Optimization of Automated tracking with situational awareness

T.Varghese, K.Hennacy @ Cybioms Corp, USA

Automation - General

1. In general, we are our own worst enemy when it comes to automation !!!
2. Often comfortable with status quo or we rationalize it;
3. In some cases, it is an emotional issue;
4. Normally, costly, routine, tedious, sensitive, complex, high bandwidth tasks lend to automation;
5. Changing the paradigm requires a fresh look with no biases - an external agent is often needed;

Automation – System Background

1. State of the art 1 meter high optical quality telescopes (Q=2) with adaptive optics to support multidisciplinary applications:
   a. Photometry, Astrometry
   b. Faint object imaging (magnitude >21) for GEO orbit debris tracking/ asset protection
   c. SLR – especially night and daytime ranging to GEO targets
   d. Lasercomm (future)
2. At the sites, weather conditions are often not good - can become adverse to system safety;
3. No point in attempting to track (and fail) OR risk safety (internal/external) OR output quality when operating conditions are NOT right;

Automation - Drivers

1. Inability to attract trained experienced personnel to handle complex system operations; Remote locations away from cities; lack of interest to relocate; at most, we can expect a low tech, general purpose care taker for the facility;
2. Safe SLR is mandatory – integrate multiple tools
3. Remote control of operations far away from the sites is a contract deliverable;
4. Accountability (warranty) for the system for 3 years;
5. Keep the cost of overall upkeep down, while maintaining the highest safety state;

6. Data Driven approach to protect contractual interest;

Automation – Factors to consider

1. Automation is like climbing a mountain peak; need multiple base camps before getting to the summit; complexity is an enemy of automation;
2. "Intelligent layer" on top of the operational layer to monitor, learn, and supervise;
3. Probabilistic reasoning needed in several instances;
4. Multisensor data to create situational awareness (inside and outside);
5. A variety of environmental data (Sky camera, pressure, temp, humidity, wind, precipitation, visibility, particle counts, and lightning) deployed;
6. Make HW, SW architectures simple to implement, test, verify;
7. SW plays a major role, but needs substantial testing for maturation;

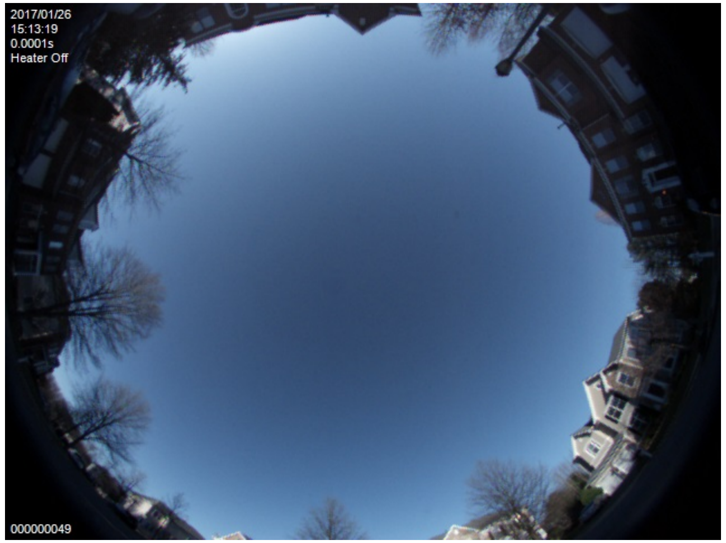
Automation – Constraints, Challenges

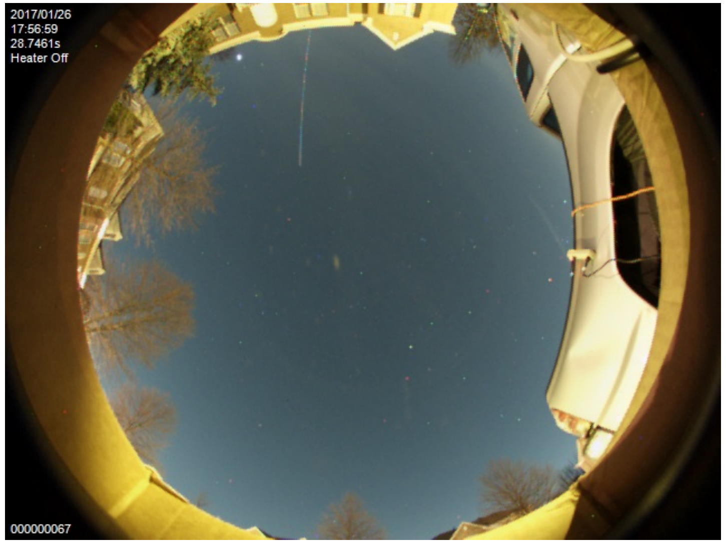
1. SLR is complex; multiple disciplines makes the complexity a non-linear problem;
2. High peak power of GW (~25mJ, 25ps) – accompanying airspace safety and liability;
3. SW development and testing for fail-proof ops;
4. HW & SW have to be stable and resilient to faults – needs redundancy + lot of testing
5. Vast array of test cases and training sets needed to validate;
6. Handling exceptions;
7. Probabilistic reasoning and machine learning;
8. ROI from automation;

SLR Automation – Major Areas

1. Scheduling and interleaving of ranging functions √
   a. currently automated; **<done>**
   b. routine prediction updates to further enhance the accuracy; **<done>**
2. Closed loop servo-control for pointing and satellite acquisition <partially done>
   a. Finite range of variability for Delta AZ, Delta EL; <partially done>
   b. RX signal amplitudes/rates as feedback; <partially done>
3. Environment monitoring, operations, and safety management; √
   a. External (aviation airspace, **Sky conditions**, P, T, H, DP, P-count, wind, lightning) **<done>**
   b. Internal (humidity, temperature,.) <to be done>
4. Collaboration through Real-time communications with other SLR stations;
   a. Near RT Tracking data from elsewhere to minimize search/ decision space <to be done>

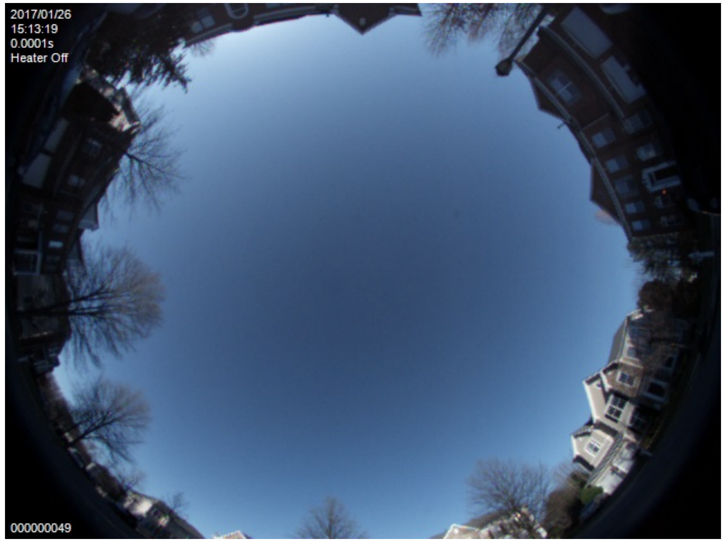
AllSky camera – Artificial Intelligence, Pattern Recognition





1. Developed classification strategy and SW to discriminate the **cloud, buildings, objects in the sky**;
2. If cloud cover persists along the LOS, then a different satellite is auto-selected along a “clearer” path.
3. Tracking is activated/terminated based on the sky conditions;
4. Twilight and night time conditions present a different challenge and is not addressed here;
5. Watch “objects in the sky”, if the 30sec data stream captures it or add extra cameras to interleave;

AllSky camera – Detection



1. Sky coloration is an important part of daytime detection;
2. Needs location based data to have reference images to discern objects other than the sky;

AllSky camera - Image analysis <1>

1. Pattern recognition well suited to assess sky transparency as clouds are variably shaped;
2. Details of shapes are not relevant to the classification as it is based on the range of colors associated within the image;
3. This approach is accurate to identify clear patches of sky, cloud cover, and dark skies;
4. In the limit of twilight to darkness and night time sky, the lack of color differentiation will cause this approach to be not successful – alternate schema to be used

AllSky camera - Image analysis <2>

- **Examples of the Images** for image recognition and classification; also other patterns;
- Challenges to sky coloration

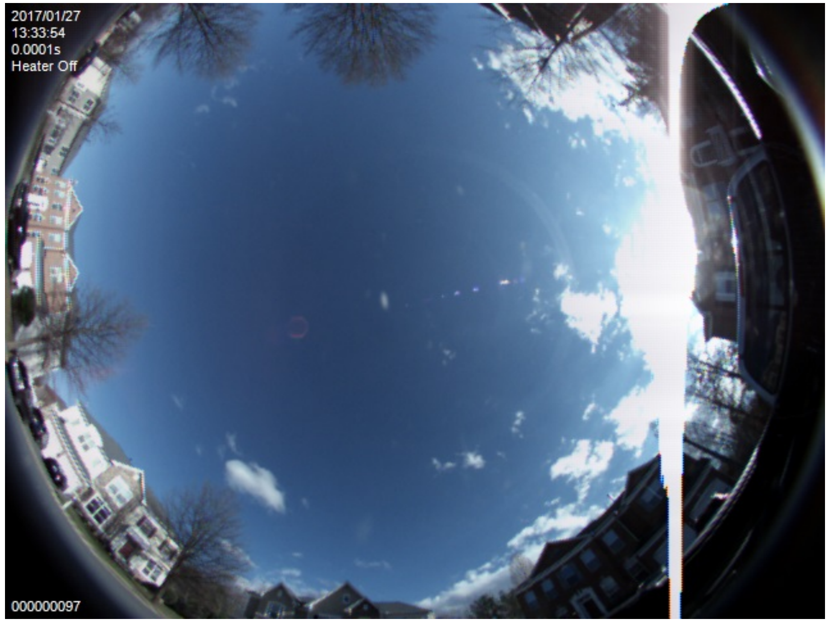
0 – Clear sky: few sample extremes and average daytime sky coloration

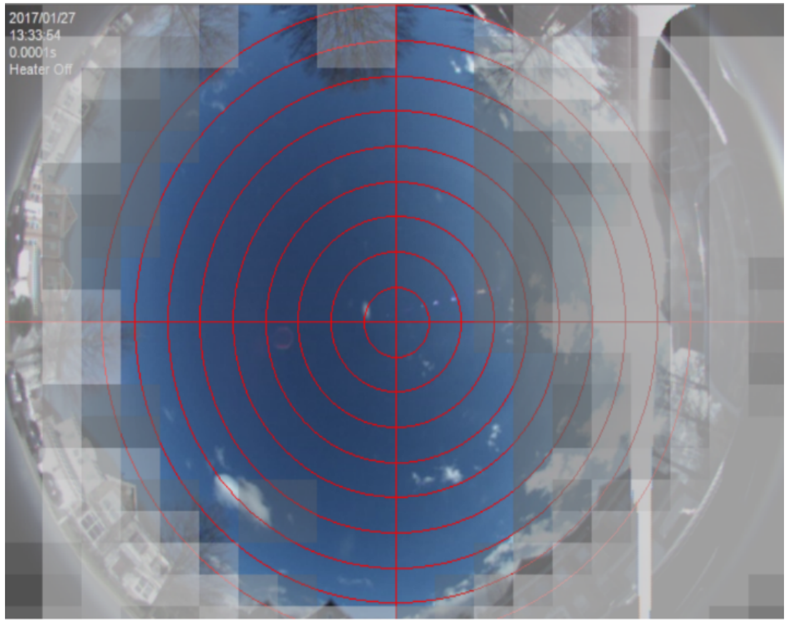
1 – Partly cloudy: arbitrary set of ref images (thin clouds, patches with both sky and cloud...)

2 – Mostly cloudy: arbitrary set of ref images (silver clouds, white clouds, dark clouds, etc...)

3 – Objects: arbitrary set of ref images; e.g., buildings, trees, aircraft, …

AllSky camera - Image analysis <3>





3	3	3	3	3	0	0	0	3	0	0	0	3	3	3	0	2	3	3	3
3	3	3	1	0	0	0	0	0	0	0	0	1	3	3	0	2	3	3	3
3	3	1	1	0	0	0	0	0	0	0	0	1	3	2	3	2	3	3	3
3	3	1	1	0	0	0	0	0	0	0	0	1	2	2	3	2	3	3	3
3	3	1	0	0	0	0	0	0	0	0	0	1	1	2	2	2	3	3	3
3	1	1	0	0	0	0	0	0	0	0	0	1	1	1	2	2	3	3	3
3	1	1	0	0	0	0	0	0	0	0	0	1	1	2	2	2	3	3	3
3	1	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	3	3	3
3	1	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	3	3	2
3	3	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	3	3	3
3	3	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	3	3	2
3	3	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	3	3	2
3	1	1	0	0	0	0	0	0	0	0	0	0	1	1	2	2	3	3	3
3	2	1	0	0	0	0	0	0	0	0	0	0	1	1	2	2	3	3	3
3	3	3	0	0	0	0	0	0	0	0	0	0	1	3	1	3	3	3	3
3	3	2	1	0	0	1	0	0	0	0	0	0	1	1	3	3	3	3	3
3	3	3	3	0	0	0	0	0	0	0	0	0	1	3	3	3	3	3	3
2	3	3	3	3	0	0	0	0	0	0	0	1	3	3	3	3	3	3	3
2	3	3	3	3	3	1	0	0	0	0	1	3	3	3	3	3	3	3	2
3	3	3	0	3	3	3	3	3	3	1	3	3	3	3	3	3	3	2	2

1. The reference images are squares - scoring grid is a square
2. Note the identification of dense and partly cloudy regions
3. Further refinement to identify sunlight glare in progress
4. Each square mapped to the AZ, EL volume space to guide tracking

0 - Clear sky

1 - Partly cloudy:

2 - Mostly cloudy

3 - Objects

Conclusions

1. Effective classification scheme and pattern recognition approach to address Sky visibility to assist automated tracking;
2. When integrated with the weather + additional environmental + airspace data provides the framework for a comprehensive situational awareness needed for SLR automation;
3. SW implementation is nearly complete and getting ready for integration with operations SW and further testing;
4. will continue to train the recognition SW with additional sensor data to further improve the accuracy and consistency;