How to Digitally Transform the Communication of the Weather Forecast Science using an Intelligent Systems Approach

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ABSTRACT
Communicating the science of weather forecasts to the general public has been a difficult task due to three main challenges inherent in any forecast: ambiguity of interpretation, uncertainty and probabilities logic. Moreover, forecasts are not meaningful and actionable to the recipients since they are not tailored to the perception of how they live the weather conditions. This paper presents a research roadmap for designing an intelligent system capable of producing massively personalized weather forecasts through a co-creation process as well as an abstract systems architecture model pertinent for the implementation that will enable experimentation and the proof of the concept.

Keywords
Communication of science, intelligent weather forecast, personalized weather forecast, digital transformation of the weather forecast communication.

1. INTRODUCTION
Weather forecast belongs to a category of public news in which all people are interested. The communication of the forecast, given its scientific nature, to the general public constitutes a challenge. The main three challenges in the communication of the weather forecast are the following:

- Ambiguity of interpretation.

In a research about interpretation of the information in an online weather forecast, it was found that interviewees "based their interpretations on prior experiences with real-life weather conditions and how those conditions correspond with the information provided in weather reports, leading to different interpretations of the same terms (and symbols). Thus, attempts to reduce the variety of interpretations by using specific terminology are not guaranteed to be successful." [1]

- Uncertainty

"Threshold probabilities for taking precautionary action varied widely among respondents for every parameter tested here, suggesting that specific forecast uncertainty would allow users to tailor the forecast to their own tolerance for risk." [2]

- Probabilities logic

"The weather forecast says that there is a "30% chance of rain," and it is believed that all people understand what it means. This quantitative statement is assumed to be unambiguous and to convey more information than does a qualitative statement like "It might rain tomorrow." […] The preferred interpretation in Europe was that it will rain tomorrow "30% of the time," followed by "in 30% of the area." To improve risk communication with the public, experts need to specify the reference class, that is, the class of events to which a single-event probability refers." [3]

The mediating role of new information technologies in communicating the weather forecast needs to be considered. "Technology is rapidly changing the sources from which people can get weather forecasts [4], with information now available via such channels as smartphones, social media platforms, and 24/7 weather alert notifications. It is unclear how these new sources will change the ways people get weather forecast information. The additional sources may further increase the variance in people's forecast-acquisition behaviors, or concrete patterns of source usage may begin to emerge." [5]

The use of new information technologies as a means of communication of the weather forecast allows recipients of meteorological information to consumer and even more, participate somehow into the assimilation of the weather forecast in a cooperative way with a view to make them more meaningful and actionable as per everyone's perception. Coproducing weather forecast Information with and for small holder farmers in Ghana showed encouraging results. "The results showed a positive evaluation of the intervention, expressed by the level of engagement, the increase in usability of the tools and understanding of forecast uncertainty, outreach capacity with other farmers, and improved daily farming decisions. The success of the intervention was attributed to the iterative design process, as well as the training, monitoring, and technical support provided. The conclusion is that the application of modern technology in a coproduction process with targeted training and monitoring can improve small holder farmers' access to and use of weather and climate forecast information." [6]

"High-quality weather and climate services (WCS) can be critical for communicating knowledge about current and future weather and climate risks for adaptation and disaster risk management in the agricultural sector." [7] Apart from the agricultural business, this knowledge may also be critical at an individual level for people with health problems, or other types of sensitivities whose personal and/or professional life that can be affected by the way they perceive and/or live the weather conditions. This paper describes a research roadmap toward a massively personalized communication of the science of the weather forecast in such a way so to arrive at meaningful and actionable information rich communication of the each and every recipient of the weather forecast, tailored to his/her own perception and way of living the weather.

2. THE CURRENT SITUATION

Visualization has been a strong tool in communicating the parameters of a weather forecast at a glance, e.g. [8] [9]. Most of them are really good at representing the information in an easily to understand visual representation and new techniques have been devised in increase responsiveness of web-based 3D meteorological visualization [10]. Apart from the visualization progress, the communication of science of the weather forecast was mainly been based on "traditional model of mass communication—by which the information is transmitted from a sender, that is, the scientists, via journalists to the audience" [11] and recently the usage of social media / web 2.0 technologies "allow nearly instantaneous access to information and make it much easier for communicators […] to directly address a broad audience." [ibid]

However, weather forecast remains broadly at a general level of information, good enough for a basic understanding of the weather conditions, but not appropriate for meaningful and actionable decision making. "Forecast information must be communicated in a way that is accessible, understandable and provides a useful input into decision making processes. In keeping with this, the papers featured within this special issue focus on: 1) the move towards providing impact based weather warnings to better support decision making processes; 2) trust and its relationship with forecast uncertainty; 3) tailoring forecasts and warnings to meet the decision needs of different user groups; 4) the emerging role of social media in the dissemination and verification of weather warnings; and 5) the wider behavioral, social, cultural and political context in which weather warnings and forecast information are used in decision making." [12]

Tailoring the weather forecast information to the individual needs of the audience is not only a matter of communication methods, but also a field for new scientific approaches. A first attempt to deviate from the scientific data and come closer to the reality of how one actually feels the weather conditions, is obviously the "feels-like" temperature index. In the following figure, apart from the nice visualization tools, this feature is represented with the human icon to denote that a human feels the temperature lower than the actual, due to the combination of humidity and wind at that particular time zone of the day.

This research idea is based on the concept of the co-creation process, firstly introduced for marketing purposes and later used in software development in order to engage the end-user in a value creation process that adds more value for her/him-self to a particular product. [13], [14], [15], [16], [17]. Although known, the co-creation process for producing additional value tailored to the individual is difficult not only in terms of engaging the end-user, but also in determining and perceiving the additional value that accrues for the engaging user. The co-creation process has started attracting interest in the weather information space in two areas:

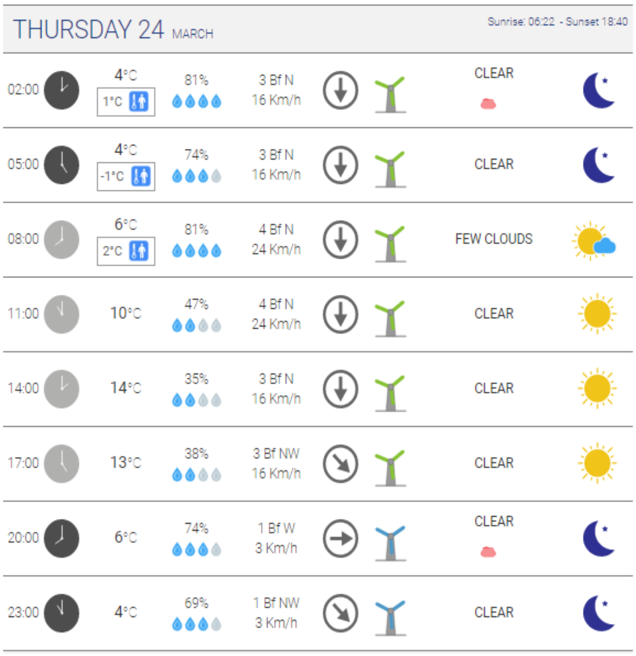

Fig.1: Daily weather forecast at shown in www.meteo.gr

"To reduce the number of possible interpretations of everyday language when used to describe weather, its usage should be co–developed with end–users and combined with graphical/numerical information." [18]

Co-creation of agromet services as a cyclical & iterative process of knowledge networks. [19]

These are major leaps forward in the way that the science of weather forecasts and general weather information is communicated to the public and to specific audiences in order to make this information more meaningful and actionable for the recipients.

3. THE RESEARCH IDEA

As everybody knows, not everybody feels the weather in the same way. People live differently the weather conditions; thus, today was a warm day for some, a lukewarm or a cold or a chilly one for others. What actually matters is how people perceive the weather conditions for their own needs, especially so when health problems and special needs increase the importance of weather conditions for them in terms of medical treatment or special provisions taking etc. Top-down communication of the weather parameters cannot be tailored to individual users, unless the end-users themselves involved into a co-creation process for attributing to the general forecast and meteo information adjectives or qualities that correspond to their own perception of the weather conditions as they feel and/or perceive them.

The needs of the user users can be summarized as a set of attributes that can be assigned to the scientific forecast information, for example:

- Temperature: cold, hot, warm, chilly, lukewarm, etc.
- Humidity: very low, low, medium, high, very high, annoying etc.
- Wind: pleasant, disturbing, dangerous etc.

Ideally, the end-user would like to be informed about the weather conditions s/he is going to live in such as a way as to correspond to her/his own definition of the words given above as attributes of the forecast's scientific parameters. How to arrive at an intelligent recommendation system that could mediate between the weather forecast and its recipients in such a way as to convey the message tailored to the individual's perception of the weather? The answer is not straightforward but certainly a research roadmap for such an intelligent information system is worth defining.

The co-creation process requires obviously to use feedback from individuals to tailor forecast data to match their own perception, recognizing that individuals have got used to different climatic situations, possess physiological characteristics as well as different experiences and depending on their acclimatization to different weather regimes. It is therefore necessary to ask the end-user, recipient of the forecast, to express in his/her own terms how s/he lives / lived the weather today. In such a way, an intelligent system can be trained to learn the particular user's own definitions of the attributes of every day's weather conditions, building gradually a personal interpretation of the weather conditions for each one of the end-users, the individuals of the weather forecast audience.

Engaging the end-user to the co-creation process requires that they can express themselves in a descriptive, not well defined, not quantitative way. Qualitative expressions can best be modelled using fuzzy logic, where dataset do not take crisp values but their definitions are blurred across adjacent values. [20], [21], [22], [23]. Asking the audience to assign the correct attribute to the various meteo information parameters in order to describe how each one lived the weather conditions is the appropriate engagement step to the co-creation process. Then, a recommender system [24] would then undertake the task of 'translating' a new weather forecast into information that are meaning and actionable on the user side, at a massively tailored scale.

The proposed method depends on a daily recording by the end-users of their "lived experience" to establish the dataset needed to train the personalized forecast, offering a novel approach of connecting the scientific information to the personal perceptions of weather. The use of fuzzy logic is proposed as appropriate for capturing an individual's experience of the weather and, through machine learning, feed this information back into the conventional forecast to produce a tailored, "personal", forecast that better reflects end-users' perception. Through a recommender system, it is possible to accommodate the needs of individual users who live in different microclimates and may feel ill-served by a general-purpose weather forecast model output. An intelligent recommendation system based on fuzzy logic has been proposed by Xiaowei [25].

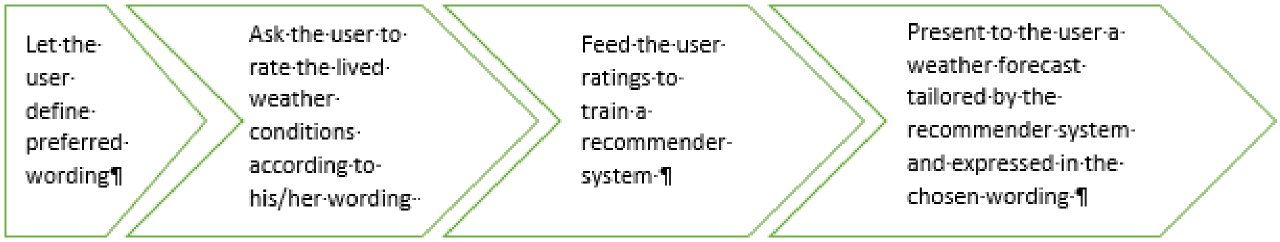

Fig-2: the co-creation process of a weather forecast through an intelligent system

This intelligent system will allow each individual user to choose their own attributes of the weather parameters by defining a fuzzy logic set of such attributes, either using adjectives or a range of comparative words to denote their preference for expressing their perception of the weather conditions and then receive the weather forecast annotated in these same terms that make more sense to them and are pertinent to the way they will live next days' weather. Recommender systems based on neural networks can be trained to correlate the past user behavior, i.e. how the end-user feedback the lived weather conditions, in order to offer personalized propositions. The combination of fuzzy logic with recommender systems has been successfully tried in the past in other areas – for example, adaptive teaching [26], career pathing [27] etc.

4. AN ABSTRACT SYSTEMS ARCHITECURE MODEL

Following all the above, the next step in designing such a system is to create an abstract systems architecture model to describe in high level all the main functionalities that a working prototype should offer. Such a prototype is necessary to be developed as a proof of concept, and as a pilot project to evaluate its effectiveness, before any further deployment is sought. Such an architecture is presented in the following figure.

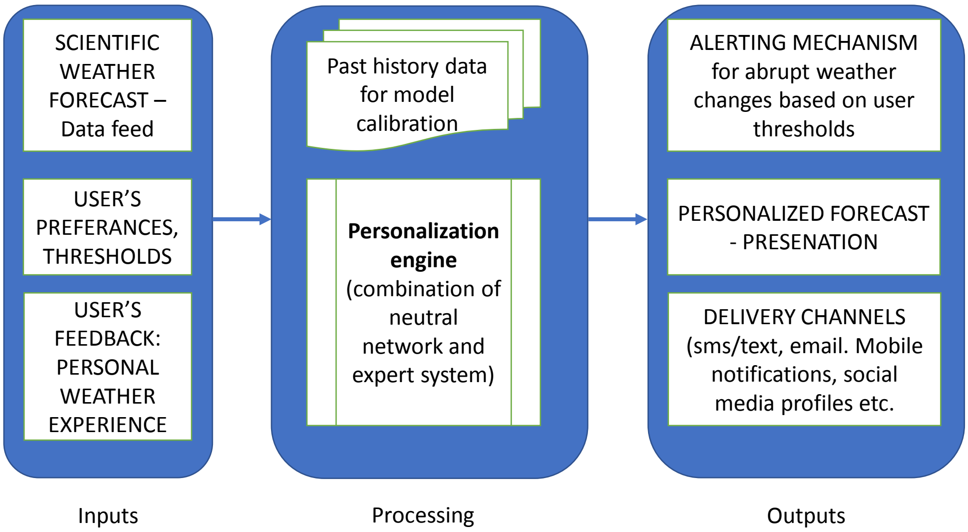

Fig-3: an abstract systems architecture model for the digital transformation of the communication of the weather forecast at a personally-relevant level.

Inputs for such a system are the continuous data feed from scientific weather forecasts (there are a lot of open meteo data which can be used for this purpose) and users' input. The user's input is the once-off configuration of the system, for example, thresholds that should trigger an alter to the user when the meteo data changes, and the daily feedback as described in the previous chapters.

Then, processing consists of a personalization engine which is mainly based on a combination of a neural network (to get training in the user's living experience of the weather conditions) and an expert system (to model constraints' regarding user's properties like health issues etc.) that work together to provide the personalized recommendations.

Finally, outputs, in terms of a personalized recommendation) are managed both as alerts, if any thresholds have been exceeded, as well as through the presentation engine that presents the recommendations in a user-friendly manner and may also push then through delivery channels to the user.

The next steps after such a model, are the detailed technical design (user interfaces and the recommendation engine) and then development and testing. After that, the solution will be ready for a proof of concept and then for a pilot operation, and, it is only at that time that experimental results will be available for presentation.

5. CONCLUDING REMARKS

Feeling mild or cold about the weather conditions is certainly an indication that people live differently the weather conditions. Therefore, the communication of the science of a weather forecast needs to be more focused on what the recipients of the forecast perceive, in order to make meteo information meaningful and actionable from the end-user's perspective. "Realizing that potential will require effective two-way communication with those whom science hopes to serve–so that it produces relevant information and conveys it in a credible, comprehensible form." [28] Therefore, a co-creation process between forecasters and end-users for producing a weather forecast is proposed, based on a combination of weather modelling and intelligent information systems to generate and deliver personalized forecast information in the future.

The value of this research idea lays in taking stock of the users' perspective of the weather experience, allow the end-user to express her/himself in her/his-own terms and then a recommender system will communicate to each individual person of the audience a personal forecast based upon the "lived experience" of weather which relates to perception and feeling, human attributes which vary very much from person to person. To this end, an abstract systems architecture model has been presented both for getting the idea clearer and for preparing the next steps for development. As soon as this research idea gets implemented, then the user satisfaction will be measured and compared to that of a general weather forecast to prove the strength of such a novel method for communicating a personalized version of a weather forecast tailored to the individual's need and expressed in her/his own terms.

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