

Automated laser ranging operations using situational awareness of external conditions from multi-sensor data

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Abstract:

Automation needs often vary substantially depending on the context of an organization or its applications. For multidisciplinary applications in an optical observatory, the complexity increases substantially depending on the extent of the coverage of the space of the applications. As part of an overall effort to improve operational effectiveness for satellite laser ranging (SLR), debris tracking, astrometry, and photometry, an effort was placed on leveraging the multi-sensory atmospheric and sky data to make intelligent decisions. This paper includes the major automation drivers of the optical observatories that Cybioms is building and describes an instance of an automation approach for screening and scoring the sky conditions to enable optimal operations through scheduling decisions.

Introduction

The system automation has become an increasingly important need within the satellite Laser Ranging (SLR) community to address the numerous satellites that are available for ranging along with an increasing manpower cost for engineering and operations. In a typical operational location, there will be extremes of temperature (low and high), high humidity, dew point affecting condensation on critical optics, rain, snow, fog, lightning, high speed winds, dust storm, cloudy conditions of various scales, solar radiation, and lunar backgrounds. These inhibit or limit optical observations and the success in getting maximum data, whether it is photometry, astrometry, debris tracking (optical imaging, laser ranging), satellite laser ranging, or space imaging applications depend on the ability to quantify as well as avoid adverse conditions. In many cases, certain adverse environmental conditions can be harmful to the system and must be avoided. The manpower problem is further exacerbated in hard to reach low inhabited mountainous locations, far away from a big city.

Technical Approach

In general, automation is a long and arduous process for development, testing, and implementation. For low volume highly specialized scientific applications, the cost and the ROI are not necessarily well justified over a short time horizon. Amongst the many areas that need automation in a laser and optical observatory to achieve maximum data, operational scheduling based on the external environment as well as the sky conditions is one of the most important ones. In the case of satellite laser ranging (SLR), an area of particular importance is the operational scheduling of satellites based on satellite priority and needed data. Due to the complexity and the stringent airspace safety requirements of SLR, any automation process deployed has to be handled as a delicate multi-step process with confidence building steps and measurements for stabilizing repeated and consistent system performance. Cybioms

has selected an approach to manage this by focusing on areas where there is significant human decision making uncertainty due to the subjectivity and the dynamics of the conditions or where human reaction responses are longer or very fuzzy at best.

Our technical approach assesses the external environment rigorously to avoid conditions that does not produce any meaningful data while unnecessarily increasing the dangers for system degradation or reduced lifetime ensuing exposure to adverse conditions. This external situational awareness has significant merit for real-time operations as it attempts to address the above issues. In pursuit of solving the above operational issues, we have developed a scoring approach for evaluating the external environment parameters to best match the required operational conditions. In this paper, we explain what we are doing with the sky conditions assessment during daytime SLR only conditions.

Results and Discussion

Figure 1 and 2 are day time sky camera images taken at two different instances of clear and partly cloudy sky captured by an AllSky camera that maps the azimuth (AZ) and elevation (EL) space into a 2 dimensional image. In many instances, the real-world is depicted by Fig.2 than Fig.1. Naturally, the sky cover dynamics also changes and hence frequent imaging is needed to assess the near real-time dynamic sky conditions.

Tracking avoidance under difficult conditions is always the right thing to do, especially when the risks outweigh the benefit. As a general rule, the satellite trajectory can be superimposed on the 2-d image to compute a score for the probability of success. Our decision schema makes use of artificial intelligence (AI) techniques to perform the scoring and the subsequent scoring based decisions to either perform or avoid tracking. This scheme can detect buildings, hills, etc., at very low elevations and perform the scoring. This is not needed for SLR as the tracking is strictly above 10 deg elevation, while important for certain imaging applications.

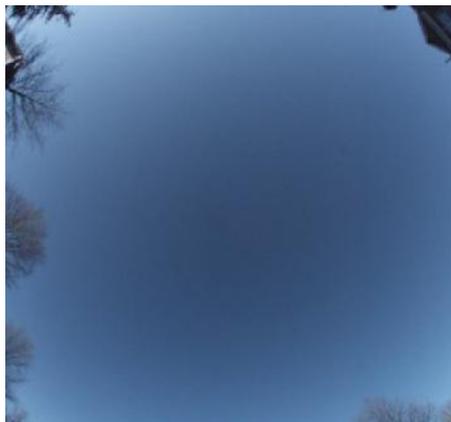


Figure 1: Clear sky;

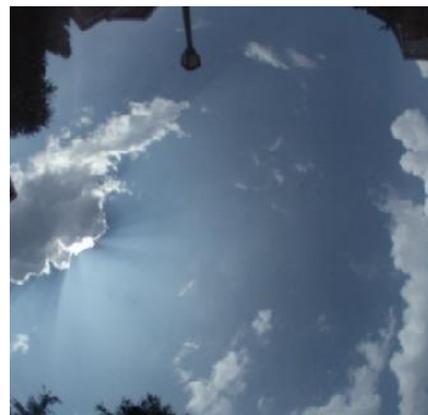


Figure 2: Partly cloudy sky

In our case, the SLR scheduling assessment is done a priori to the tracking. This should address most of the satellite passes/pass segments. However, there can be exceptions to this. Even in cases of pre-computed favorable conditions, if the data yield is sparse or non-existent, then the near real-time decisions will be made (based on the emerging sky conditions). In general, tracking LEO satellites is much easier, which can yield data even under sparse tracking conditions. This is not true of GEO SLR targets especially during daytime. The link margin is rather tight for HEO and GEO targets, especially under daylight conditions due to the needed spatial and spectral filtering as well as the mostly single photoelectron tracking conditions. Typical planned dwell time on a SLR satellite pass segment is ~1 minute for LEO to HEO, while it is longer for especially for daytime GEO targets. The knowledge of the elevation dependent SLR link for the satellite in combination with the sky AZ, EL score supports either a target selection or a target drop in near real-time based on a specific satellite trajectory, thus providing a framework for automated scheduling and tracking.

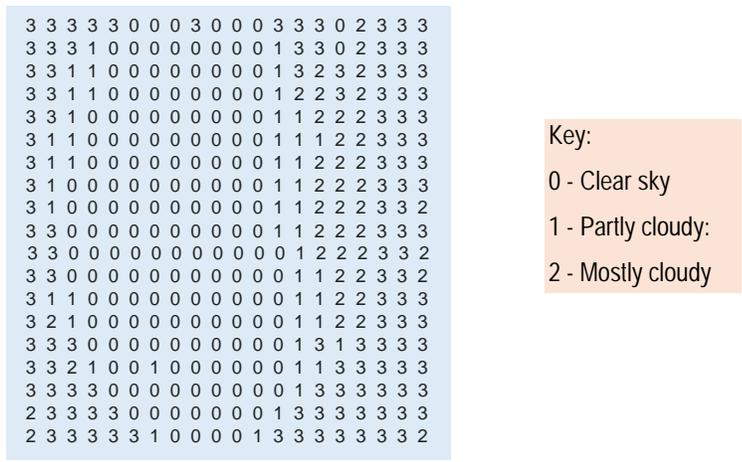


Fig: 3; Scoring of an experimentally measured sky image

Extensive laboratory simulations have been done to analyze the various tracking conditions to optimize the algorithms. Figure 3 depicts the scored sky conditions based on an actual image of the sky. Based on the combined score of the satellite link with the sky score, one can decide on which satellites to select for the upcoming tracking. The tracking performed under various score values will be correlated with the observed data (which is an indication of the actual sky conditions as well as the state of the satellite ranging system) will then be performed to estimate the departure and the optimization effort towards a comprehensive a priori model.

Conclusions

Laboratory simulation results to date have given us the confidence on the robustness of the approach that we have taken in a key area of an optical observatory automation. Many parameters in our decision space will still need final tuning to achieve optimal operations and generate maximum data. Such operational SLR data collection and correlation

analysis with the predicted will drive the fine tuning of the AI decision space, which will occur with the full deployment and operations of the system.