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Community Workshop: Charting the Future of Terrestrial Laser Scanning (TLS) in the Earth Sciences and Related Fields

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Community Workshop: Charting the Future of Terrestrial Laser Scanning (TLS) in the Earth Sciences and Related Fields

Project Summary. We propose a 3-day workshop to be held in October, 2011 in Boulder, Colorado to bring together Terrestrial Laser Scanning (TLS) users from the Earth sciences and related fields to outline a strategic vision for the future of TLS as applied to a broad range of research activities. The workshop will address the current and future needs of researchers based on the present state of the art and will provide recommendations for the advancement of TLS data acquisition, processing, analysis, and distribution to all levels of the community. The goals of the workshop are to capture ideas, to advance community interest, and to establish requirements needed to pursue current and future trends in: 1) science applications, 2) data processing and analysis, 3) definition and adaptation of formats and standards for data and metadata including data/metadata exchange, archiving, interoperability, precision and accuracy, 4) best structures and practices for community-oriented facilities for TLS hardware, software, and data distribution, and 5) integrated community planning to support future developments and community requirements. Workshop deliverables include reports and web resources encapsulating strategic, community vetted recommendations. These deliverables will be relevant to TLS users at all levels, from individual investigators to large scale initiatives such as Critical Zone Observatories, and will be particularly useful as strategic aids to help NSF supported facilities such as UNAVCO, INTERFACE, and Open Topography best meet the needs of the research community now and in the future.

Intellectual Merit. This workshop will directly contribute to greater development, awareness and utilization of TLS applications and data analysis practices, standards and products for optimum scientific benefit across a range of fields. Research projects incorporating TLS data involve a wide range of disciplines within the Earth sciences including tectonics, geophysics, geology, volcanology and geomorphology. TLS has also proven to be a valuable tool for related fields such as cryosphere, terrestrial ecology and archaeology. TLS practices, formats and standards overlap with and often evolve from engineering fields, while TLS data handling and visualization are elements of cyberinfrastructure. High-resolution TLS imaging and integration with other techniques and among diverse fields of research promise high science return across a spectrum of investigations.

Broader Impacts. This multidisciplinary workshop brings together diverse users from a variety of fields to identify and contribute to achieving common goals in a symbiotic and synergistic framework. Research applications being advanced by TLS data and benefiting from this workshop have significant societal and economic relevance in areas such as natural hazards, environmental change, preservation and urban infrastructure. At least 10% of workshop participants will be graduate students, possibly including protégés of the UNAVCO RESESS or UCAR SOARS internship programs or groups underrepresented in STEM fields. TLS data visualizations present a unique opportunity to engage students and scientists and help seed new education and outreach initiatives and materials, including K-12. The practices and products recommended by this workshop will be incorporated into TLS education and outreach activities such as community short courses and undergraduate field camps thereby engaging a broad cross section of users at all levels including students who are future researchers.

Summary of Request

We propose a three-day workshop to be held in late October, 2011 in Boulder, Colorado to bring together Terrestrial Laser Scanning (TLS) users from the Earth sciences and related fields to outline a strategic vision for the application of LiDAR scanning to a broad range of Earth science research activities. Considering the nature of our goals and the diverse range of community members we seek to engage, we envision a workshop on the order of 50 participants. The workshop will address the current and future needs of the research community based on the present state of the art and will make recommendations for the advancement of TLS data acquisition, processing, analysis, and distribution to all levels of the community. The goals of the workshop will be to capture ideas and to advance community interest, and establish requirements needed to pursue current and future trends in: 1) science applications, 2) data processing and analysis, 3) definition and adaptation of formats and standards for data and metadata including data/metadata exchange, archiving, interoperability, precision and accuracy, 4) best structures and practices for community-oriented facilities for TLS hardware, software, and data distribution, and 5) integrated community planning to support future developments and community requirements. Workshop deliverables include reports and web resources encapsulating strategic, community vetted recommendations.

Introduction

Terrestrial Laser Scanning (TLS), based on Light Detection and Ranging (LiDAR) technology, is part of a suite of new geodetic and imaging technologies that are becoming increasingly important to the Earth sciences community for use in myriad research applications. TLS, also known as ground based LiDAR or tripod LiDAR, offers an unprecedented capability to image at centimeter-level resolution 2.5-dimensional surfaces such as topography and fully 3-dimensional shapes such as cultural objects or rock or ice outcrops with overhanging features. TLS instruments are very precise, reasonably portable, relatively easy to operate, and have been used successfully to support a wide range of geoscience investigations including detailed mapping of fault scarps, geologic outcrops, fault-surface roughness, frost polygons, lava lakes, dikes, fissures, glaciers, columnar joints and hillside drainages. Moreover, repeat TLS surveys allow the imaging and measurement of surface changes through time, due, for example, to surface processes, volcanic deformation, ice flow, beach morphology transitions, and post-seismic slip. TLS is applicable to problems with areal extents at the 10-meter to kilometer level where detailed analysis is needed. Concurrent GPS measurements can provide accurate global georeferencing of the TLS data and absolute 3D coordinates, particularly important in repeat studies where the stability of all surfaces is uncertain. Coincident high-resolution digital photography allows the generation of photorealistic 3D images that open the potential to analyze and extract geospatially referenced observations in the laboratory. TLS measurements complement spaceborne and terrestrial radar, airborne LiDAR, and spaceborne LiDAR techniques in providing smaller-scale, higher-resolution plots of important areas and by filling in areas inaccessible by these other techniques.

Over the past few years, significant progress has made TLS instrumentation more available to the Earth science community and in developing best practices for acquiring datasets optimized for scientific investigations. This is can be largely attributed to: 1) improved instrument

performance (especially scanning speed and range) combined with sustained or lowered instrument costs, and 2) expanded development of and access to community resources such as the UNAVCO TLS instrument pool. This has led to a dramatic increase in the number of research and education projects that benefitted from TLS technology. However, other aspects of TLS have not advanced at the same rate and are becoming increasingly significant barriers to realizing the full potential of TLS as a tool for the Earth sciences. These limiting conditions to growth include data analysis workflows and tools, data format standards, and metadata standards. Current TLS users typically have developed specialized and often unique workflows optimized for the particular instruments they use and the science they engage in. While effective within its context, this arrangement has led to a heterogeneous approach to TLS data analysis that is not overly conducive to advancing the community as a whole. While there will never likely be a single "silver bullet" approach to TLS data analysis, it remains a tenable goal for the community to identify and develop fundamental guidelines to facilitate the analysis and exchange of TLS based scientific data and findings.

Workshop Objectives

The overarching goals of this workshop are community motivated. They are advised by existing and emerging TLS users, by an expanding UNAVCO community and UNAVCO governance, and by a broader, NSF geosciences community that shapes the geodesy facility's direction through formal review mechanisms. In this context, the workshop will advance these goals:

1. Engage new and potential users of TLS across Earth science subdisciplines,
2. Seed planning that is inspired by a variety of recent innovative geosciences applications,
3. Identify future TLS research directions and the appropriate structures/collaborations to support them, and
4. Define community user requirements for TLS data products to guide UNAVCO in planning and seeking resources to provide end users with research-grade data products as rapidly as possible.

To help achieve these goals, the following thematic sessions are planned:

1. TLS science applications.
2. TLS data processing and analysis.
3. TLS data and metadata formats and standards.
4. Community-oriented facilities for TLS hardware, software, and data distribution.
5. Comprehensive outlook and plan for the future.

An overview of these sessions and their context is as follows.

> ***Session 1: Science Applications.*** TLS has become an increasingly common technology applied to Earth science research endeavors as indicated by the growth of TLS related conference presentations and publications (e.g. *Wang et al*., 2011; *Alfarhan et al.,* 2010; *Connor and Connor*, 2010; *Eitel et al.,* 2010; *Feliciano et al*., 2010; *Gold et al.,* 2010; *Haddad et al.*, 2010; *Oskin et al*., 2010; *Perroy et al.,* 2010; *Pitlick et al*., 2010; *Williams et al.*, 2010; *Arrowsmith et al*., 2009; *Aryal et al.,* 2009; *Oldow et al*., 2009; *Oldow and Singleton*, 2008). Compelling support for the proliferation of TLS technology into the

science community is found in the several national meetings where TLS applications are fully integrated into science theme session (see 2010 GSA National Meeting and 2010 Fall AGU Meeting). The proposed workshop will build on this growth and help find common ground amongst a broad range of TLS practitioners and to facilitate the establishment of a support system for technical advance in a manner similar to the support UNAVCO provided the GPS community over the last decades. Plenary sessions and breakout groups will highlight successful scientific projects to date and explore the current and future interests and needs of the community. Inherent to this topic will be presentations and discussions on observed "real world" accuracy, precision and error sources. Participants and presentations will be invited to represent a wide variety of research applications in geomorphology, tectonics, volcanology, natural hazards, cryosphere and other related and overlapping fields.

Session 2: Data Processing and Analysis. Acquiring TLS data is easier than ever. Scanners are faster, have greater range, record more data (waveforms, multiple returns, photo imagery, etc.), and are more easily accessible due to a greater number of users and new community resources such as the UNAVCO instrument pool. And all scanners produce a single basic data product: a LiDAR point cloud. The process of merging, aligning and georeferencing point clouds is a mostly straightforward process using current TLS instruments, software and field practices. And the resulting point cloud datasets represent unique solutions, all things being equal. Subsequent data products derived from point clouds however, such as surface models, represent non-unique solutions that are highly dependent up on the algorithms employed. The variable quality of derivative products is commonly known to (and unfortunately commonly observed by) users of airborne LiDAR data, and is one aspect that distinguishes "research grade" airborne LiDAR. One objective of this session is to ask workshop participants to recommend and share examples of known good processing and analysis techniques and workflows, and to help define general guidelines for various types of applications. Possibilities include examples of successfully used workflows for mapping geologic outcrops, measuring ground motions, measuring biomass, filtering vegetation, producing surface runoff models, and so on. Another objective is to seek feedback on the most appropriate levels of support potentially offered to the community by UNAVCO and INTERFACE. For example UNAVCO currently enables users by providing access to example workflows and applications, remote computing resources, software tools, and collective community knowledge. However, it has been recommended that UNAVCO increase the scope of support to include providing higher level data products. Filtered and unfiltered terrain models are an example of higher order products. Higher level TLS data analysis could provide access to a much broader spectrum of potential users. Inherent to such added support would be for UNAVCO to utilize analysis methods appropriate to the science being pursued, which ideally would be based on recommended community guidelines an examples. Such guidelines, examples and frameworks would help guide UNAVCO, INTERFACE, and indeed all data analyzers in the earth sciences and related fields.

Session 3: Data and Metadata Formats and Standards. GPS data can be freely shared among the research community thanks to the Receiver INdependent EXchange format

(RINEX). Unfortunately there is no equivalent open, standard format for TLS data. Raw observables are locked within proprietary formats that vary by manufacturer and instrument. Manufacturer and instrument specific software is required to view, edit and export data into any common exchange format, such as text or LAS (the airborne LiDAR data exchange format), a process that inevitably involves permanently lost information as well as unwieldy data products that are unlikely to withstand the test of time and software revisions. It is beyond the scope of this workshop to resolve these issues but our intent is to identify potential existing solutions and strategies for moving forward. Participants and presentations will be invited to discuss the issues and to discuss and propose a community based plan to move forward in this critical area.

Session 4: Community-oriented facilities for TLS hardware, software, and data distribution. A final discussion topic will be recommendations from the community for the best combinations of support for the range of users with respect to TLS hardware, software, and data distribution. Under what conditions is it optimal for an individual research group to have its own system versus access community resources such as those available from UNAVCO? What are the expectations with respect to software? What software products--and where in the TLS data workflow--are desktop versus server oriented applications better utilized? Shall we organize data archival and data distribution with users in mind so that deep archives hold all TLS project-related data while map and 3D geometry-based and semantically enabled discovery systems serve the wide range of education and scientific users beyond even the data gathering team?

Session 5: Comprehensive Outlook and Plan for the Future. Over the course of the three-day workshop, many individual topics such as these will be discussed. The overarching goal is synoptic, however: a comprehensive, integrated plan to advance the state of the art and science of TLS as a tool for supporting and advancing Earth science research.

Workshop Deliverables

1. Website. A website will be developed for posting of presentations and posters as well as reports and other relevant information and resources.
2. Preliminary Report. A preliminary report and presentation will be prepared and circulated for community discussion and distribution. This report will outline the primary initial findings of the workshop and will serve as a stimulus for further discussion and recommendations by the community. Community input based on this report will be solicited at community gatherings (one possible venue would be a Town Hall session at the 2011 Fall American Geophysical Union meeting) and via a post-meeting website and user forums designed to facilitate continued discussion.
3. Final report. Once the community input has been acquired and synthesized, the information will be incorporated into a final report that will be presented to NSF and the participating communities by electronic means in early 2012. This report will also be posted on the UNAVCO website and the post-meeting website.
4. Workshop evaluation. An independent evaluation of the workshop will be coordinated by UNAVCO's Education & Outreach program.

Workshop Target Audience and Recruitment Plan

We particularly want to draw upon the experience and expertise of researchers from the geosciences and overlapping fields who are familiar with the current capabilities and challenges of TLS technologies and methodologies. As many pioneering projects involving TLS are being led by graduate students (e.g. *Feliciano et al*., 2010; *Douglas et al*., 2010; *Rengers et al.* 2010; *Jones et al.,* 2010; *Gold et al,* 2010; *Haddad et al*., in review; *Herrs et al*., 2009) we will encourage strong participation from students whose participation will be encouraged and facilitated through travel support and invited presentations. Rather than provide a list of potential applicants by name, in the spirit of growing the community and attracting experienced users from disciplines outside the geosciences, such as engineering and terrestrial ecology for example, we propose the following recruitment process.

1. Community representation and outreach. The organizing committee will identify key community representatives from the targeted audience and fields to help chair sessions and to attract participants.
2. Printed announcements. The workshop will be advertised in widely distributed geoscience publications such as Eos and GSA Today as well as other venues beyond the geosciences to be identified by representatives from other fields.
3. Electronic announcements. The workshop will be advertised by email announcements distributed through a number of channels including 1) community mailing lists such as UNAVCO, SCEC and EarthScope, 2) to geoscience department chairs via AGI, and 3) to NSF funded investigators identified through award announcements for programs such as GEO, SGP, TE/GLD, DEB.

We will implement a workshop application process. Applicants will be asked to complete a survey as part of the application process. This survey will be designed to provide the organizing committee with information regarding 1) the applicant's potential contributions to the workshop goals and 2) the workshop's potential value to the applicant's professional goals.

Workshop Organization

Workshop dates: October 17-19 *or* 25-27, 2011.
Workshop venue: Millennium Hotel, Boulder, Colorado.
Workshop size: 50 participants.

Boulder was chosen as the location due to 1) ease of access for participants based on a central location within the continental U.S. and proximity to a major airport, 2) proximity to the UNAVCO Facility to facilitate logistics, reduce costs, and allow demonstrations of the UNAVCO instrument pool, 3) this location draws upon a large number of TLS users from local institutions such as Colorado School of Mines in Golden, University of Colorado Boulder, Colorado State University in Fort Collins and other institutions, and 4) estimated expenses for the meeting venue and participant travel costs were lower here than other locations considered for the selected dates.

The following tentative workshop agenda focuses on the five session topics described above. Each session will include a small number of presentations followed by breakout groups and group discussions designed to stimulate open dialog and constructive recommendations. Breakout sessions will deal with specific questions and will report back to the group for discussion and synthesis. The workshop organizers and appointed community representatives will moderate the breakout sessions and facilitate discussion. Evening sessions will include poster presentations, TLS instrument demonstrations and informal breakout sessions.

Day 1
- Breakfast
- Welcome and charge for the meeting and day.
- Comments from NSF.
- Session 1: Science Applications
- Lunch
- Session 2: Data Processing/Analysis/Visualization (software, workflows, deliverables)
- Dinner
- Evening session: Posters, instrument demonstrations, informal breakout sessions.

Day 2
- Breakfast
- Welcome and charge for the day.
- Session 3: Data and Metadata (standards, formats, archiving and distribution).
- Lunch
- Session 4: Community Resources (existing, required, desired).
- Dinner
- Evening session: Posters, instrument demonstrations, informal breakout sessions.

Day 3
- Breakfast
- Welcome and charge for the day.
- Session 5: Charting the Future (community building, resources, products).
- Closing comments by NSF
- Closing comments by organizing committee
- End formal proceedings
- Lunch
- Report writing (organizing committee/writing team).
- Optional afternoon activities (e.g. tour of UNAVCO Facility or scan of local geology).

Workshop Organizers

The following individuals developed this proposal and will coordinate overall workshop goals, proceedings and deliverables:

- David Phillips, UNAVCO.
- John Oldow, University of Texas at Dallas.
- Doug Walker, University of Kansas.
- Ramon Arrowsmith, Arizona State University.

- Charles Meertens, UNAVCO.

To represent the broader target audience for the workshop and to enrich and diversify the workshop's planning, content and products, we plan to recruit community representatives to serve as additional organizing committee members and/or session chairs. Such individuals may include:

- Lori Collins (archaeology, University of South Florida)
- David Finnegan (cryosphere and engineering, CRREL)
- Leigh Stearns (cryosphere, University of Kansas)
- Gerald Bawden (geosciences and visualization, USGS)
- Christopher Crosby (data handling and visualization, Open Topography)
- Craig Glennie (engineering, NCALM)
- Bob Anderson (geomorphology, University of Colorado)
- Keith Turner (engineering, Colorado School of Mines)
- Lee Vierling (terrestrial ecology, University of Idaho)

Budget and Budget Justification

Our requested budget is $49,488. The budget includes participant support for workshop attendees, publication costs to announce the workshop, two weeks of salary for a UNAVCO administrative assistant, and UNAVCO indirect costs. Costs are based on a workshop size of 50 participants with accommodations and meeting rooms at the Millennium Hotel in Boulder, Colorado. Having the accommodations and the meeting facilities collocated eliminates the need for daily ground transportation to and from the meeting site and allows more meeting time and personal time for participants. The budget includes audio-video presentation equipment, Internet, poster boards, and meals and refreshments for participants during the workshop. The budget assumes that half of the participants will be able to cover their own transportation and accommodation costs through other funding sources or due to being based in the local area. Full travel support will be provided for half of the participants including meeting organizers and students.

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