Application of fuzzy logic to improve the Likert scale to measure latent variables

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ABSTRACT

The research studied the process of improving the Likert scale based on fuzzy logic to measure latent variables and to compare the quality of the data as measured by the improved Likert scale with data measured by the Likert scale. Qualitative study and survey study were used as the research methodology. Data analysis included content analysis and statistics comprising the arithmetic mean, standard deviation, standard error, consensus index, and the Kolmogorov—Smirnov test. It was found that the Likert scale could be improved by using Mamdadi fuzzy inference which included four important steps: (1) fuzzification, (2) fuzzy rule evaluation, (3) aggregation, and (4) defuzzification. A comparison of the two different approaches showed that the data measured using the improved Likert scale was more suitable to be analyzed with the arithmetic mean and standard deviation than the data measured using the Likert scale. More importantly, the distribution of data measured by the improved Likert scale was normal with a lower standard error, making it appropriate for data analysis for statistical inference.

Introduction

Internal validity of quantitative research is a measured validity. Thus, the instrument which is used to collect data on the variables measured is important. Subjective variables are latent traits—they are not directly observable or measurable. Instead, they are measurable through feelings, behaviors, expressions, and personal opinions, and data can be acquired using a questionnaire. The Likert scale is one of the popular instruments to measure such latent traits. The scale was introduced by Likert (1932) and consists of a series of questions which are indicators of the latent traits. Each question has a five-scale response: least, less, moderate, more, and most with the scores for the scale being 1, 2, 3, 4, and 5, respectively. Edward (1957) stated that the scores in question are based on an interval scale as they are acquired through psychological scaling. The latent variables are measured by the combined scores of all questions, which are on an interval scale (Tirakanan, 2008, p. 57). However, many scholars have argued that naturally, in the Likert scale, the choice or answer is only the data organized on an ordinal scale (Hodge & Gillespie, 2003; Pett, 1997). With reference to the Likert scale, Cohen, Manion, and Morrison (2000) stated that the interval range of different levels are not equal in value. The Likert scale, thus, should be arranged on an ordinal level. It is inappropriate to analyze the data using addition, subtraction, division, or multiplication. Furthermore, it is inappropriate to analyze such data using the arithmetic mean and standard deviation (Clegg, 1998). Thus, it is inappropriate to measure the latent variables by combining the scores of all the items from a Likert scale. In addition, Sukasem and Prasitratsin (2007, p. 2) explained that researchers in general would combine the scores from each item, and then use the combined scores to measure

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the variables, which is incorrect as each item is unequal in its weight.

Because of the problems described above, many attempts have been made to deal with this issue and to develop a suitable scale. One of the methods is fuzzy logic. It was developed from a fuzzy set by Zadeh (1965). Lalla, Facchinett, and Mastroleo (2004) and Li (2013) applied fuzzy logic to improve the Likert scale, which resulted in a new scale known as the fuzzy Likert scale (FL). Li also compared the efficiency of this scale with the Likert scale and found that measuring the variables using the fuzzy Likert scale was more accurate than measuring with the general Likert scale. For the reasons described, the current research tried to determine the process for applying fuzzy logic to the Likert scale to measure the latent variables in a more valid and efficient manner. It is expected that the research would lead to measuring methods which are more effective and appropriate.

Literature Review

Attitude Measuring Using the Likert Scale

Attitude is an important variable with latent traits. According to Saiyot and Saiyot (2000, pp. 52–60) attitude means the emotions and feelings of a person coming from an experience in learning something called a target. From learning, there appears a feeling of like or dislikes, agreement or disagreement. That tendency runs from a low to a high intensity. Likert (1932) was the first to propose the method to measure an attitude by combining the scores of each question. This method was called summated rating (Tirakanan, 2008, pp. 191–192). However, the Likert scale has a disadvantage; it is unclear whether the data measured are based on an ordinal level or interval level (Jamieson, 2004). Although Likert assumed the data acquired were based on an interval level, it can be observed that the data measured by the Likert scale are based on ordinal order (Hodge & Gillespie, 2003; Pett, 1997). Data on an interval level show an equal range for two consecutive values, whereas the feeling measured by the Likert scale has a different interval range between two levels (Cohen et al., 2000). As a result, the Likert scale cannot estimate varying interval ranges between data (Russell & Bobko, 1992). What can be measured by the Likert scale is only the information which cannot distinguish the interval. Furthermore, alternative forms of the Likert scale are similar. Respondents have to choose only one option, which is unrealistic and unreliable (Hodge & Gillespie, 2003; Orvik, 1972).

Consequently, due to these explained disadvantages of the Likert scale, it is apparent that the data acquired may be unreliable. Several academics have attempted to improve the Likert scale. Chang (1994) proposed that more levels of the scale should be added so that more details could be obtained. However, it may be difficult for respondents to identify their genuine feelings at such a level of detail (Russell & Bobko, 1992). Albaum (1997) proposed two steps. First, there are only two choices: agree or disagree. After that the respondents have to answer according to the intensity level: less or more. By

doing this, it is possible to avoid the answer of 'moderate'. Hodge and Gillespie (2003) proposed that the question should be divided into two parts. First, the leading question was raised to encourage respondents to express their feelings, which was followed by a secondary question on the contents of the leading questions, both positive and negative. The respondents can choose from 0 to 10 depending on the intensity. However, this method may not be effective, as the respondents can get lazy in answering all the questions. Li (2013) proposed the construction of the fuzzy Likert scale (FLS). The respondents have only one choice. Its membership value lies between 0 and 1. That is, if an opinion is inclined towards that choice, its value is set at 1. On the contrary, if the opposite happens, the answer is an ordered pair. The first is an answer and the second is the value of membership. The acquired answer is adjusted into the fuzzy Likert scale:

$$FLS = \frac{\sum u_o A_o}{\sum A_o} \tag{1}$$

where, FLS is the fuzzy Likert scale. u_o is to the level of an opinion according to the Likert scale, and A_o is the area of the membership function that is truncated by the membership value. Although the improved scale may provide more details and greater reliability, there are disadvantages as respondents may find it hard to decide and they may get bored. As a consequence they may not give genuine answers.

Fuzzy Logic

Fuzzy logic originated from the dissertation of Zadeh (1965). It is based on the principles that out of all things in the world, there is a small portion that is certain. Things are mainly uncertain. The things which are uncertain are characterized by two traits: random and fuzzy.

The classical set is an undefined term, as it characterizes a group consisting of various members which are identifiable. However, there are a lot of groups which cannot be explicitly identified. The group having such characteristics is called a fuzzy set. It refers to the set of things for which it cannot be identified whether each thing in question is a member of the set or not. Nevertheless, it is possible to indicate the tendency of something to be a member of a set through the membership function whose value ranges between 0 and 1. If the membership value of something gets closer to 1, that has a high level of membership. By contrast, if the membership value gets closer to 0, it has a low level of membership.

Definition. If X is not an empty set, x is any member of X and A is a fuzzy set whose membership function is μ_A, then fuzzy set A can be written in the form of a pair set as follows:

$$A = \{(x, \mu_A(x))/x \in X\}, \ \mu_A(x) : X \rightarrow [0, 1]$$

Membership function is used to determine the membership level for x. There are many types of membership function. Which type is to be used depends on suitability