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DREAM 3

DRone tEchnology for wAter resources and hydrologic hazards Monitoring 3

Executive summary

Global warming is an extremely important topic nowadays. Ice melting of glaciers all over the world is proceeding fast in a dangerous way. Many cities are highly dependent on the water resources of glaciers and this is why it is important to analyze, monitor and forecast their change in time.

The DREAM3 project aims at developing new tools for monitoring the glaciers and their evolution in a fast, cheap and safe way. The monitoring consists, in general, in building a 3D model of the surface of the glacier and compare it with the one obtained in the previous years. This strategy relies on the photogrammetry technique, which allows to perform reliable measurements starting from photographs taken by means of drones specifically built for this purpose. The Belvedere glacier, which lies at the base of the east face of Monte Rosa has been chosen as a reference point for conducting the surveys. This choice has been made since this glacier is one of the few Alpine ones not retreating but moving forward. However, the developed tools can be used for any other glacier or surface that requires monitoring. The traditional way of performing photogrammetry to build a 3D model of surfaces relies on the use of helicopters, which are very expensive and dangerous. In the recent years drone technology has attained a huge progression and nowadays they are widely used for replacing helicopters.

DREAM3 is the third step of a 3-years effort: with respect to the previous projects, which started the monitoring of the Belvedere glacier, the main novelty lies in making use of direct photogrammetry. In general, surveys consist in acquiring, together with the pictures taken by the drone, the precise GPS positions of some points on the glacier surface, in order to correctly orient the 3D model in a standard reference system. Normally, in indirect photogrammetry, the acquisition is done manually: this operation is quite dangerous due to frequent prohibitive weather conditions and the continuous sliding of the glacier. In addition, to have a reasonable accuracy, usually a really high number of points are needed. DREAM3 identified direct photogrammetry through drones as the best solution, since, thanks to a GPS system placed on the drone itself, it is possible to know the exact location of the photos at the very moment in which they are taken. This results in a drastic reduction of the number of points to acquire manually on the glacier surface and, consequently, in an increase of the safety and in a reduction of the measurement time.

Solutions relying on drones for direct photogrammetry are already present on the market; however, their cost is relatively high (i.e. more than € 25’000), which make them hardly affordable. The team performed a study in order to find an alternative solution, which led to the creation of a low-cost sensors’ kit comprising of an EMLID Reach GNSS (Global Navigation Satellite System) unit, a camera with a hot shoe output, and a suitable antenna. The Reach unit is connected to the camera through a special cable, inserted in the hot shoe output; in this way, a time stamp is created on a GPS log whenever the shutter of the camera is triggered. The kit was mounted on a Parrot Disco UAV, which was purchased due to its performance and price balance, and subsequently heavily modified in order to house all the equipment.

TEAM MEMBERS

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Several tests on the above-mentioned kit were done. First of all, the team ensured that the novel idea was working under the weather and surface conditions of the suburbs of Torino. Consequently, a campaign has been done in the Spring of 2018 for testing the new setup of the drone over an avalanche at the feet of Belvedere glacier and demonstrated the effectiveness of the new acquisition system in a concrete application.

Moreover, in parallel to this work, following in the footsteps of the two previous DREAM projects, like every year, data have been collected with the traditional technique to monitor the evolution of the glacier. For this purpose, two campaigns were carried on in the Autumn of 2017 to get the needed data for building an updated 3D model of the surface of the glacier. Beside the fact that the weather conditions had a big influence over the performances of the drones in terms of battery capabilities and stability, the campaigns were always successful. After a long phase of post processing of the images and GPS measurements (performed in the laboratories of Politecnico di Torino) the work gave as a result the latest 3D model of the surface of the glacier.

As an additional element of novelty, for the first time since the DREAM project started, the team decided to investigate on the thickness and morphology of the glacier and of the bottom soil, in order to perform also a hydrological analysis. In this regard, geophysical surveys have been carried out in July 2018. Surveys were conducted by means of geo-electrical and passive seismic methods, but the surface conditions of the glacier were not appropriate. However, referring also to previous geophysical campaigns, it has been possible to employ the collected results in a mathematical model found in literature for approximating the ice mass flow rate sliding downstream.

Since the DREAM project has started, every year the glacier surface and movements are compared and analyzed. DREAM3 is the proof that, with a well-studied combination of new technologies, the behaviour of glaciers can be monitored in an accurate and definitely more safe way.

Key Words

Glacier, Survey, Photogrammetry, UAV

Figure 1- view of the Belvedere 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. An example is the massive shrinkage of mountain glaciers, with the consequent problem of water resources reduction for civil population and ecosystems. 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. DREAM3 project aims at investigating new technologies and tools, especially Unmanned Aerial Vehicle (UAVs) for evaluating water resources at different scales. The eastern slopes of Monte Rosa and its glacier tongue (Belvedere glacier) has been used as test site. Research method analysis mainly followed fours steps. 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 the first step, we have used commercial UAVs to acquire images, in order to generate a dense DSM (Digital Surface Model). The acquisition was carried out with an ad-hoc field campaign realized in October 2017. Data have been elaborated with different photogrammetric software in order to investigate the ratio quality of the product/time consumption, with respect to hydrological purposes. The DSM obtained has been compared with the ones realized in 2015 and 2016 to estimate the volumes' variations, and the glacial motion in the periods October 2015-October 2016 and October 2016-October 2017. In the second step, we have customized a commercial drone in order to make direct photogrammetry, i.e. acquiring, together with the pictures also the precise GPS positions of some points on the glacier surface, in order to correctly orient the 3D model in a standard reference system. In the third step, we have used the modified drone in an ad-hoc field campaign realized in May 2018 together with commercial drones in order to check the validity and potentiality of the modified drone. In a fourth step geophysical surveys have been carried out in order to retrieve information about glacier thickness which combined to glacier motion could validate glacier dynamics models. Finally, we have been compared the obtained results with the existent literature in alpine areas.

Figure 2 - markers coordinates acquisition

Figure 3 - mounting the modified drone

Team description by skill

Pasquale Walter Agostinelli: contributed in the development of the Mathematical model of the glacier according to literature and participated to the third campaign. Moreover, he was charged of the development of the promotional video of the project.

Alessio Durante: participated to the first and third campaigns, gave its contribution in the post-processing of the GPS data acquired during the campaigns to obtain the markers coordinates, performed the loading tests of the drone and worked on the alternative solution of the flight planner software.

Davide Rago: participated to all the three campaigns and, with knowledge in civil engineering, topography and photogrammetry, worked alongside with Alessio for the post-processing of the GPS data, the loading tests of the drone, and to the investigation of alternative software solutions. Moreover, he was charged of the geophysical part of the project and estimated the amount of melted ice comparing models of previous years.

Giada Risso: partecipated to the first campaing. Building and analyzing the 3D model of the glacier was her responsability. Moreover, she assisted Tommaso Verri at Politecnico di Torino in the hardware development. Particularly she contributed to all the test carried out at Campovolo in Turin and the last test performed with Roberto Russo.

Roberto Russo: was the team controller and took care of the communications with tutors and with the ASP board. He participated to the first and third campaigns, worked on the second phase of modifications on the drone taking care of the post processing of the last GPS data and to the determination of the final sensors' kit after the last test of the solution. He worked on the report structure and writing. Moreover, he took care of the economical part of the project.

Tommaso Verri: participated to all three campaigns and took care of the hardware components of the drone. His work started with the benchmarking of the various available drones, to proceed with the definition of the GPS recording system, together with camera choice and battery modification. All the hardware modifications to the drone itself were supervised and carried out by him in the Politecnico di Torino labs, with the help of Horea Bendea. Furthermore, the loading tests and flight tests carried out at Campovolo in Turin were also his responsibility.

Figure 4 – DREAM3 team members

Goal

The DREAM3 project follows the path traced by the DREAM and DREAM2 groups that, in recent years, have reconstructed a 3D model of the Belvedere glacier (Macugnaga - Monte Rosa) through the use of equipped drones for land mapping: these projects proved the concept that a drone could be used instead of current technologies for surveying, which require the rental of a plane equipped with a camera, significantly reducing costs and increasing the collected data due to easy access to drone technology. While the DREAM project firstly showed the feasibility of drone technology for this purpose and the DREAM2 project investigated the possibilities to develop and build one ad hoc drone, focusing on weight, battery life, payload and camera quality, the aim of DREAM3 is to continue the work on the Belvedere glacier in order to monitor and study its evolution. In particular, the project focuses on collecting updated data for the hydrological analysis of the glacier, on further developing the techniques adopted for their acquisition and on exploring the potential of low-cost UAV technology in environmental engineering applications.

Figure 5 - drone built by DREAM2 project

Understanding the problem

In the last decades, the phenomenon of global warming has increased its relevance: the surge of temperatures, the melting of the glaciers, the rising of the global average sea level and the shifting of the rainfall patterns are phenomena involved in this global climate change. The latter affects mostly regions characterized by fragile equilibrium between the influence of hydrological processes as the Alpine regions, where the relevance of this change is greatly due to the melting of the glaciers that is happening at an alarming rate. This is the result of very complex interacting environmental phenomena that limits the predicting capabilities in case of experimental data shortage. Therefore, the “work on field” had to be extended to detect the rapid changes that are taking place.

Figure 6 - commercial drone used for photo acquisition

For this purpose, photogrammetry techniques have been investigated for the last three editions of the project; in particular the objective is to use photogrammetry to build a 3D digital model of the surface of a glacier, in order to study its evolution along the years. The Belvedere glacier has been chosen as test field to conduct these photogrammetric surveys and the technology being adopted relies on Unmanned Aerial Vehicles (UAV).

Exploring the opportunities

UAV technologies have been already employed in the field of engineering for photogrammetry purposes. They have been substituting since many years the use of helicopters equipped with suitable cameras for performing these kind of surveys. The available solutions typically rely either on quadcopters or fixed-wing drones, more suitable for wider areas.

Figure 7 - SenseFly eBee Plus for direct photogrammetry

As regarding the acquisition method, the majority of the UAV technologies currently employed is based on indirect photogrammetry, a technique requiring a lot of physical effort, since, in order to orient the obtained models in space, it is required to acquire manually the GPS position of a relevant number of points placed on the surface to be modeled. This may not be such an issue in urban contexts, but when it comes to the glacier environment the need of employing safe and fast operations is a must.

In this respect, a suitable solution would be represented by direct photogrammetry. By means of a GPS antenna equipped on the drone, it is possible to acquire the position of the camera in the exact moment in which the picture is taken, in order to heavily reduce the number of needed point to be measured on the ground.

The DREAM3 project identified the direct photogrammetry as the best method to be investigated to improve the data acquisition technique for building the 3D model of the surface of the glacier. Indeed, the most recent UAVs available on the market make use of direct photogrammetry techniques, but their cost is still very high. As a conclusion the DREAM3 team has come out with the objective to find a solution, cheaper to the ones available on the market, to realize direct photogrammetry with the reasonable level of accuracy to make proper hydrological estimations.

Generating a solution

The starting point for the DREAM3 team has been the purchasing of the fixed-wing Parrot Disco drone, since it was identified as the best compromise between cost and performance.

After that, the team performed suitable loading tests on the drone and executed accordingly detailed analyses of the components to be purchased to realize the wanted solution.

Therefore, the drone has been heavily modified to leave space to the additional equipment: a RICOH GR camera, a Tallysman Multi-GNSS and an EMLID Reach board supplied by a lighter and more performing set of batteries (whose cells have been separated for balancing purposes) by means of a DC-DC converter.

Figure 8 - Parrot Disco modifications

Figure 9 - Final solution: balancing test

The camera is set in time-lapse mode. In the meantime the EMILD Reach board records continuously the GPS position of the drone measured by the antenna; as soon as the camera takes a picture, the signal coming from the hot shoe is used as trigger to place a marker in the GPS logging data. In this way, it is possible to know the position of the camera in the moment the picture is taken and realize a first solution relying of direct photogrammetry.

The solution is characterized by a cost of about 1300€ and a payload of about 300 g from the Parrot Disco.

The solution has been tested at first on site, surveying an avalanche near the Belvedere glacier on May 2018 and, few weeks later, on the "Volare sui Tetti" aeroclub near Turin, proving its actual effectiveness and providing suitable guidelines for its further improvement.

Figure 10 - Model of the Belvedere glacier

In addition, in agreement with the path followed by DREAM and DREAM2, the team has been collecting and processing the data coming from two measurements campaigns performed in October and November 2017, to build the updated 3D surface model of the Belvedere Glacier.

After an initial phase consisting in processing of the GPS data of the markers delocalized all over the glacier, the photos taken by the drones have been exploited to realize a 3D model, suitably georeferenced, which describes the surface of the Belvedere glacier with a precision of 2 cm for each of the computed points.

From the comparison between the previous models, it has been estimated that about 4 millions of cubic meters have melted within last year.

Moreover, geophysical measurements have been performed by means of electric and seismic techniques in two relevant section of the glacier, with the objective to estimate its depth.

Finally, the results have been exploited to feed a mathematical model widely used in literature, in order to provide an estimation of the ice flow rate going downstream.

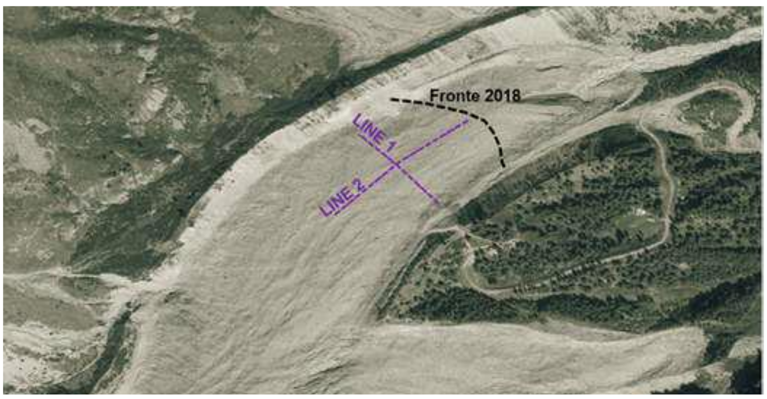

Figure 11 - glacier's sections investigated with geophysical surveys

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