1. **Research activity (max 1.000 words)**

Specific objective

The specific objective of my PhD is to understand the correlation between causes and effects of rockfall phenomena through the integrated use of acoustic, optical, thermal, radar, laser and meteorological monitoring tools available at the Poggio Baldi Natural Laboratory of the Department of Earth Science.
More specifically:

- understand the relationship between rockfalls and predisposing and triggering factors such as thermal, seismic, and meteorological stress
- Using innovative monitoring tool identify any correlations between displacements and subsequent rockfall
- understand whether small detachments (identifiable with extremely sensitive devices such as GigaPan optical systems) represent useful precursors for the prediction of larger rockfall

General Objective

This PhD project aims to contribute to a better characterization of rockfall in order to provide a contribution to their spatial and temporal prediction and to the development of early warning systems.

Introduction and state of the art

Varnes in 1978 described the rockfall process as “a detached fragment of rock that falls along a vertical or sub-vertical cliff, proceeds down slope by bouncing and flying along ballistic trajectories or by rolling on talus or debris slopes”. Rockfalls are the most frequent and widespread instabilities affecting steep slopes in mountain regions and, after earthquakes, cause the greatest number of victims and damage to built-up areas, infrastructures, environmental, historical and cultural assets. Therefore efficient monitoring activities can help us to get more information about this natural phenomenon. In general terms, monitoring has several functions: validating the geological models of the investigated slopes; supporting the management of risk scenarios; setting up early warning systems if sensitive structures/infrastructures are present. In the last few years, innovative techniques (such as laser scanners, terrestrial interferometry, etc.) have joined traditional geotechnical and topographic techniques. The lack of long-term prefailure deformations compatible with the acquisition frequency of even the most modern displacement monitoring systems makes this kind of measurement not suitable for rockfalls. A reliable prediction of rockfall hazard in fractured rock slopes is still far away, both due to the lack of evident precursors preceding the fall event and to the complex mechanism not yet fully understood. Using precision instrumentation and a greater number of innovative remote sensing techniques could expand knowledge in this field. Currently, an example of the use of these innovative techniques in monitoring landslides is certainly represented by the Poggio Baldi site. The first activation dates to 25 March 1914, and on 19th March 2010 a 4 million m^3 landslide was re-activated damaging a regional road and some houses. According to Varnes (1978) and based on morphological evidence, the landslide can be classified as a complex movement started as a rotational slide, then evolved into an earthflow whit rokfall on the vertical portion of the slope. In particular, the annual volume depletion from the cliff is between 2×10^3 and 3×10^3 m^3/year, with a total number of 84 rockfalls, developed in the three days of monitoring. In the last years, on this site, to ensure effective monitoring, numerous remote sensing tools have been used: Terrestrial Laser Scanning (TLS), Close Range Photogrammetry, Terrestrial RADAR (TInSAR) and a camera with support GigaPan Epic Pro V. In the last year a permanent monitoring base was built and to the previosly described tool a weather station and an acoustic monitoring system were added. The use of data of classic monitoring techniques integrated with those obtained through new technologies is an excellent method to increase the current state of knowledge on possible problems relating to fall phenomena.

Work plan

The achievement of the goal will take place in several distinct phases. At first, bibliographic research will be carried out on the kinematics of the rockfall and their dynamic analysis, with particular attention to situations comparable to the study area. subsequently, the used tool will be prepared and calibrated, evaluating the scanning rates and sampling duration, the nature of the sensors and the generated output by each individual monitoring tool. The microphone (01dB DUO Smart Noise Monitor), the optical instruments, two cameras with a resolution of about 20 Mpx that acquire RGB images in real colors at a preset rate (e.g., every 5 minutes), and the weather station will remain active for the entire duration. of the project. The High-Resolution Optical System (GigaPan), the Radar System (HYDRA - G) and the LiDAR System (TLS) are not currently suitable for a continuous monitoring. For these tools, because of the large amount of information they can generate for each individual use, it will be necessary to prepare periodic data acquisition campaigns lasting several days, which allow to obtain data on a quarterly / six-monthly basis that can be used for research purpose. Subsequently, the data obtained from each instrument will be filtered and processed to identify any correlations between small displacements and rockfall, and the possibility that small rockfall are precursors of larger rockfall. Displacement maps deriving from TInSAR will be integrated with 3D point clouds obtained from TLS and photogrammetry, in order to identify unstable areas and their possible pre-failure deformations.

Using the IRIS software, developed by the Sapienza start-up (NHAZCA s.r.l.), it will be possible to process automatically, using the change detection technique, the images obtained from the photomonitoring system and sent to the Sapienza server. The same processing chain will be applied to Gigapixel images, obtained with the GigaPan system, and it will be possible to geolocalize the events and evaluate the possibility that small rockfall are precursors of larger rockfall. The data obtained through the weather station, already active at the laboratory, combined with any measurements made via thermal imaging camera will be used to evaluate the main triggering factors of the fall process. Obtained data form microphone, once calibrated during the first investigation campaigns, will provide essential information on the presence and extent of the rockfall event, even remotely 24 hours a day. This continuous monitoring tool will make it possible to acquire a greater amount of data on the frequency of rockfall implementing knowledge on the main factors that determine their cause.