Automatic gale warning proposals for Swiss lakes and regional aerodromes based on genetic programming

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INTRODUCTION

Strong wind gusts represent a potential danger to aviation and maritime safety. Therefore, gale warnings must be issued for lakes and aerodromes when the probability of gust exceeding 25 knots is high, so that the people affected can take protective measures. In Switzerland, gale warnings are issued for more than 50 lakes and aerodromes, a process not yet automatized. Consequently, forecasters are obliged to permanently monitor the local weather evolution at these numerous sites. Not surprisingly, quality assessment demonstrates that efficiency is low with events frequently missed.

This challenging situation is taken up by GenWarn which is part of the OWARNA project at MeteoSwiss, where weather warnings in Switzerland are aimed to be optimized and modernized. The goal of GenWarn is to implement a semi-automatic gale warning system based on an evolutionary algorithm, established in the field of genetic programming, which was initially developed in collaboration with the Artificial Intelligence Laboratory of the University of Zurich. The system delivers precursory proposals for gale warnings, supporting forecasters in their ongoing weather surveillance.

METHOD

Working on a predictor set specific to each lake or aerodrome, the evolutionary algorithm, which is a machine learning technique inspired by the evolution theory of species, constructs, evaluates, selects and improves algorithmic expressions - actual Java methods - aiming for forecasting maximal gust intensity within the next hours. 20 such evolution runs are performed once for each warning object, leading to an ensemble of 20 Java methods specific to each site. These 20 methods build a probabilistic forecast for the occurrence of wind gusts at a specific lake or aerodrome in the next hours. The verification of this ensemble forecast determines the optimum probability of occurrence above which an alarm proposal is sent. The data used for this learning step consists of a 4-year set of relevant observations and short-term forecasts from the 2-km numerical weather prediction model COSMO-2 which is run by MeteoSwiss.

In operational practice, the 20 methods of each warning object are evaluated every 10 minutes and deliver probabilities of gale occurrence that are displayed as warning suggestions if exceeding the pre-defined threshold. The forecaster must either confirm or reject the alarm. Figure 1 resumes the different steps of the method explained above.

RESULTS

The GenWarn system is currently being operationally implemented and the very first real-time tests could be performed by the weather forecasters of MeteoSwiss. Due to the lack of storm events encountered up to now, no significant statistical evaluation of the actual impact of the tool on the gale warning performance could yet be achieved. Figure 2 shows nevertheless the result of an event-based verification conducted over 2-years past data. The warning performance is expressed by the combined value of the false alarm ratio (FAR) and

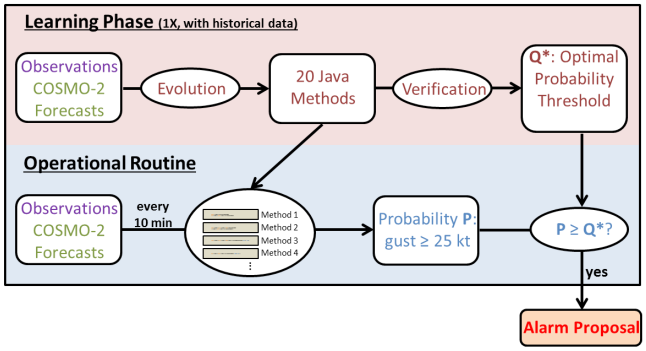

Figure 1. Overview of the method used to produce the automatic gale warning proposals. The learning phase is conducted once for each warning object based on site-specific observation and forecast data. The result of the learning process is a set of 20 Java methods which are verified in order to determine the optimal probability threshold Q* above which a warning is sent. In operational mode, the latest data available is provided every 10 minutes to the Java methods which deliver the probability P that a wind gust reaches 25 knots in the next hours. An alarm proposal is sent if P exceeds Q*.

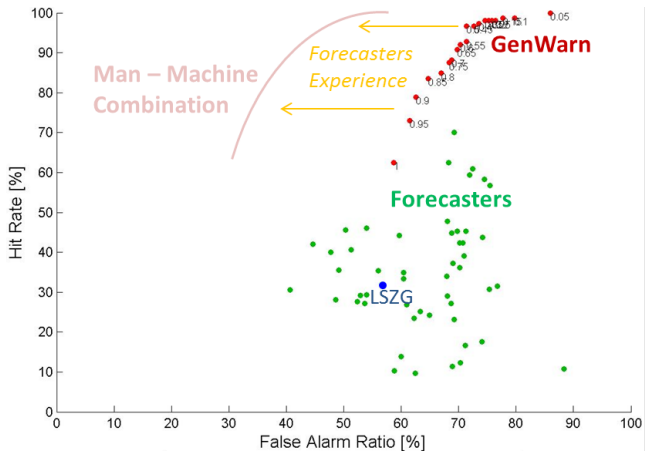

Figure 2. Diagram showing the warning performance of the different warning systems. The False Alarm Ratio is represented on the horizontal axis, the Hit Rate on the vertical axis. The green points show the warning performance of the forecasters for each warning object in Switzerland. The point highlighted in blue corresponds to the aerodrome of Grenchen (LSZG). The red points show the warning performance of the GenWarn system for the aerodrome of Grenchen. The corresponding probability of occurrence is written next to each individual point. The pink curve corresponds to the hypothetical performance of the combination man – machine.

the hit rate (HR). An ideal warning system would be situated at the top left of the diagram, where the HR is high and the FAR is low. The green points show the warning performance of the weather forecasters for each lake and aerodrome in Switzerland. We observe that, generally, the HR is low, mostly below 50%, and the FAR on average to high, between 40% and 90%. The reason for the low HR is mainly because the first strong wind gust is frequently missed. On the other hand, the red points represent the performance of the GenWarn system for the aerodrome of Grenchen (LSZG). Since other warning objects were found to behave similarly, we can assume this curve to be the general performance of the GenWarn system. The corresponding probability of occurrence is written next to each individual point. We observe that the automatic system has a high HR, between 70% and 100%, but also a high FAR, between 60% and 90%. This shows that the use of the GenWarn System would lead to an overall increase of the HR. However, this improvement would be strongly object-dependent : for some objects, the improvement would be huge, but for some other objects, the improvement would be tiny.
In practice, we can imagine that the forecaster, thanks to his broad experience, could filter the alarm proposals given by the machine and in this way decrease the high FAR, so that the GenWarn curve would be shifted to the left, thus improving the overall performance.

CONCLUSION

The introduction of the GenWarn tool delivering automatic gale warning proposals will strongly support the forecasters in their ongoing weather surveillance. While continuously monitoring the weather situation at all warning objects, the automatic system should lead to an increase in the detection frequency of the first strong wind gust which is otherwise often missed. Combined with the forecaster's experience, the utilisation of the GenWarn System should lead to a general improvement of the gale warning quality for Swiss lakes and aerodromes.

KEYWORDS

Automatic Warning Proposals; Gale Warnings; Genetic Programming.

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