on computers. One of the most popular ways to employ the hedges within them is to construct a database in which each hedge is denoted with one suitable mathematical formula. Therefore, the theme of how to determine the formula for each hedge has attracted interest of many researches for long time. For example, the way to describe the function of "*very*" is one of the most famous examples. Two different formulations of "*very*" have been proposed and verified through psychological experiments [2-3, 5-8].

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Importance and originality: In above applications, there is an implicit and important assumption on the hedge's function: *it works equally over different modificands*, that is, its function is independent of the attributes that it modifies. If the formula would differ among the modificands, it had to be determined for each modificand used in each application. Moreover, if it were to do except an error in identification of the formula, unstableness over time and individual difference, a human being has to memorize all the verbal expressions that consist of one hedge and tremendous modificands.

As previous studies related to this issue, *Takemura* [9] experimentally examined assignment of numeric probabilities to a set of linguistic probability terms such as "*very high probability*," "*slightly low probability*" under four different scenarios: abstract probability, and probabilities of rainfall, passing an exam, and taking a disease. He concluded that the difference among those scenarios did not almost affect those assignments. Meanwhile *Zimmer* [10-11] found that the interpretation of quantifiers related to probability, such as "*all,*" changed with the contexts. He proposed "*the scope functions*" to explain the obtained results.

In both the cases, the context dependability of the hedges' functions concerning probability, so-called "*the context effect*" was examined, but comparison among attributes has not been performed. So it is important to validate the assumption experimentally.

Purpose of the work and results obtained: In this paper, we aim to discuss the independence of the functions of the verbal hedges from the modificands through the membership functions identified by seventy-two subjects. In section 3, we confirm the independence of four hedges' functions from four bipolar modificands. The results obtained show that the differences of the modificands do not affect the hedges' functions. In addition, disagreements among the functions for the same hedges over the different modificands are explained by the error of identification of them. In section 4, we discuss problems of the Zimmer's scope function and propose another explanation on the context dependability based on our obtained results.

2. Experimental methods

Subjects: Subjects were undergraduate and graduate students and faculty staff at Kyoto Institute of Technology. All of them were volunteers. At first, *seventy-two* subjects were divided into *six* groups named *G1* to *G6* respectively and were engaged in the experiment. Then, extra subjects participated additionally until the number of effective data to analyze became up to *twelve* per one group. In the results, *ninety-one* subjects participated in this experiment. All the subjects were native Japanese speakers, so that they were able to understand the meanings of the hedges and the modificands exactly.

Hedges and modificands: Four of the hedges were used in the experiment: "*very* (非常に, *in Japanese*)," *"quite* (かなり)," "*slightly* (ちょっと)," "*neither ~ nor ~* (どちらとも言えない)." The attributes were as follows: "*tallness*," "*beautifulness*," and "*comfort*." Each attribute was used in forms of both a pair of affirmation and antonym and a pair of affirmation and negation, for example, both "*tall – short*" and "*tall – not tall*" respectively. We named the former pair "*an antonymous expression*" and the later "*a negative expression*." Besides the three attributes, "*linguistic truth values*," such as "*very true*" or "*slightly false*" were used in the antonymous expression. ***Table 1*** shows assignment of the modificands for each group. Each group took three modificands, namely, one of the three antonymous expressions, one of the three negative expressions with the different modificands each other, and linguistic truth value.

Table 1: Assignment of modificands to six subject groups.

Grp	Antonymous expression	Negative expression
G1	short – tall	not comfortable – comfortable
G2	short – tall	not beautiful – beautiful
G3	uncomfortable – comfortable	not tall – tall
G4	uncomfortable – comfortable	not beautiful – beautiful
G5	ugly – beautiful	not tall – tall
G6	ugly – beautiful	not comfortable – comfortable
All	false – true	(Left-hand – Right-hand)

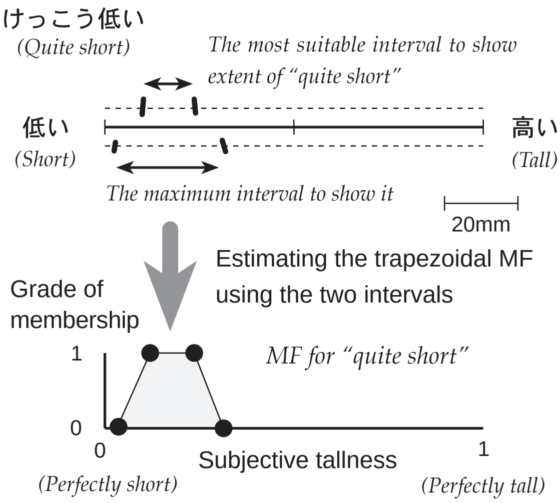

Figure 1: An example of graphic rating scale used (upper) and trapezoidal membership function estimated from the rating results (lower). Each subject rated the extent of verbal expression located in left upper by marking four boundaries in pen or pencil. Both the verbal anchor beside rating scale were assigned according to *Table 1*. The trapezoidal membership function for each verbal expression was estimated on universe of discourse for subjective extent: [0, 1] based on the four boundaries.

Procedures: The experiment was executed for each subject using a set of questionnaires printed in Japanese. Seven of the verbal expressions with the same modificand were printed on one page. In each group, a subject was assigned to one of the six possible permutations of three modificands to counterbalance an influence on presenting order of the modificands.

The subjects answered the extent of the linguistic truth values, the antonymous expressions and the negative ones by using the modified fuzzy graphic rating scale method [12-13]. ***Figure 1*** is an example of the questionnaires used in this experiment. This scale is 10 *cm* in long. There are three anchors (ticks) at both ends and center on the scale, and a pair of verbal anchors listed on *Table 1* beside each end. The left end corresponds to the maximum extent of the antonymous or negative modificand and the right end corresponds to the maximum extent of the affirmative modificand. In *Figure 1*, for example, the left end and the right end correspond to "*perfectly short*" and "*perfectly tall*," respectively. These were instructed to subjects by printing on the questionnaires and by word of mouth. The subjects answered both "*the most suitable interval to show extent of a verbal expression*" and "*the maximum interval to show it*" by drawing the four boundaries on the bipolar graphic rating scale in pen or pencil.

3. Results

Preparing the data obtained: For each subject, a trapezoidal fuzzy set for each hedge is calculated based on the two intervals obtained. The left end and the right end on the graphic scale correspond to *zero* and *unity* respectively. First, “the most suitable interval to show extent of the verbal expression” is assigned to unity level set, whose membership grade is at *unity*, while “the maximum interval to show it” is assigned to support set whose membership grade is greater than *zero*, as shown in *Figure 1*. Next, membership grades between the two level sets are interpolated linearly by connecting two lower (left-hand) edges of the two level sets and two upper (right-hand) ones respectively.

Evaluation indices: Evaluating independence of hedges' functions from the modificands requires some indices to describe a relationship of two fuzzy sets. *The matching measure* and *the similarity measure* [14] are first candidates for the indices, since all the graphic rating scales used in this experiment are isometric. The matching measure is obtained from a maximum membership grade for a logical product set between fuzzy sets, while the similarity measure is obtained from a ratio of cardinality of the logical product set to cardinality of the logical sum set. However, we could not use the matching measure, since 91.4 % of all the data in this experiment became *unity*. Meanwhile, value of the similarity measure decreases by either shift in position or difference of width between two fuzzy sets (See ***Figure 2***). So it is insufficient to clear the source of the decrease.

We thus utilize as the indices both a value subtracting from unity a distance between gravity centers for

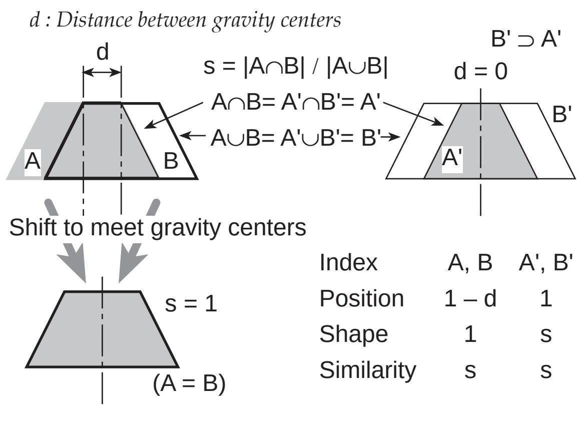

Figure 2: Illustration of three indices for evaluating difference between two fuzzy sets. In the above examples, A' and B' are equal to A∩B and A∪B respectively under the condition where B' include A', and A does not include B and vice versa. In case of these examples, the similarity measure cannot distinguish difference between the two cases.

two fuzzy sets and the similarity measure of two fuzzy sets matching the gravity centers [13]. Hereafter, we call the former *the index of the position*, and the later *the index of the shape*. The former shows extent of the shift in position, and the later shows extent of the difference in shape mainly, as shown in *Figure 2*. Closer both index values get to *unity*, more two fuzzy sets are similar in each sense.

Examples of these index values: First we calculated the two indices for three combinations among three verbal expressions that have the same hedge, such as “*very true* versus *very tall*” and so on, for each subject. Then mean values and standard deviations over twelve subjects for each group were made. ***Table 2*** shows the integrated results. As seen from the table, we can find the tendencies that in the position index the values for hedges laid near by three ticks, especially “*neither ~ nor ~*,” get higher than the ones for hedges laid between the ticks, such as “*quite*,” and in the shape index the former gets lower than the later contrary.

Agreement among the modificands: First, we investigate agreement with hedges' functions among the modificands based on the two indices. As mentioned above, both the indices get *unity* when two fuzzy sets agree exactly. So we execute t-test of the hypothesis that a sample mean of each index shown in *Table 2* matches a population mean, that is, *unity*, for each combination of the expressions (see *Table 1*), each group and each hedge. As a result, all the hypotheses of the two indices are rejected at significance level of 5%. Hence these results reveal that the functions of those hedges among the modificands do not exactly agree.

Comparing among the combinations of the modificands: Next, we examine influences of combination of the modificands on the hedges' functions. So we do *ANOVA* in one-way layout for each hedge and each index by treating same combination of the modificands for different groups as different elements, namely, *eighteen* elements. As seen from *Table 2*, only significant effect is detected in the position index for “*quite*” with antonymous or negative modificands at the significance level of 5%. Consequently we conclude that the differences between the combinations of the modificands do not affect the two indices.

Discussions: Let us think cause for the decrease of the index values. *Yoshikawa* [15] has already examined stability of hedges' functions over time elapsed. He had four subjects identify nineteen linguistic truth values, which contained the same truth values used in this experiment, at six times using the same graphic rating scales used in the experiment. We add to *Table 2* the mean values and the SDs for two indices calculated over 60 data (15 possible combinations of the six trials × 4 subjects). To evaluate the difference between those two results, we executed unpaired t-test of difference between the mean value calculated over 216 data (72 subjects × 3 combinations) and the mean value in reference [15] for each hedge. As a result, the differences concerning five hedges in the position index and one hedge in the shape index are significant at 10% level respectively. As seen from the table, however, the greatest difference between the mean values in the position index is 0.019 and this difference corresponds to 1.9 *mm* on the rating scales used in both the experiments. Considering errors of marking in pen or pencil and measurement using ruler, these results reveal that the decreases of the index values obtained from this experiment are similar to the ones from the repeated measurement with the same modificands. Consequently we can conclude that the decreases are not caused by the differences between the modificands, but by inherent vagueness contained in the hedges, marking error and measuring error.

Table 2: Results obtained from this experiment.

Combination		with Antonymous / Negative modificands								with Affirmative modificands					
		very		quite		slightly		Neither ~ nor		slightly		quite		very	
	Grp	shape	position	shape	position	shape	position	shape	position	shape	position	shape	position	shape	position
T-A 1)	G1	0.822	0.986	0.812	0.967	0.745	0.976	0.680	0.993	0.718	0.969	0.749	0.942	0.680	0.981
	G2	0.776	0.974	0.743	0.942	0.871	0.985	0.676	0.994	0.807	0.974	0.776	0.948	0.782	0.981
	G3	0.699	0.970	0.744	0.931	0.780	0.963	0.604	0.994	0.781	0.963	0.761	0.924	0.722	0.978
	G4	0.687	0.972	0.763	0.933	0.726	0.949	0.663	0.988	0.821	0.943	0.744	0.945	0.727	0.981
	G5	0.663	0.975	0.746	0.957	0.689	0.964	0.577	0.991	0.744	0.969	0.711	0.953	0.599	0.970
	G6	0.690	0.972	0.784	0.939	0.769	0.966	0.641	0.991	0.732	0.958	0.785	0.933	0.716	0.983
T-N 1)	G1	0.680	0.982	0.765	0.953	0.823	0.958	0.764	0.993	0.789	0.955	0.785	0.955	0.710	0.984
	G2	0.721	0.973	0.812	0.918	0.786	0.969	0.677	0.996	0.798	0.979	0.817	0.962	0.698	0.977
	G3	0.715	0.968	0.678	0.908	0.760	0.935	0.592	0.993	0.752	0.960	0.706	0.914	0.732	0.976
	G4	0.671	0.969	0.741	0.946	0.763	0.962	0.631	0.991	0.776	0.952	0.740	0.939	0.665	0.977
	G5	0.705	0.973	0.719	0.950	0.718	0.955	0.662	0.994	0.751	0.964	0.747	0.939	0.676	0.969
	G6	0.748	0.976	0.749	0.910	0.767	0.954	0.588	0.990	0.795	0.957	0.793	0.913	0.707	0.979
A-N 1)	G1	0.722	0.981	0.768	0.954	0.821	0.963	0.709	0.991	0.836	0.963	0.812	0.942	0.860	0.991
	G2	0.774	0.978	0.768	0.917	0.755	0.968	0.782	0.994	0.803	0.971	0.793	0.958	0.759	0.974
	G3	0.661	0.968	0.786	0.897	0.761	0.949	0.775	0.994	0.812	0.962	0.800	0.952	0.734	0.980
	G4	0.721	0.973	0.721	0.946	0.752	0.954	0.594	0.990	0.840	0.947	0.736	0.934	0.720	0.980
	G5	0.706	0.976	0.731	0.969	0.777	0.955	0.801	0.992	0.790	0.968	0.777	0.957	0.712	0.974
	G6	0.732	0.971	0.679	0.908	0.745	0.965	0.720	0.992	0.810	0.962	0.745	0.915	0.713	0.979
mean 2)		0.716	0.974	0.751	0.936	0.767	0.961	0.674	0.992	0.786	0.962	0.765	0.940	0.717	0.978
SD		0.195	0.022	0.155	0.057	0.146	0.036	0.216	0.007	0.132	0.041	0.127	0.047	0.195	0.020
ANOVA 3)		0.55	0.55	0.68	1.88*	0.96	1.17	1.36	0.79	0.82	0.60	0.78	1.29	0.87	0.81
repeated 4)		0.714	0.979	0.805	0.925	0.781	0.980	0.657	0.994	0.786	0.972	0.782	0.947	0.715	0.969
SD		0.153	0.017	0.103	0.059	0.116	0.017	0.201	0.004	0.108	0.019	0.104	0.048	0.182	0.024
t-test 5)		0.10	1.67*	3.22#	1.30	0.78	5.81#	0.56	1.86*	0.02	2.67#	1.00	0.92	0.09	2.77#

1) T: linguistic truth values, A: antonymous expressions, N: negative expressions (see Table 1 in detail).

2) Averaged over 216 data (72 subjects × three combinations).

3) ANOVA in one-way layout over 18 elements (6 subject groups × 3 combinations) considering subjects as repetation. Each figure stands for F-value. The symbol '*' means significant effect at 5 % level.

4) Used data from the reference [15]. Averaged over 60 data (4 subjects × 15 combinations of 6 trials).

5) T-test between the two mean values shown above. Each figure stands for t-value. The symbol '*' and '#' mean significant difference at 10, 1 % level respectively.

4. General discussions

Expansion of Zimmer's model into general physical stimuli: In the literatures [10-11] *Zimmer* has proposed the scope function to describe context dependability of quantifiers. The context dependability in the literatures means that "*the standard meaning of quantifiers is modified by the subjects knowledge about the normal scope of discourse in the contexts* (*Zimmer* [11], pp. 84)." The scope function means a filter for membership grades. For example, in the context of everyday events extreme judgments are often shunned, so that the membership grades in corresponding ranges are decreased (See upper illustration in ***Figure 3***).

In those literatures *Zimmer* has described only the quantifiers concerning probability that are defined on numeric occurrence rates. However, the context dependability of hedges is seen not only in probability, but also in extent of general physical stimuli. When we will expand the Zimmer's model for treating the context dependability on occurrence rate into the general physical stimuli, we can adopt two methods. The one is as follows. First we replace the universe of discourse common to the standard functions, the scope function, and the context dependent functions, that is, occurrence rates, into given subjective extent, which corresponds to given physical stimuli but is independent of range of them. Next the context dependent functions determined on the subjective extent are mapped onto the physical stimuli as shown in *Figure 3*. This way, however, is inconsistent with the results that differences among the modificands do not affect context dependent functions on different subjective extent by reason that linguistic truth values are interpreted in the context of natural sciences, and the other three attributes do in the everyday events. Therefore, as the other way, only the standard functions and the scope function are projected from the subjective extent upon the physical stimuli before calcu-

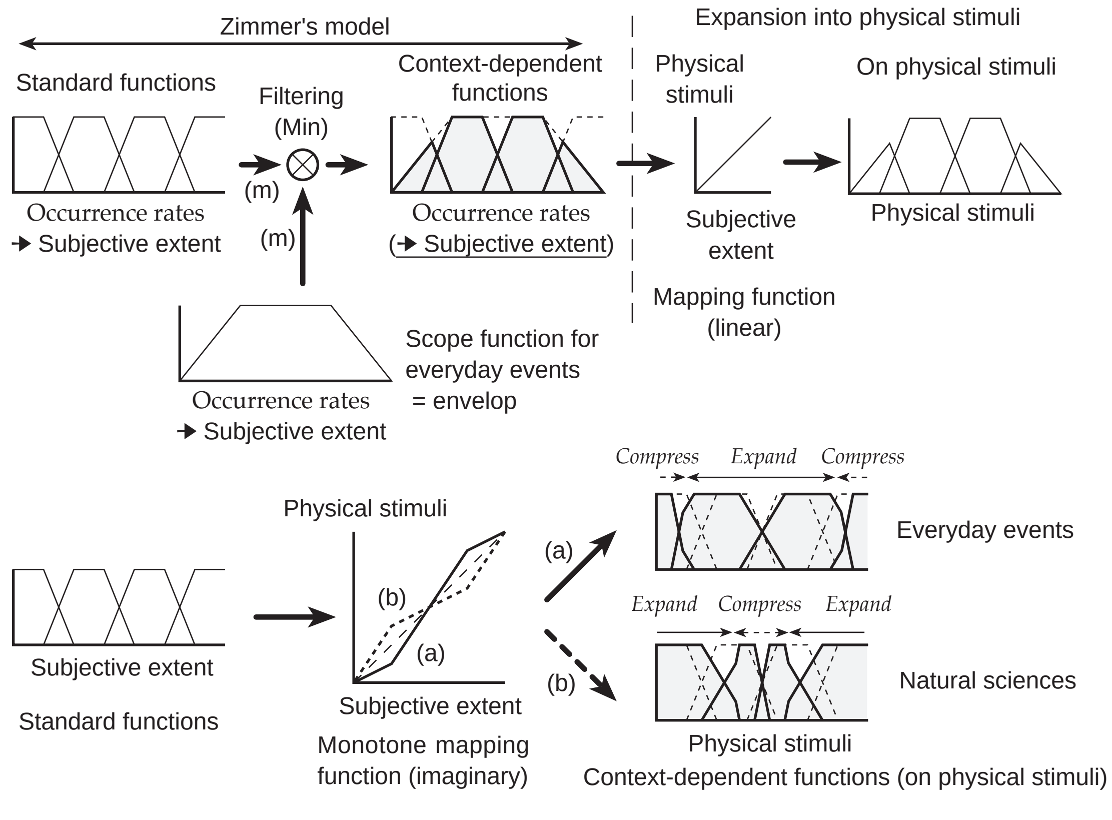

Figure 3: Expression of context-dependent functions for hedges on general physical stimuli continuum in Zimmer's and proposed model. When we will expand context-dependent functions for hedges on numeric occurrence rates into physical stimuli in Zimmer's model (upper figure), we can adopt two ways: One is that the universes of discourse common to standard functions, scope function and context-dependent functions, that is, numeric occurrence rates, is replaced into universe of discourse for the subjective extent, and then the context-dependent functions are mapped onto given physical stimuli continuum. This way, however, is inconsistent of the result that context-dependent functions on subjective extent are not affected by difference among attributes. Consequently, the standard functions and the scope functions are mapped onto the physical stimuli before calculating the context-dependent functions (at the position (m) in the upper figure). Meanwhile, trimming monotone mapping functions from the subjective extent to the physical stimuli adequately, we can offer the effects similar to the scope function offers (lower figure).

lating the context dependent functions as shown at the position (m) in *Figure 3*.

Proposal model: We may generalize the Zimmer's model using the later way. However, existence of both the scope functions and the mapping functions complicates the expanded model. *Zimmer* had to use the scope function to describe context dependability since the standard functions were determined on the numeric occurrence rates, in other words, there was no mapping function in the original model apparently.

Meanwhile, the mapping function from subjective extent onto physical stimuli can offer the context dependent functions on physical stimuli by affecting the elements on the subjective extent, but not the membership grades. As lower illustration in *Figure 3*, the similar context dependent functions obtained from the Zimmer's model are realized by trimming arbitrary monotone mapping function adequately. For example, we can explain the context dependability on the numeric occurrence rates, considering subjective extent of occurrence as the subjective extent in the proposal model. Consequently, we recommend this model from the point of ease to implement on computers.

5. Conclusion

Through the experimental study, we have confirmed that the differences of the modificands do not affect the functions of hedges. Moreover, we have proposed the new model for treating the context dependability of hedges that *Zimmer* has indicated. However, the model proposed in this paper has not yet been validated by experiments. So we need to validate this model and compare with the Zimmer's model experimentally.

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