Optimization of snowmaking in high mountains ski resorts

Loubier JC(2); Kanevski M (2); Schumacher M(1);
Timoni V(2); Claret S (1); Zieba A (1); Doctor M(1)
(1) HES-SO Valais; (2) IGAR-UNIL

Abstract

This paper presents a software prototype based on artificial intelligence to help ski resorts better manage their snowpack. It combines on one hand a General Neural Network for the analysis of the snow cover with a multiagent simulation of skiers for the analysis of mantle.

Keywords: Snowmaking; spatial prediction; multiagent simulations; General Regression Neural Network

PROBLEM OF ARTIFICIAL SNOW MOUNTAIN

Since the early 2000s, the use of artificial snow to ensure activity in ski resorts is controversy: The paradigms of climate change and sustainable development appear to be opposed to the economic necessities of winter tourism. Recent publications on climate change (IPCC, 2007) combined with the dynamic development of production facilities of snow show that this conflict of interests will widen further in coming years.

The ski economy therefore plays a strategic role in the high alpine valleys, allowing the maintenance of a local economy and social fabric. To ensure activity, ski resorts are investing heavily in production facilities of snow. This poses two problems:

1. The installation costs of the production systems and the maintenance of the snow coat weights heavily on rentability of the ski resorts (Agrawala 2007)..
2. Environmental issues related to the production and use of this snow is still poorly understood and evaluated.

Project “Juste Neige“

This project is developing a software tool for managing the production of artificial snow by simulation. In this way, it will be possible to:

- Reduce production costs and improve profit margins for companies;
- Reduce environmental impacts by producing less snow.

General architecture

The tool consists of two blocks in connection with a database that allows storage and exchange of information. (Fig 1)

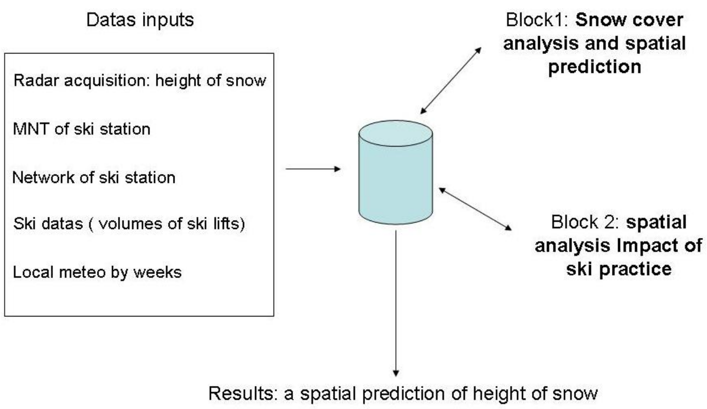

Figure 1: General architecture

The treated data is modeled as a grid referenced in space, by a DTM with a mesh. The heights of the snowpack and the various impacts are calculated with a resolution of 5m.

BLOCK 1 : SNOW COVER ANALYSIS AND SPATIAL PREDICTION

For modeling and mapping of snow depth along the ski-tracks, General Regression Neural Network (GRNN) model was applied. This machine learning model was chosen, because GRNN is an efficient and reliable model for operational use.

General Regression Neural Network: background

GRNN is the one of the most effective method for performing a regression task. A GRNN is just another name of a well-known statistical nonparametric method - Nadaraya-Watson Kernel Regression Estimator. (Nadaraya 1964 and Watson 1964). It is interpreted in terms of neural networks (Sprecht 1991). This method is based on kernel nonparametric density estimation (Parzen 1962)

Application to snow depth estimation

The GRNN with 3 inputs (X,Y,Z) and 1 output (depth of the snow) was used. Firstly, all duplicated points (within distance less than 5 m) were removed. The minimum value was used for replication. Then optimal parameter of the σ value was estimated with cross-validation procedure.. The result is a map of the snow depth. The prediction was made on “validity domain” only. (Fig 2) It means in case of effective radius of correlation 5-10 meters, prediction can not be made for points which too far from measured locations.

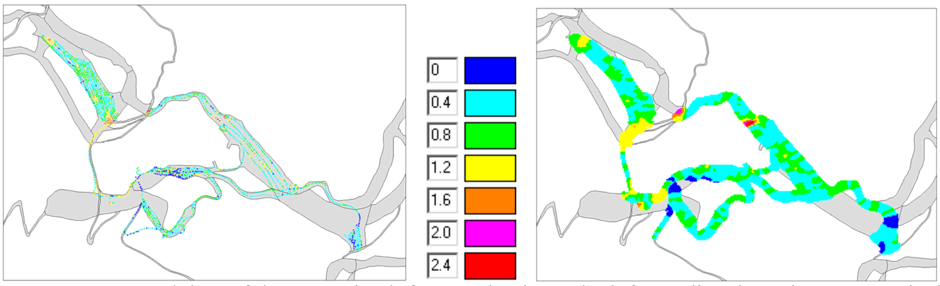

Figure 2: Measured data of the snow depth for one day is on the left, predicted continuous map is the right

BLOCK 2: IMPACT OF SKI PRACTICE

This block models is a complex problem that we deal with the technique of multiagent systems (Wooldridge 2009). The idea is to simulate the passage of skiers (modeled as autonomous software agents) on slopes based on an analysis of the average behaviors of skiers.
We realize the simulation in two steps:

- First, we simulate the flows at a global level for the whole resort;
- Then, we run micro-simulations for each slope.

Global level

The first step runs on the global graph of the ski resort. This graph is made by the different mechanical installations and the slopes. Each slope is a directed route from one node to the other, maybe with several branches. Those branches may rejoin after separating.

The goal is to determine for each possible route in the resort graph, the number of skiers to simulate.
The starting data that we need are the total daily counts of each mechanical installation. Those counts are taken from the statistics of each mechanical installation of a whole year. To define which statistics to use, we have clustered our past statistics on specific example days by using variables such as the meteorological conditions, the time of the year (holiday period, etc.) or the week day.
We know for each specific installation the number of skiers of a specific day. Therefore, we now the number of skiers that arrived on the top of this installation and that started ski from this departure node.
We can thus know the number of agents that will choose to go from one starting node to arrival nodes.

Local level

We run a micro-agent simulation of each specific route in the graph of the ski resort. This is done on the grid.
Firstly, we decided for each agent the route that it will follow to achieve its destination node. For this, we take into account the difficulty of the slope and the class of agent (beginner, middle, good skier)
The second operation is to transform the ski slopes into a grid.. Each skier is simulated as an agent that goes down on the slope, roaming from one square of the grid to the other. For the time being, we have modeled a very simple skier behavior.
Finally, the calculation of the impact of a day is the sum of all passing agent. Each mesh has a corresponding elevation of snow at a relative height of 1000 and the impact "removes" a quantity of height between 1 and 10 every time the agent goes on a mesh.(fig 3)

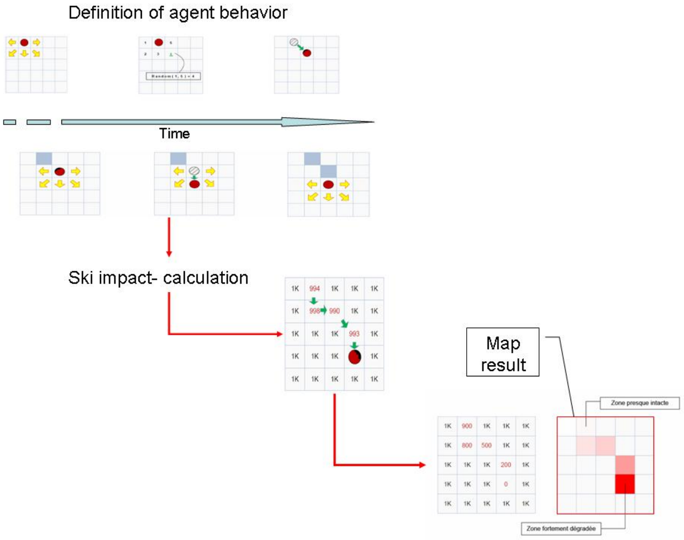

Figure 3: Process in action in local level

CONCLUSION

This work focuses on a theme that has been little discussed: the dynamic management of a snow mantle in ski resort. Our initial results show that simulation of the evolution of the mantle heights by probabilistic methods seems possible. The second phase of our project planned on measurements in the stations Zermat, Champery and Sass Grund more of Verbier will verify the accuracy and robustness of our prediction at both the local level but also in various topoclimatic situation.

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