Online Ballooning Portal

Ethan Harstad*
Aerodyne Labs, Ames, IA, 50010

An online balloon flight prediction system was developed as part of a grant from Taylor University. This system is currently being extended to include tracking and data analysis components. Tracking and telemetry data will be collected by distributed ground stations and forwarded to a central server. This data is archived in a database for live display or later data analysis. The collected tracking data will also be used to continuously improve the prediction algorithms used. Collecting all these tools in one place will help to make the ballooning process more intuitive to beginners and enable more advanced applications for experienced users.

I. Introduction

The popularity of high-altitude ballooning has exploded in recent years.[1] Many of these flights are conducted by people with little or no experience. These beginners frequently conduct flights without proper pre-flight predictions which could lead to unsafe landing conditions. Many of these people feel that the currently available prediction and tracking tools are too difficult to use. These leads them to ignore predictions and to use alternative (and possibly illegal) methods of tracking such as cellular phones. This paper details efforts and plans to create an integrated balloon mission management system that is useful to beginners and experienced balloonists alike.

II. Prior Work

Several organizations have developed online and offline infrastructure over the years. The now offline Near Space Ventures predictor was widely used but only offered predictions and was somewhat difficult to use for first time launchers. UKHAS has developed somewhat disparate but effective pre-flight prediction and in-flight tracking systems that are seeing wide use, especially overseas. The relatively new ASTRA system by the University of Southhampton even brings some new predictive features to the scene. However, all of these systems fall short of a truly comprehensive solution.

A. Habhub Predictor and Tracker

The UKHAS (UK High Altitude Society) has developed an open source balloon flight predictor and a separate open source tracking system.[2] These systems see widespread use, especially in the UK. The habhub prediction system was one of the first easy to use online prediction systems, integrating automatic sounding retrieval with online Google Maps. The tracking extension provided through Spacenear provides real-time mapping and predictions on a public website.

The Habhub system is however somewhat limited. The prediction engine uses a very simplified constant ascent rate model. The tracking system is currently only capable of being updated through an open source software radio modem called dl-fldigi. This program is currently unable to handle APRS tracking, a tracking method widely used in the United States. Habhub also does not handle additional telemetry data well or archive data for later viewing and analysis.

*Hardware/Software Engineer, Ames, IA 50010

B. ASTRA Predictor

The University of Southhampton developed the ASTRA balloon flight planner to provide several useful prediction features.[3] The most useful features include the ability to predict floating balloon flights and an attempt to categorize prediction errors with a monte carlo model. The ASTRA model varies the wind predictions to account for uncertainty in the forecast. It also varies burst altitude and several other parameters to account for manufacturing variances of the balloon envelope. The ASTRA team also performed a statistical analysis of many balloon flights to develop a stochastic drag model.[4] This is particularly important as the balloon experiences several orders of magnitude variation in Reynolds number, spheres and similar shapes experience a drag crisis as the wake detaches from the balloon.

Though the ASTRA predictor presents its interface in a pleasing manner, it actually involves more user inputs than the Habhub system. The user fields also offer little to no guidance as to what appropriate values would be. The ASTRA system is also pre-flight only and provides no in-flight or post-flight features.

III. Current Work

Work is currently proceeding on the ballooning portal on multiple fronts. Active development is being conducted on a simple prediction and tracking system with heavy planning to ensure that this system can easily be extended. Research is also being conducted to identify possible existing components that can be reused as well as to identify possible areas of improvement.

A. Stratocast

Development of Stratocast was funded by Taylor University through an NSF grant.[5] Stratocast is currently a prediction only system but is designed to be modular and plans are in the works to extend its functionality to include tracking and data analysis. Stratocast currently operates from NOAA NOMADS data sources and makes this data available over a REST web interface. Predictions are also requested and returned via a REST interface, allowing these tools to be easily integrated with further development efforts.

Active work on Stratocast is currently suspended while the interpolation methods described in the next section are developed and evaluated. Standards are also being developed to allow easy extension and interoperation. Development is expected to resume at the end of the summer.

B. Interpolator Development

A limitation of Stratocast and many other prediction engines is the use of simple interpolation strategies for atmospheric data. Most systems use a simple nearest neighbor over latitude, longitude and time and linear interpolation over altitude. This produces rapid kinks in wind direction and is obviously not all that similar to the exponential variation of pressure versus altitude. The nearest neighbor approach is also particularly bad in rapidly changing conditions such as sunrise/sunset and weather fronts. Trilinear[6] and tricubic[7] interpolators over latitude, longitude and time are currently being evaluated.

These methods increase both the amount of data required and the simulation time required, these factors will be evaluated against any change in accuracy. Some analysis has been done on these methods by comparing their outputs created from input data with an artificially reduced domain, but this kind of testing is unable to characterize the performance of the methods on small scale features. More flight paths are needed to evaluate the performance of these methods.

C. Tracker Development

Several common tracking systems are already being integrated into the web interface and database. This includes APRS and popular ASCII formatted serial modems. These simple tracking methods require the user post their telemetry formats and frequencies and other parameters for other potential listeners to manually configure their receivers and tracking software. Manual configuration is sufficient for testing purposes with experienced users but unsuitable for beginners. Further development to improve upon this is discussed in section IV.

D. Visualization Development

Intuitive visualization of collected data is essential to learning, especially to those without background knowledge of the measurements, such as middle and high school students. Graphs and other visualizations present a much more comprehensive picture of the data than spreadsheets alone. Unfortunately, good graphs are hard to develop, especially in such a universal format as general purpose data collection.

The first step in developing a visualization framework is to identify commonly used types of displays and common types of physical units. With a collection of displays, a wizard can be developed that should fit the majority of use cases. A simple wizard would allow the user to select a visualization and data ranges and then make simple tweaks to the presentation, much like the Microsoft Excel chart wizard.

E. Standards Identification and Development

One major obstacle to adoption of any particular infrastructure is the multitude of competing standards for telemetry and telecommand. Standardizing these systems would allow many benefits like a distributed network of listeners that can be used to track long duration missions over the horizon. Sharing data between organizations will also require standardized formats or at least a standardized data description format.

These problems have in large part already been solved by the CCSDS, Consultative Committee for Space Data Systems. The CCSDS is a collection of space agencies that have developed standards and recommendations for everything from telemetry/telecommand to interoperability and networking.[8] These standards have even been adopted by some cubesat groups. As high altitude balloons are frequently used as a testing platform for small satellite payloads, this interoperability would be a major benefit. Relevant standards from the CCSDS and other sources must be identified before further implementation and planning can take place.

IV. Future Work

Future work on this system mostly involves long term development and performance evaluation. It is intended to carry out all future development in an open source and community driven way. A mailing list will be set up to discuss the future of the project and will be open to potential developers and potential users alike. New features will be developed in a manner consistent with user indicated priorities.

A. Performance Evaluation

Reliable metrics will need to be established to evaluate the performance of the prediction system. These metrics will automatically be run against every tracked or uploaded balloon flight to track the performance of the predicted models. The results of these metrics can be used to pinpoint areas of improvements and can even be used with automated machine learning techniques discussed in the next section to automatically improve the predictive models.

Several simple metrics already exist. Comparing the final landing position to the predicted landing position provides a rudimentary characterization of the performance of the predictive model. Graphing the evolution of this error over the length of the flight is even more constructive. For instance, the evolution of the error would show a sudden change if an unexpected event, such as early balloon burst, occurred that would not be seen by only comparing final error values.

The performance of these systems can also be used to provide an estimate of the prediction error during new predictions. The error differentials can be propagated through the prediction to arrive at a probable landing area. With multiple evaluation metrics, different sources of error can be identified and simulated using monte carlo methods.

B. Machine Learning Development

Machine learning systems can be used to help improve the performance of the predictions. A classifier can be used to classify each flight record as typical or atypical. Typical flights can be automatically analyzed and fed into statistical models. Atypical flights can be flagged and sent to a human to determine why the prediction failed. In this way, the performance of the prediction engine should improve with each new flight record that is used to train it.

C. Universal Tracker Development

A long term objective of the tracking system development is the development of an automated universal tracking system. The goal of this system is to develop low cost hardware that can be used to track and command nearly any high-altitude balloon payload. A user can simply register their mission with the system and define their communications parameters. The central server then communicates with all registered listening stations and configures them to properly communicate with the registered payload. The receiving station then uploads any telemetry received to the central server for use in the tracking system. Received signal strength measurements from the listening stations can be used by the server to select the optimal station to transmit remote control commands from. With this system, payloads can easily be tracked and controlled, even over the horizon, without resorting to expensive satellite modems or other exotic solutions.

The Habhub tracking system already utilizes a similar system to this and several systems have been proposed for global cubesat tracking networks. The open source components of these systems can be reused to reduce development time. Open source software defined radios can also be used to allow tuning to nearly any frequency with any well defined modulation strategy. However, the system would benefit from using a single or relatively few modulation and encoding formats, either custom or preexisting.

References

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