KUOLEVA JÄÄTIKKÖ

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Executive summary

Why Kuoleva Jäätikko? Belvedere glacier is a valley glacier located above Macugnaga of the Valle Anzasca in the region of Piedmont. It lies at the base of the east side of Monte Rosa. It reaches approximately 2200 metres above sea level at its highest point and terminates near the Alpe Burki at about 1800 metres. It is a debris-cover glacier because the glacial mass is mainly covered by debris and rocks. With an area of about 5 km^2, Belvedere glacier is also the largest glacier of Piemonte region. This glacier has had a volume increase in the second half of 20th century (period 1957-1991), but in the first twenty years of 21st century, it has presented significant reductions of its volume (~10^6 m^3/yr). Belvedere glacier is dying (Kuoleva Jäätikko means dying glacier in Finnish), so the aim of this project is to monitor in continuous-time the health conditions of Belvedere glacier using webcams, and time-lapse photography.

Key Words

Glacier, water, monitoring

Glacier front of Belvedere debris-covered glacier.

Project description written by the Principal Academic Tutor

Nowadays, expected effects of climate change at local, regional and global scales endanger hydrologic budgets of Alpine regions. The massive shrinkage of mountain glaciers, with the consequent problem of water resources reduction for civil population and ecosystems is an example. Therefore, it is very important to monitor glaciers' evolution, in order to allow an estimation of glaciers' reduction and possible effects on the hydrologic cycle.

This project aims at monitoring the health conditions of one of the southeast glaciers of Alpine chain: the Belvedere glacier (Kuoleva Jäätikkö) using new technologies such as webcams and time-lapse photography. Usually, glacier's thickness, area evolution, and glacial motion are monitored using time-consuming field activities, e.g. analysis based on point stratigraphy and mass balances or radar sounding, which do not allow to obtain a continuous-time, detailed and accurate information about surface and volume evolution at fine spatial resolutions.

In Kuoleva Jäätikkö, the ASP team has developed, in a original way, two monitoring stations to control in continuous-time the evolution of the glacial front. Each monitoring station is composed by a camera, a controlling circuit, based on microcontroller, a small single-board computer with internet connection, and a battery and a solar panel. The ASP team has designed, assembled, and deployed on site the two monitoring stations, which are properly working. The two monitoring stations will permit to acquire precious data to follow the evolution of Belvedere glacier.

Team description by skill

The team is composed of seven aspiring engineers: three coming from the aerospace sector, and the other four coming respectively from the mathematics, mechatronic, nuclear and physics sectors. The blend of knowledge and skills represents the main strength of the group and allowed the development of a multidisciplinary approach to the problem. On the other hand, the fact that the team is composed of engineers only was an advantage given the particular problem to be addressed: the common engineering background turned out to be crucial to communicate in a more direct way and to collaborate more efficiently. This led to a more practical approach to the solution.

It is important to highlight, however, that no team member had particular knowledge about the problem: indeed nobody had an academic background related to the field of *environmental engineering*, and neither related to the *electronic* one, which instead revealed to be a fundamental part of the solution that was designed. Consequently, it goes without saying that each student had to gather information, in order to frame the problem and to have the necessary tools to design a solution.

Other skills which could seem secondary, but which proved to be of primary importance, concern the ability to deal with the severe alpine environment during the field campaigns. Indeed, in its dynamic evolution, the glacier has modelled a harsh location with unsteady and detrital terrain: hence the need to be able to proceed safely.

Lastly, but not less important than the previous points, some technical and manual skills were required to produce the first prototype, to create a second one and to install it on the glacier.

Goal

In the epoch of climate change and global warming, *glacier melting* is one of the main changes our planet is facing. While glaciers and their composition have been deeply investigated in the past - they represent well known entities nowadays - during the last years their melting has not been studied in detail. The *Kuoleva Jäätikkö Project* aims to help covering these missing information.

The goal of the project is to monitor the health conditions of the Belvedere Glacier. In particular, the previous ASP Projects have tried to monitor the whole glacier by comparing the images taken in two different moments of the year. Consequently, they managed to give a complete vision of the situation, but just in an exact temporal instant. The main goal of this project, instead, is to analyse what happens with the passing of time, day by day (even hour by hour), especially during the summer period, when the main displacements take place and the melting of the glacier is more evident. To do so, the focus is placed on surveying not the whole glacier, which clearly would not be feasible, but the element affected by the greatest changes: its terminal tongue. In particular, the Belvedere Glacier presents two terminal tongues: the major one (*west tongue*) was chosen.

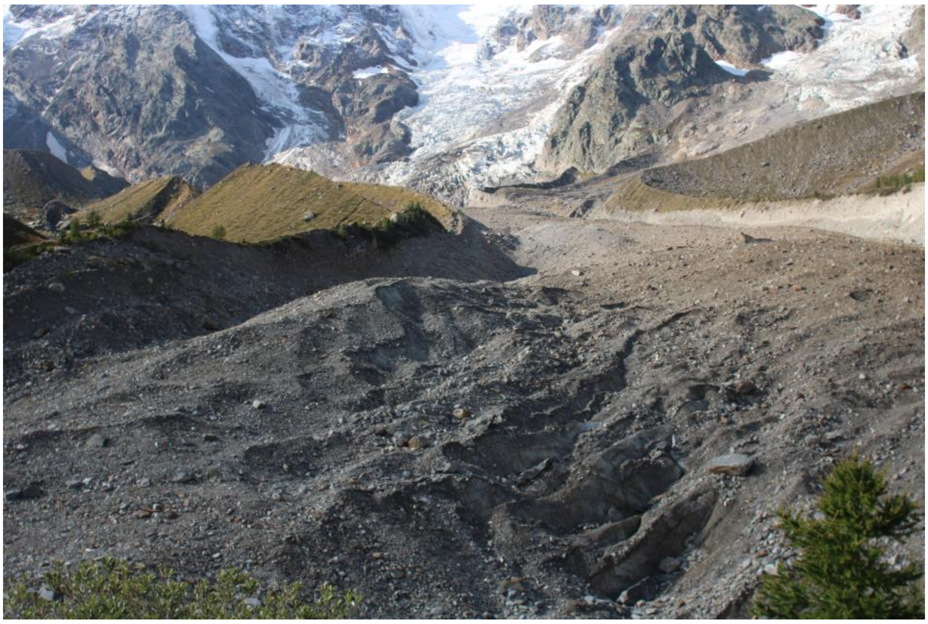
Moreover, in addition to the academic objectives, there is a further goal: the increase of the awareness of global warming effects among people. It is to be hoped that having the possibility to show people the rapid and huge modifications of the glacier will strongly help to sensitize the public opinion and to promote a change in people's habits and lifestyles.

Understanding the problem

Climate change and global warming, and the consequent glacier melting is posing serious challenges. The disappearance of these historical entities is radically transforming the alpine environment: with the strong volume reduction of the last years glaciers are leaving behind them black and unsteady rocks, which will progressively delete the memory of the white and blue ice and snow which occupied those areas before. This strongly impacts the tourism of those areas: Belvedere Glacier is a popular touristic destination reached by thousands of hikers both during the summer and the winter.

But tourism consequences of glacier melting are nothing compared to the consequences to hydroelectric energy production. In fact, the melting water of the Belvedere glacier feeds a river which is exploited by two hydroelectric centrals placed in the Anzasca Valley. Especially during the summer, the contribution of that water is particularly precious. The impact of the glacier disappearance would strongly affect the energy production and could put serious challenges also in that sector.

All these effects need to be considered in planning the activities of the next few years, and it is thus clear how, in the absence of precise and reliable data and studies about this glaciers, nothing can be done.



One of the photos taken by our system during the days following the installation

Our group during the provisional installation of the system

Exploring the opportunities

The presented goal is definitely ambitious and brought with it many practical issues. The objective to monitor the behaviour of the glacier throughout the time did not allow to perform effective analyses just through field campaigns (for our purposes, this would have meant performing a large number of expeditions and reaching the glacier every time, even when weather conditions are prohibitive).

Since the beginning, it was clear that some device that could be installed *in situ,* allowing *remote access* and *control*, had to be designed. Furthermore, the proposed solution was expected to be *scalable*, in order to be applicable to other glaciers (or similar points of interest) with relative simplicity. The solution had also to be *cheap*, because of the budget limit imposed by the ASP, and *reliable*, because of the difficulties in reaching the installation places of the systems. In particular, the reliability requirement is particularly demanding, considering the harsh environmental conditions the system is expected to work in: low temperatures (up to -11°C), strong wind (gusts up to 130 km/h), meters of snow and rapidly varying weather conditions. Finally, the absence of electric power and a too low Wi-Fi connection of the area made everything more complicated.

Generating a solution

In some sense, in order to meet the original goal of capturing and analysing the modification of a glacier, the elaboration of a solution consisted of two phases. While the second one simply concerned the design and the physical construction of a suitable device, the first one was more conceptual: "how to quantitatively detect and measure the movements of a glacier?". For instance a graduated rod anchored to the ground may be the simplest way to measure the height of the snow layer and its variations in time (but clearly is not that suitable for the present case…).

The surveying method that was considered to be most suitable for the purpose of the project is the so-called *photogrammetric technique*: by acquiring at least two photos from two different places, it is possible to digitally reconstruct the surface of the glacier with a high precision (~1-10 cm). By comparing the surfaces created it is possible to calculate the displacements of the glacier, in particular of its terminal tongue. The permanent installation of the two "eyes" near the terminal tongue allows acquiring data about the displacements continuously in time.

Concerning the realization of the measuring station, the requirement on its complete automation led to the design of a system to command a digital camera. As said before, this should be characterised by robustness and low consumption; in fact, because of the absence of a direct electrical network, the entire machinery must be powered with a solar panel. The size of the latter has obviously to be very limited because of the environmental constraints (like adverse weather conditions). As a consequence, the designed system is composed of a *Raspberry Pi*, an *Arduino* and a circuit containing a clock. The *Arduino*, which is notoriously a low-consumption component, is commanded by the clock and wakes up the camera to take the photos. The *Raspberry Pi* instead is active once a day and allows the data transmission.

Data transmission is performed at the actual state via Wi-Fi. However, considering the behaviour of the system, a mobile network connection is advised and future developments foresee it. The data connection allows also to communicate with the Raspberry Pi and to modify its parameters such as those connected to the camera, the number of photos taken every day and all the parameters that rule the system.

Finally, a few words need to be dedicated to the installation: actually one of the two systems is installed through a provisional support (a tripod fixed to a big rock). The definitive installation foresees a fixed support strengthened with three tie-rods.

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