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"My personal forecast": the digital transformation of the weather forecast communication using a fuzzy logic recommendation system

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Abstract. Communicating the scientific data of the weather forecasts to the general public has always been a challenge. Using computer graphics' visual representations to convey the message to average people has certainly helped a lot to popularize the weather forecast consumption by the general public. However, these representations are not information rich since they are abstractions; moreover they are not very actionable on the receiver side to help one decide how s/he will "live" the forecast weather conditions and prepare appropriately. Therefore, there is a need to personalize the forecast based on past experience of the individuals and their personal needs. The forecast has to become more human- and needs-oriented and more focused to the particular requirements of each individual person. We, thus, propose a new co-creation process in which the audience is called to provide a daily feedback on how they lived the weather conditions personally on a daily basis, so that, "my personal forecast" can be produced making the forecast more actionable on the user side. Preliminary such attempts focused solely on the "feels like" temperature forecasts. To arrive at the "my personal forecast", artificial intelligence based recommender systems need to be applied, using fuzzy logic as the appropriate method for the user to express the individually perceived weather conditions.

1 Introduction

Meteorological data representation has been standardized long ago to facilitate communication and symbols (Trafton and Hoffman, 2007). Although very useful in helping the understanding of complex weather situations, these visualization system have limitations. "For example, too many complex parameter adjusting are discommodious for the forecaster, can't support the experience or knowledge of the forecaster which formed in past analysis of weather situations" (Yongguang, 2004). The current state of the art of visualization in meteorology includes visualization techniques from the fields of display design, 3D visualization, flow dynamics, feature-based visualization, comparative visualization and data fusion, uncertainty and ensemble visualization, interactive visual analysis, etc. (Rautenhaus et al., 2017). The pursuit for human-centered, easily assimilated and well defined weather conditions communication is still ongoing.

Translating the message to the general public is an even more challenging task. Visual representations try to convey the message of the weather conditions in a way that is assumed to be very close to the understanding of the general public as well as to how people "live" the weather conditions. However, visual representations may have different interpretations by various stakeholder groups. Moreover, abstraction as a means of easier communication loses information depth; it is not an information rich method of advising an action-oriented behavior by individuals who need to respond appropriately to weather conditions' information.

This paper is a research idea on the digital transformation of the weather forecast communication with a view to personalize the forecast to make it more suitable for assimilation by individuals who live and feel the weather conditions. The personalized forecast will be the result of an artificial intelligence (AI) based recommender system using fuzzy logic that will "translate" the weather conditions based on how the

person lived similar previous weather conditions in the past, according to his/her own judgement. In essence, this paper is a research roadmap for a big project that will demonstrate how the weather forecast can be digitally transformed to become more relevant on a mass personalization basis.

2 Towards the digital transformation of the weather forecast.

Digital Transformation is the digital capabilities' driven revamping of the value creation process for an organization, a product or an asset in such a way as to increase efficiency, effectiveness, customer orientation, personalization of offerings and risk reduction (https://www.cio.com/article/230121/what-is-digital-transformation-2.html, last access: 21 March 2022).

The trip towards personalizing the weather conditions' message has already begun. "Feels like" temperature takes into account factors such as wind and humidity to find out how the weather would feel if one actually goes outdoors. For measuring the feels like temperature, meteorologists use the Heat Index (HI): "HI is an index that combines air temperature and dew point (relative humidity) to determine the human-perceived equivalent temperature. At 85 degrees Fahrenheit with 10% humidity, the temperature feels closer to 79 degrees, but at 90% humidity, it will feel closer to 100 degrees. These values are found using a complex formula, but thanks to the National Weather Service, you can find the 'feels like temperature' using this simple calculator" (https://www.scienceabc.com/eyeopeners/what-is-feels-like-temperature-and-how-is-it-measured.html, last access: 21 March 2022).

What really people need? In essence, people need to know whether (a) they have to get dressed heavier or lighter, (b) humidity will be higher or lower than yesterday – especially for those with musculoskeletal problems, (c) It will be more or less rainy than yesterday, (d) the roads will be more slippery than yesterday, (e) it will more or less windy than yesterday. This has to do with personal feeling, perceptions, biological/health robustness, very micro-climate conditions etc. The research idea, explained in the next section, addresses the requirement of a forecast that is meaningful and actionable on the individual level.

3 Fuzzy logic and the weather forecast

Fuzzy logic is a mathematics theory to deal with uncertainty by assigning linguistic descriptions to data sets whose meaning do not correspond to a crisp numeric value but rather to a set of possible numeric values. Upon these data sets, domain specific functions can be defined to provide meaningful results within a good enough degree of approximation that makes sense to the recipient. Input membership functions allow non-crisp definitions of the boundaries for the fuzzy

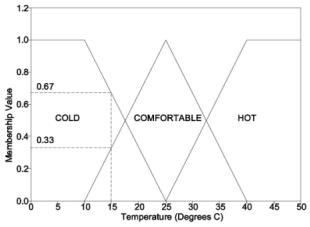

Figure 1. Room temperature from Hayward and Davidson (2003).

words used to describe the meaning of the domain specific values of the dataset.

The use of fuzzy logic (i.e. data values and operations that use uncertainty and approximations to produce good enough, tailored results for problems where crisp values cannot be used) is not new in the area of meteorology and weather forecast. Fuzzy logic-based weather forecasting models have been thoroughly discussed my many research papers (Al-Matarneh, et al., 2014; Saima et al., 2011; Tektaş, 2010; Agboola et al., 2013; Janarthanan et al., 2021).

The reason why fuzzy logic is particularly useful when communicating the weather forecast is eloquently explained by the following excerpt: "Each user of a descriptive word has a somewhat different definition of the value carried by that word. To use a common example, hot, when used to describe the temperature of a room, conveys very different thermometer readings to someone from a nordic climate than to someone from the tropics. This lack of precision is not random so vagueness cannot be treated by statistical means.

A fuzzy variable is one of the parameters of a fuzzy model which can take one or more fuzzy values, each represented by a fuzzy set and a word descriptor. The room temperature is the variable shown in Fig. 1. Three fuzzy sets: hot, cold and comfortable have been defined by membership distributions over a range of actual temperatures. The power of a fuzzy model is the overlap between the fuzzy values. A single temperature value at an instant in time can be a member of both of the overlapping sets." (Hayward and Davidson, 2003). Since there aren't crisp boundaries between the sets, a given temperature of, say, 12°, can be cold for some people and comfortable for some others, making this value a member of different data sets. Here is where fuzzy logic is useful and meaningful.

Apart from temperature, meteorological data themselves are sometimes expressed as probabilities, for example 40 % chance of rain, which makes communication to the general public even more difficult to interpret and the use of fuzzy logic for modelling these ambiguities more appropriate.

4 The research idea

Modern marketing and communications theory advocate the use of the co-creation paradigm (Hilton et al., 2012) "as planned resource integration behaviours by actors intended to

realise a value proposition". The personalized weather forecast can only be shaped through such a process where scientific product (the forecast) is blended with user experience to produce higher communication value, more meaning and actionable at the individual level.

Our model proposes the integration of the objective knowledge produced by the scientific forecast with the subjective opinion of the receiver of the forecast to implement the co-creation process of a new, digital, personalized forecast service. The user provides continuous feedback upon how one lives, assimilates, comprehends, perceives the weather conditions so to train the recommender system, so that this can provide after a while recommendations which are more appropriate for the specific user – individual. The user feedback is simply an expression of how the user understands today's weather conditions that s/he has lived, expressed in fuzzy terms, such as:

- Temperature – hotter/colder in comparison to previous day,
- Humidity – more or less, depending on body reactions rather than numbers,
- Umbrella taking or not
- Windy – more or less, etc.

Suppose that an individual watches the weather forecast through a web site, where s/he enters daily personal perceptions on the weather conditions, such as those above, using uncertain / fuzzy terms: {too little/little/same/more/much more/too much} etc. The user is practically asked to provide a fuzzy rating on how s/he feels the today's temperature as compared to yesterday's weather. Collecting such data on a daily basis for some time, the recommender system can be trained to produce recommendations which are tailored to what the specific individual should expect as weather conditions for her/his own way of feeling. The frequency of collecting user feedback need not be daily; the daily basis is only proposed for practical reasons so as not to disturb people several times a day asking them to provide feedback. However, in areas where the weather usually changes rather rapidly within the day, users could be asked to reply in the morning, in the afternoon and in the evening to provide more data to the system for training, for different weather conditions. Usually, people watch the weather forecast once to two times per day (Pajarillaga and Vargas, 2021).

This paper proposes that a personalized weather forecast is the outcome of the scientific weather forecast combined with the subjective opinion of the user's perception of the weather conditions – the "personal difference" as we name it. So, personalization is based on these two principles:

1. My_personal_forecast = f (curreny_weather_forecast, personal_difference)

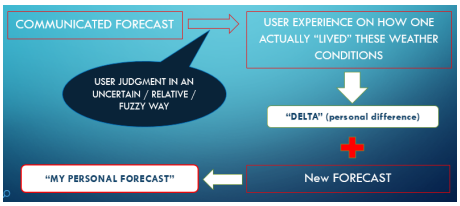

Figure 2. Schematic of the research idea: The co-creation process of "MY PERSONAL FORECAST".

2. personal_difference = weather_forecast + perceived_difference.

The perceived difference, as expressed by each user individually, is a value from a fuzzy logic set of values designating how weather parameters are felt by the individual as compared with the previous day {very low, low, medium, hi, very hi style of choices}. When the recommender system gets enough training based on the user's input, it will be able to produce weather forecasts that are tailored to the specific user, in a mass customization outcome.

5 "My personal" weather forecast

Using fuzzy logic in recommender systems is not a new idea in the research literature (Cao and Li, 2007; Yager, 2003). Various artificial intelligence algorithms (i.e., item-to-item, Bayesian networks, clustering, etc.) have been used for recommendations as well as for hybrid solutions, including Rule-Based and Horting filtering to increase the reduction of the uncertainty (Vassiliou et al., 2006). However, the added value of this research idea is that each individual user, expressing in fuzzy logic terms her/his perception of the weather condition, trains the recommender system in order to provide after some time a weather forecast that is more meaningful and actionable for her/him. Such a co-creation process for new service delivery has the potential to become the new digital paradigm for communicating the weather forecast is a massively personalized way.

While recommendation algorithms, such as Collaborative Filtering (CF) make automatic predictions about the interests of customers by collecting information from number of other customers, the "my personal forecast" is based on the same user's historical data of judgement about the perceived feeling of certain weather conditions on a daily basis, to arrive at a personal weather forecast that will be much close to how the individual is about to live next day's weather conditions, i.e. the forecast. In this way, communication of weather forecasts becomes digitally transformed in the sense that personalized experience of the expected weather impacts can be produced using AI/recommendation systems and fuzzy logic.

6 Conclusions

"The impacts of climate change are not felt equally by all residents. Poorer communities, the sick, and the elderly are more at risk" (Boland et al., 2021). Based on this factual observation, the aim of this research idea is to use fuzzy logic and artificial intelligence techniques to personalize weather forecast communication so as to customize the interpretation of weather conditions for each one individual member of the audience.

Instead of relying on expert knowledge and/or objective criteria to estimate the boundaries of values, this paper proposes that the user her-/him-self defines the scope and the meaning of the linguistic values that best fit to their own perception and feelings of the weather conditions by repetitively assessing them using her/his own subjective opinion in order to train the recommender system to produce a personalized weather forecast. This is aligned with the observation that effective two-way communication has been proposed as mandatory in science communications (Fischhoff and Scheufele, 2013). After a long enough time (an initial estimation of one year of user feedback is necessary) and given that a rich enough dataset of weather conditions has been experienced, the recommendation system will be able to provide proposals for weather conditions that would be much closer to what average people would expect to be communicated as a weather forecast tailored to them personally.

Data availability. No data sets were used in this article.

Author contributions. DSS has contributed the fuzzy logic, recommendation systems and personalization ideas, whereas PAG the parts that have to do with uncertainty features of forecast parameters and the communication of science related material.

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