Development of a high accuracy, user-friendly Lunar Laser Ranging telescope steering and pointing software package at HartRAO

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Abstract: Development of a user friendly, high accuracy steering and pointing programme is an essential component of the Lunar Laser Ranger (LLR) system being constructed at HartRAO in collaboration with NASA (GSFC) and the Observatoire de la Côte d'Azur (OCA) of France. The software source code is being written using C++ on a Windows platform. A small (125 mm) refractor mounted on a robust equatorial mount is being used as a test-bed. This allows easy evaluation to ensure that the code and servo drives perform as required. Two Ingenia Venus digital servo drives that are able to drive motors at 1 kW continuous and 2 kW peak are utilised. These drives are small enough to be used for the test-bed telescope; this approach therefore allows the hardware and software to be migrated to the 1 metre optical telescope to be used for LLR purposes. Differential encoders are used for positional feedback and an RS232 interface (daisy-chained) for communication to the servo drives. We report on the strategy employed, describe inter-programme communication using Dynamic Data Exchange (DDE) for shared memory purposes, and initial results on the testbed. The final planned configuration of the LLR telescope drive system is outlined. Currently, 0.5 arc-second rms statistical values are achieved on the testbed telescope.

Introduction

In collaboration with NASA (GSFC) and the Observatoire de la Côte d'Azur (OCA) of France we are developing a Lunar Laser Ranger, based on a 1-m aperture Cassegrain (az-el) telescope (Combrinck 2011 ; Combrinck and Botha, 2013)). The objective of the HartRAO LLR is to make ranging observations with sub-centimetre level accuracy. Tracking of the corner cube reflector arrays located on the Moon, satellites or inter-planetary probes or even planet-fixed beacons equipped with laser transponders are envisaged as targets that must be catered for. All these ranging targets require accurate pointing and smooth tracking so as to stay on target. A small refractor (Figure 1) is being used as testbed, simplifying the process of initial software development.

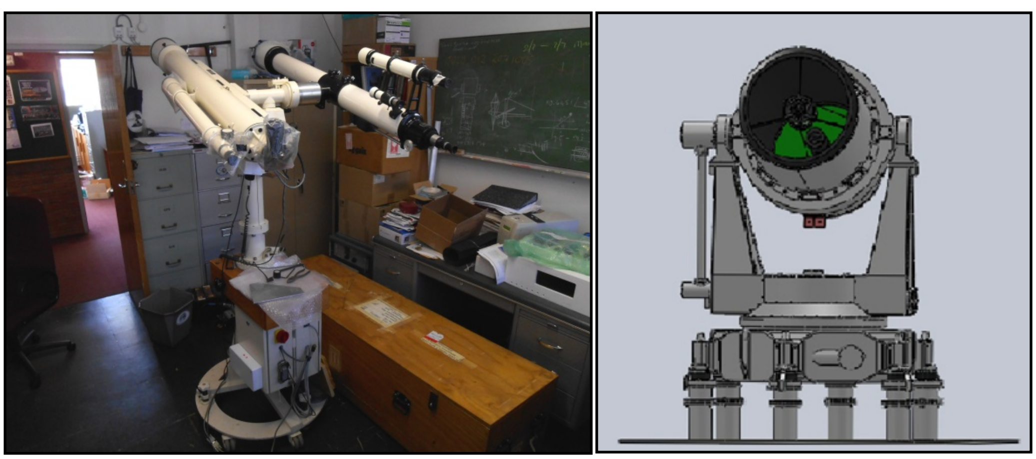

Figure 1. (Left) Small dual refractor used as testbed for the LLR software. Control of relays are done via an ATMega 2560 microcontroller. (Right) Similar control sections will be developed for the LLR telescope.

Software and hardware parameters

Table 1 lists selected hardware and software properties of the telescope drive system. Although utilised on the testbed telescope, similar units will be used on the LLR telescope.

Table 1: Selected software and hardware characteristics.

Hardware	Testbed Telescope	LLR Telescope	Software
Servo drives;1 kW continuous - 2 kW peak	2 x Ingenia Venus servo drives RS232, daisy-chained	4 x Ingenia Venus servo drives RS232, daisy-chained	Embedded Motion Control Library, C++ (LLRSteer)
Motors	Maxon DC brushed 24 V, 1 A	Mattke DC brushed 48 V 5 A	Monitored remotely (LLRServoControl)
Encoders	10000 counts per cycle, differential (Automation Direct), located on motor shaft	Four encoders; one on each motor (10000 counts per cycle, Leine & Linde), one on each shaft (az and el) (to be selected)	C++ (LLRServo)
Power supplies	Regulated lab-type/local control	Rack mounted, (Delta Elektronika) 0-100 V, 0-30 A, remote/local control	Controlled via ATMega2560 cards, C++ software (LLRServoControl)

Methodology

All previous ideas (Nickola and Combrinck, 2011) of using LabView have been discarded in favour of using C++. The design of the LLR is software-centric, therefore most of the control functions, system parameter monitoring, telescope pointing and steering, as well as preliminary data quality checks will be under software control.

This approach allows rapid and relatively easy changes or additions to specific functions, flagging of out-of-spec parameters, rapid response to situations which require interventions such as system failures which require safe shut-down or closure of telescope shutters etc. Communication between programs is done through the Dynamic Data Exchange (DDE) protocol, which is a message-based protocol and employs no functions or libraries. The DDE transactions are conducted by passing certain defined DDE messages between the client (e.g. LLRSteer and LLRServoControl) and server (e.g. MSExcel) applications.

In our application, LLRServoControl and LLRSteer will write and read parameters directly to and from MSExcel, the spreadsheet cells are linked, so the programs share memory with no interaction. This allows inter-program communication and access to the graphical and statistical functions of MSExcel (see Figure 2). Use of DDE is suitable for data exchanges where no user interaction is required and sends messages between applications that share data and uses shared memory to exchange data between applications. In this application the DDE protocol is used for continuous exchanges and all applications send updates to one another as new data become available.

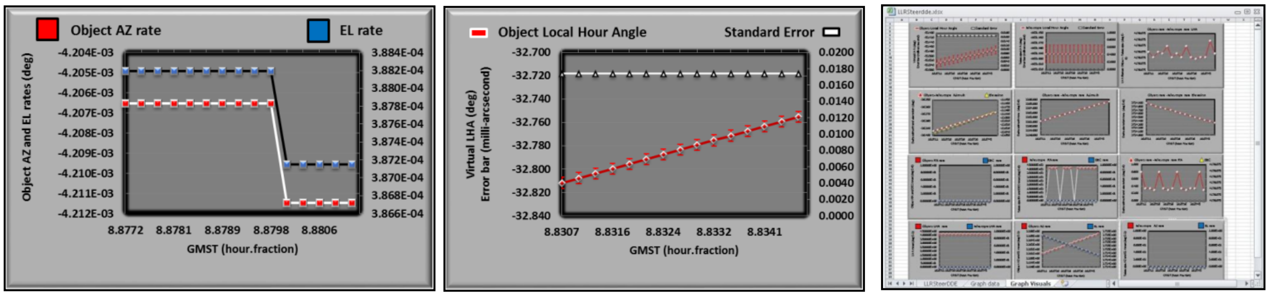

Figure 2. Examples of using MSExcel via DDE; the telescope control software does not require separate plotting and statistical functions, it can directly access those of MSExcel.

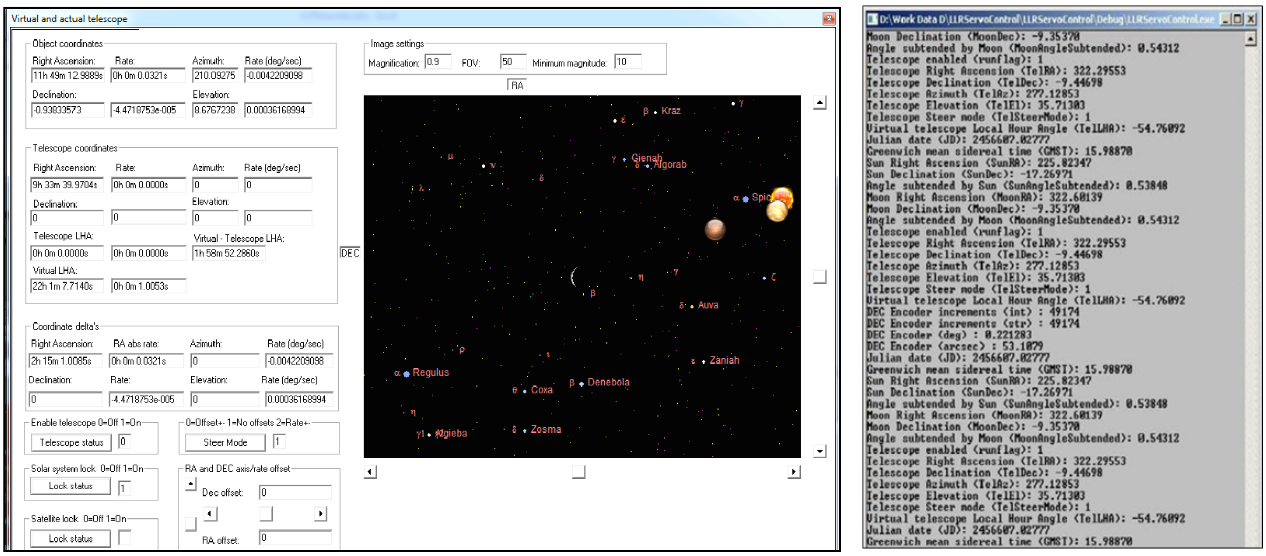

Figure 3. Some of the Graphical User Interfaces (GUIs) of LLRSteer. The software is designed to be intuitive and easy to use. The console type display in the right-hand corner is that of LLRServoControl, it takes no screen/keyboard input but can be used to inspect values, in principle any of its parameters can be displayed in MSExcel if required. LLRServoControl sends instructions to and receives feedback from the servo drives.

Servo programming

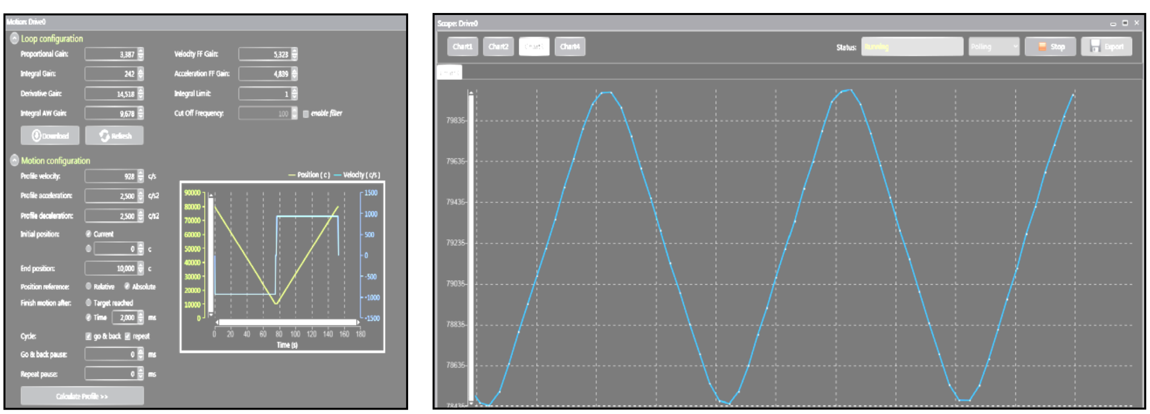

Figure 4. (Left) MotionLab is used to set up the servo drives. **(Right)** Plot of the declination axis of the testbed telescope set to run at sidereal rate (928 counts per second). The position control is smooth and repeatable

The Ingenia MotionLab software tool (Figure 4) can detect servo drives connected to the software network, access one servo drive for configuration, tuning, testing and programming, test different motion modes (position, velocity, torque, force, etc.). In addition MotionLab can be used to program stand-alone macros (uploaded to the servo drive) and monitor information with the digital scope. The software module LLRServoControl directly accesses the Embedded Motion Control Library (EMCL) located in the Venus servo drive hardware. The EMCL (firmware) manages all functions related to motion control and communication of the motion controller system and also allows controlling general purpose digital and analog inputs and outputs. The module LLRServoControl can detect four daisy-chained Venus drives and send instructions and receive feedback for further processing.

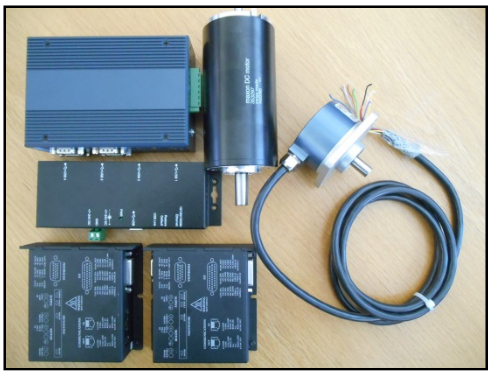

Figure 5. Servo drives (bottom), encoder (right) and (top) RS232 device server, USB device server, and DC motor to be used for the LLR telescope.

Results and conclusions

Current RMS error values on the testbed telescope are at the 0.5 arcsecond (RMS) level. Additional subroutines (advanced error checking, astronomical routines, pointing map etc.) remain to be implemented in the software, these will be phased in and developed as the project progresses. The pointing model will incorporate data from a thermal monitoring and modelling system to allow for thermally induced pointing errors.

Acknowledgements

We express our gratitude to NASA, OCA and the Department of Science and Technology of South Africa for their continued support of this project.

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