When Does Automation Make Sense?

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Abstract
Increasing levels of automation of tasks at laser ranging stations has been a goal and fact since Satellite Laser Ranging (SLR) started in the 1960s. However, what do we currently mean by automation, and what prevents us from getting there? The costs of advancing automation depends on the level of automation, robustness of the automation, and fail-over capabilities. Depending on the objectives of automation - reduced manpower, higher productivity and more consistent outcomes, operations in remote locations - the costs may or may not be justified. This presentation will explore several of the possibilities.

Introduction

The term "automation" means performing certain tasks with minimal human intervention. For SLR, the goals of automation are to improve reliability, increase data volume, reduce manpower and other costs, improve safety, and probably others. Earlier automation projects included computer control of the telescope mount (rather than having a person tracking each axis manually); on-site filtering and normal pointing of data; downloading and processing of predictions; radar aircraft avoidance rather than a mount observer; and single operator ranging.

There are certain "drivers" that now propel automation projects. With the ever-lengthening list of targets to track, the stations must be able to effectively prioritize, schedule, and track as many satellites as possible. To be effective, the tracking should be optimized to range during the three important segments of each pass (rise, meridian, and set), interleaving passes where possible, while avoiding the sun, clouds, and aircraft. In this busier world, where human operators are either too slow, imprecise, or expensive, stations strive for unattended ranging (i.e., remote or no operators) 24/7/365. With the need for a more evenly-distributed global coverage, there will be more remote stations where reliable operations can only be achieve by a high level of automation. As with most industries in much of the world, the cost of personnel and other long term costs of operation are constantly subject to reassessment and reductions. There can also be improvements in data consistency gained with automation by removing the "observer equation", in which the differences of operator skills and habits result in different amounts and quality of data. Another need is to maintain safe operations. By removing a fatigued operator from operations, there should be less issues with station safety.

Automation, however, is not free (in any sense of the word) and comes with some limitations. There are trade-offs between the short term costs of building or upgrading a station and long term savings in operational costs and improved data volume in three areas: 1) legacy versus new stations, 2) technical challenges, and 3) regulatory and safety issues.

Cost of Automation for Legacy Stations

For legacy stations, i.e., those built before full automation was a possibility, there are special concerns. There must be a realistic assessment of whether the system can be automated. Considering the age of the system, will one failure, such as a main axis bearing or laser, shut down the system permanently? Is there a basic design issue with the station, such as a mount with large, unmodelable pointing errors, that makes automation unfeasible? If so, this system is not a candidate for automation.

If the station passes the above tests, what automation would provide the greatest return on investment? A new timing system? New hardware that can tell tracking software whether it is safe to range? New tracking software and hardware that support satellite interleaving? A new servo system? The improvements do not need to involve full automation, just progress towards some goal or goals mentioned above.

How would the upgrades be made? Can the station be taken off-line for a long period of time to make upgrades, or would the upgrades be made incrementally while the station is still taking production data? If the station is to be shut down, what will existing personnel do during that time? If the changes are incremental, how will changes be integrated in such a way as to insure data integrity and continuity throughout the process? Every time a change is made to the measurement chain in the production system, the data needs to be vetted by the ILRS Analysis Standing Committee.

Cost of Automation for New Stations

Is there enough time and a large enough budget to build a new station? If there is a legacy station, will there be money and personnel to run it while the new station is being built? If the legacy station is shut down and all energy is spent on the new system, how will the data time series from the old and new stations be connected?

In considering the cost of the new station, realize that there are multiple phases, each with its own potential for delays and cost overruns. Personnel management and availability will also be an issue during each phase – are the right people available to do the work? Some of the phases are as follows.

- Design: is this to be done in-house or contracted out? The contracting itself will take time.
- Hardware and software acquisition or development: will COTS hardware be used and adapted for station use, or will unique hardware be built? What is the expected lifetime of the components? What is their Mean Time Between Failure (MTBF)?
- Integration and testing: Is there a test plan? Is there room in the schedule for a re-work of components that do not work as expected?
- Operational costs, including long term sustaining engineering: Are the projections reasonable, and is there a long-term source of funding?

Can there be collaboration or consultation with other stations to provide ideas, expertise, personnel, and so forth? Collaboration or consulting could reduce the time and cost of developing and implementing a station design and operations plan.

Other Cost Considerations

There are advantages to phasing in steps toward automation over time, even years. The cost of automation can be spread out, avoiding a single, big budget item. Phasing in the different parts of the project can give time to learn how the subsystems work and provide time for software development.

The costs of automation should reduce the long term maintenance and personnel costs. While there are additional advantages to automation, this can be a big benefit.

If personnel are lost as a result of automation, be sure that your “corporate memory” doesn't leave with them. The station still needs to be operated and maintained in the long term.

Automation also benefits from economy of scale, so the costs of automation will decrease and benefits increase for networks of several stations spread among different, often remote, sites. The design and software costs can be spread over several stations.

Technical challenges

The challenge of automation is not only the monetary and time costs; it also includes technical hurdles which will determine whether the project will be successful in the long term. For example, part of the system design will determine what sensors are needed for meteorology and metrics. What meteorological instruments are needed beyond pressure, temperature, and humidity? A sky camera will be useful to observe cloud conditions. Wind speed, direction, precipitations, and other weather conditions will need to be measured reliably and integrated into the station's safety system. The internal operating temperatures and power levels, etc. of various equipment need to be measured and then used to assess the health and safety of the system, shutting it down and alerting others if dangerous conditions are detected. Another requirement will be fire and water damage monitoring and alerts.

The mean time between failure (MTBF) of the various components and subsystems needs to be considered, whether for the laser, radar, sensors, computers, or others. Especially for remote sites without skilled personnel on location, this factor could mean the difference between a successful system and one requiring frequent costly maintenance trips.

Software complexity, analyzing edge cases, and the planning for thorough testing are also challenges. Algorithms must be carefully developed and tested to ensure the system is not, for example, wasting time tracking through clouds or endangering the station by failing to close the station during rain, high winds, and lightning. A thorough test plan with simulations of as many of the anticipated hardware and weather scenarios as possible will help mitigate this challenge.

Sending data from a remote station to a central facility for analysis and for detection of degrading performance will require design and development of central software with its attendant costs. This software will also need clever designs to detect changes in the station data quality and volume and subsystem performance, and will also require thorough testing. All of this raises the cost of the station or network.

For remote sites, sustaining engineering may be a significant challenge. Successful operations will require decisions as to the level of repair or engineering capacity of on-site personnel balanced against the cost of hot spares for critical systems, and against the need for emergency engineering trips to the site. Having good remote diagnostics and trouble shooting procedures will be critical.

IT security is a difficult enough challenge for local facilities, and can be much more of a problem for remote sites. The approach to IT security should be considered before the station computer networking is designed to prevent the need for significant re-design later.

Regulatory and Safety Challenges

Safety must be the top priority. Local and national safety standards must be adhered to, and safety provisions may have to be inspected by the appropriate agencies. There are likely to be at least electrical, plumbing, and building codes to deal with. Hazardous chemicals will require appropriate handing and reporting. These standards may also vary significantly by country or locality, so a lot of research is needed.

Radar or other aircraft avoidance techniques will need to be vetted by the appropriate safety and aviation agencies. In some cases, it may not be possible to fully automate the station because of aircraft avoidance concerns alone.

Laser safety, both from an electrical and eye-safety standpoint will need to be addressed. Ground target ranging, if used, may have dangers associated with flashing unsuspecting passersby, especially after dark. Care must be taken to ensure outdoor eye safety guidelines are followed, and perhaps barriers or ways to automatically detect obstructed (or missing) ground targets will be needed.

Releasing personnel when moving from a non-automated station to full automation may cause some issues with governmental regulations or labor unions.

Conclusions

There is a spectrum of automation and funding levels available to different stations, and based on the above discussion, we can make some conclusions in certain cases.

Full automation is possible in the case where most of these resources are present.

- A large (enough) budget.
- Resourceful personnel, available time, and expertise to find, experiment with, and adapt components and algorithms for the station.
- Ability to use another laser station as a model to help reduce development time and cost.
- Have someone else build it: there are several companies and organizations that have experience building laser ranging stations

Having a network of stations is a particular motivation for automation, both in the economy of scale and reduction of personnel costs.

Some automation is possible in the case where

- there is budget for major renovations;
- there are identifiable projects with a clear path and a large return on investment, e.g., a pixelated detector, a precise event timer, software automation of some tasks; and
- it is possible to identify the most important outcomes: more data, more reliable operations, lower costs of operations, etc.

Do not pursue automation if a combination of these is true:

- there is little chance of a budget to do more that operate the station;
- this is a legacy system not adaptable to major renovations or automation;
- personnel costs are low; or
- there is no institutional support for expanded operations.

Hopefully, most legacy and proposed stations plan a substantial level of automation. There is a growing roster of satellites of all types that require more coverage than is currently possible from most existing stations. The speed and accuracy of computation and decision making needed to efficiently track the highest priority passes interleaved with other passes while avoiding clouds and ensuring the safety of personnel and equipment is quickly slipping from