Abstract

The lack of predictive hail models, which allow for the protection of assets, is a problem in Uruguay and worldwide. To create them, we need more information about the phenomenon. In this work, I analyze key aspects for the design of a hail sensor, propose a design, implement it, calibrate it, and evaluate it.

Firstly, I present a literature review on the characteristics of hail and the damages it causes worldwide. I also explain the traditional methods for characterizing hail, which can be divided into two major categories: observational methods and methods that utilize some form of technology for detection. In the methods of the first category, the population reports characteristics of hailstorms. These types of reports and inquiries initially began via telephone and now make use of websites and mobile applications. The methods in the second category can be further divided into two subcategories. On one hand, the use of long-range technology such as radars and satellites, and on the other hand, specific technology that involves direct contact with the storm, which I conducted an exhaustive study on. My sensor falls into this last category.

The first reported hail sensor, the *hailpad*, dates back to the 1950s. It was also the most widely used hail sensor throughout history due to its simplicity and effectiveness. This sensor and its early successors were mechanical, although some sensors incorporated electronics. Currently, due to technological possibilities and driven by the increasing capacity to handle large volumes of data, there is a push to automate the acquisition of hail information. This is a highly contemporary topic, and the state of the art has evolved significantly from when I began researching the subject in 2019 to the present day. In particular, commercial sensors with very similar operating principles to the one I was developing have emerged.

I believe the primary value of this work lies in demonstrating why modern commercial designs make sense and academically explaining how this type of sensor functions. I hope that the knowledge I've generated in this area through research contributes to the improvement of these systems and promotes the development of such sensors with Uruguayan involvement, making it possible to popularize them in our country. In this regard, I was motivated by the interest in my work shown by the Uruguayan meteorological community.

The sensor I propose operates on an acoustoelectric principle. One notable aspect of this work is the design of the element exposed to the weather, where vibrations are generated with each hail impact. Another significant aspect is the placement of piezoelectric transducers within this component. These transducers

are the elements I use to convert the vibrations into electrical signals. A portion of my work involved conducting systematic tests to obtain these electrical signals. Based on the processing of these signals, I made design decisions.

The aspect that I consider central to this work is related to the calibration of the designed sensor. One of the reasons for this is that the same calibration method can be applied to both the sensor I designed and commercial sensors. This includes the development of a testing platform, the need for which I identified. This platform was designed as part of an Electrical Engineering graduation project that I proposed and supervised. The testing platform is based on the *Energy Matching* technique, which is widely referenced in the literature as it has been used to calibrate hail sensors since their existence.

Currently, the prototype I built is placed outdoors, awaiting the occurrence of hailstorms.

The aspects I would like to work on in the future include: making the prototype independent of the electrical grid, replacing the current computer with one that can be embedded in the sensor, substituting the current data acquisition card with an economical one, studying the influence of temperature on the signals, and integrating the prototype into a wireless sensor network.

In the context of this research, I have made two publications in journals [1, 2] and presented papers at three events [3–5].