Informatics and Control Problems 43 Issue 2 (2023)
journal homepage: www.icp.az

Predictive models: necessary and sufficient

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ARTICLE INFO

Article history:
Received 16.12.2022
Received in revised form 05.01.2023
Accepted 12.01.2023
Available online 20.09.2023

Keywords:
Predictive models
Necessary and sufficient models
Earthquake prediction

ABSTRACT

The article discusses Event Prediction Models, which are further differentiated into "necessary" and "sufficient" models. These concepts are explained, and the article provides algorithms for planning the next course of action to develop much better predictive models. The article discusses the use of predictive modeling in a specific area – earthquake prediction.

1. Introduction

The scope of predictive modeling is vast and includes the tasks of predicting natural phenomena: earthquakes, landslides, tsunamis, floods, etc., as well as the tasks of predicting the economy (business, macroeconomics), political events (elections, distribution of political power), medicine and other fields.

For predictive modeling, definitions of the concepts of necessary and sufficient models are introduced.

Necessary predictive models are those models whose set of predictions always includes a set of actually occurred events. Obviously, such models often give incorrect predictions, but they predict every event that occurs.

Sufficient predictive models are models whose predictions are always correct, even though they cannot predict all events that occur.

If sufficient models predict that a particular event will occur, that event will definitely occur. However, other events may also occur that were not predicted by sufficient models. In practice, there may be too few such models (for example, in earthquake prediction) or too many of them (for example, in economics).

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www.icp.az/2023/2-04.pdf https://doi.org/10.54381/icp.2023.2.04

2. Necessary predictive models

Suppose there are models $A_1, A_2, \ldots, A_n$ for predicting a particular event. Each of these models is necessary, which means that the event in question has the necessary antecedents for which these models are developed. n is the number of antecedents under consideration. These models do not consider models that take into account unnecessary antecedents, which is why they could not predict the occurred event. As demonstrated in [1], the necessary predictive modeling requires the calculation of "true prediction probabilities".

The true prediction probability of the model A_i is the ratio of the number of occurrences of an event to the number of occurrences of an event predicted by the antecedent of this model, expressed as a percentage, i.e., the probability of the A_i model's true prediction K_i is equal to:

$$K_i = \frac{m}{p_i} \cdot 100\%,$$

where m is the number of events that occurred, and P_i is the number of occurrences of the event according to the A_i model, which was based on a_i n antecedent.

For cases where we have a large number of necessary predictive models, we may arrange them according to the prediction time [2, 3]. In the beginning, we put the model that predicts the earliest (M_1), etc., and the last model predicts an event (Mn) before the occurrence of (t_v) event. Fig. 1 illustrates such distributed models that allow for the possibility of the timely response of the corresponding services. These are predictions that allow to manage the relevant institutions and organizations.

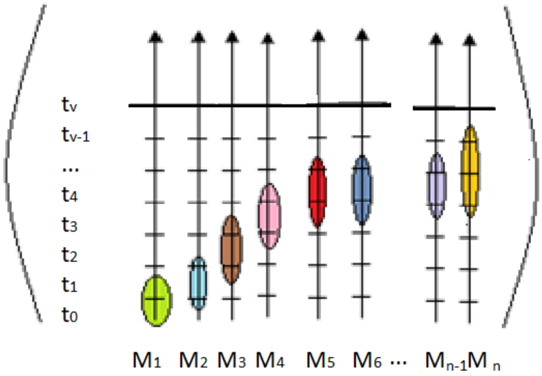

Fig. 1. Predictive models ordered by time.

We discussed combinations of models (two, three, etc.) and estimated the probability of their combined correct prediction. Estimation and selection of combinations are made according to the definition of "parallel probabilities" [4]. It has been proven that when predicting events, if pairs of models are selected for which the number of "coincidences" of incorrect predictions of a given event is the smallest, but the presence of correct predictions for each of them is a necessary condition, then the true prediction probability calculated for such a best pair is always greater than or equal to the true prediction probability of the best model among all models (Fig. 2).

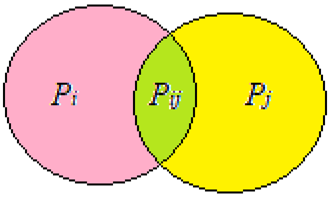

Fig. 2. Graphical illustration of two-model set case in an Euler-Venn diagram.

This is an interesting metamorphosis – one may find a couple of models that individually often give incorrect predictions, but the intersection of their predictions gives the best results.

In addition, in case of the necessary models, it demonstrates that the more predictive model intersections we take, the better the prediction. For example, the best three – a combination of three predictions (Fig. 3) gives better results than the best pair of predictions (two), the best four give better results than the best three, etc. Thus, it makes sense to discuss the necessary sets of models.

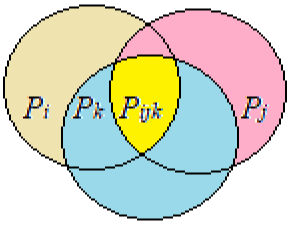

Fig. 3. Graphical representation of three-model set case in an Euler-Venn diagram.

In necessary modeling we do not consider unnecessary models, although the Bayesian approach does not make such a distinction [5]. On the contrary, all existing models are used to answer the question of whether a given event will occur or not. Depending on the predominance in terms of quantity or other characteristics (yes or no), an answer is given to the question of whether this or that event will occur at a given time.

3. Sufficient predictive models

In practice, when there are very few sufficient models and there is no single universal model that predicts all events, the question arises whether these sufficient models can be used in such a way that their combination predicts all events, that is Necessary predictive models, that is, the combination of models become sufficient.

For example, let us consider the history of a predictable event that has occurred n times over a period of time, such as one year or ten years. Suppose one of the predictive models predicts that a certain event will occur k times, the second – p times, and the third – q times. If $k<n$ *or* $p<n$ *or* $q<n$, then this means that none of the models individually will be sufficient, but if we consider a combination of all three models, then together they may predict n number of events. It follows that having considered a combination of these three models in combination, we may get a sufficient model (see Fig. 4):

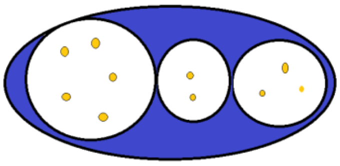

Fig. 4. A sufficient model built by combining three models.

The figure considers three models. One predicted the event five times, the second model – 2 times (different from the first), the third model – 3 times. Jointly, the three models predicted ten events, that is, exactly as many events as occurred, which means that their combination can be considered a sufficient model.

When considering the necessary models, combined models implied the intersection of these models, and in the case of a combination of sufficient models, we need to consider their unity (rather than an intersection). In the case of an earthquake, there may be so few sufficient models that only two or three can be chosen. For example, if there were seven earthquakes, and one model predicted 3 of them, another predicted two others, and the third predicted two more, then together, that is the combination of all three models predicted all seven earthquakes.

Such models are sufficient, that is, they do not make predictions that do not come true. The necessary models are not sufficient, but the combination of these sufficient ones results in the necessary model, that is, we completely cover the set of all events that have occurred, so in this case, we are trying to get the most complete prediction of all occurred events. It may not be 100%, but in the end, after combining a sufficient number of models, it will be close to 100%, and also, obviously, here we also combine antecedents and narrow down identical, repeating antecedents to a single antecedent. Here too we can consider which antecedent results from which of these antecedents.

The main objective is to bring the probability of guessing such a combination as close as possible to 100%. For example, if the probability of guessing is 90%, that means that combining enough models will cover 90% of the events, which will be a very good result.

The question is when the best models should be obtained from the necessary models and also when the best combination of best models should be identified. Obviously, the algorithm that was created first will analyze all existing models and existing data and obtain the appropriate number of required models, the intersection of which gives the best result. Also, from these models, a combination of sufficient models is obtained, which will be closest to the correctness of all forecasts, while their number is less compared to other combinations.

Obviously, after each event, it may turn out that we already have new models, or some of the old necessary models may turn out to be unnecessary, which means that they could not predict the event that has occurred, in which case such models are discarded, and we will need to look for new pairs.

As for sufficient models, after each event, it may turn out that some sufficient models from the penultimate to the last event gave an incorrect prediction. In this case, such sufficient models are also discarded, and if a new sufficient model is introduced, then it is also processed to identify new and old sufficient models that cover events as fully as possible.

4. Conclusion

We have explained what necessary and sufficient models are. For the necessary models, an algorithm was proposed for choosing the intersection of two or more models, which in combination give a more probabilistic forecast. We have also discussed sufficient models and an algorithm for choosing sufficient models whose combination completely covers all occurred events. That is, there is also a need to combine such sufficient models. Thus, it is possible to obtain a sufficient or almost sufficient prediction model by intersecting the necessary models and by combining sufficient models to obtain the necessary or close to the necessary model.

In the algorithm proposed by us, unnecessary models are not taken into account when using the necessary models. If there are models that cannot predict the event (but are not sufficient models either), then such models are discarded from our database. Similarly, when considering sufficient models, where an excess forecast of an event is given, such a model can be excluded from the database of sufficient models.

Thus, we have explained what is necessary and sufficient models for predicting events, how to derive necessary models from sufficient ones, and determined how to derive sufficient models from necessary ones.

From sufficient models, we derive the necessary model, which will be both sufficient and necessary at the same time. In addition, we combine such sufficient models to obtain the necessary model.

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