Communication, Coordination, and Automation for Future Geodetic Infrastructures

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Abstract In the second half of 2017, a Springer book was published explaining ideas, implementations, and solutions for future geodetic infrastructures. It explains seven years of technical research in computer science applied to systems of space geodetic techniques. The main focus is laid on stable and safe scientific software, an extended common software toolbox, autonomous production cells, and remote access and monitoring. The book addresses students as well as engineers at the observatories. These stations are seen as multi-agent systems which operate worldwide and are centrally coordinated to offer their geodetic products of the Global Geodetic Observing System (GGOS).

Keywords GGOS, infrastructure, automation, control, communication, coordination

1 Introduction

In August 2017, Springer published the textbook "Applied Computer Science for GGOS Observatories: Communication, Coordination and Automation of Future Geodetic Infrastructures" (ISBN-10: 3319401378) in Earth Sciences, Geography and Environment in English language. It is the first edition available as hardcover and eBook covering questions of the Global Geodetic Observing System (GGOS) with state-of-the-art methods from computer science on 546 pages. Real examples from the Geodetic Observatory Wettzell are taken to explain strategies and solutions to implement software for modern observatories with a focus on remote and autonomous operations [Springer(2017)]. The following sections are related to the book [Neidhardt(2017)].

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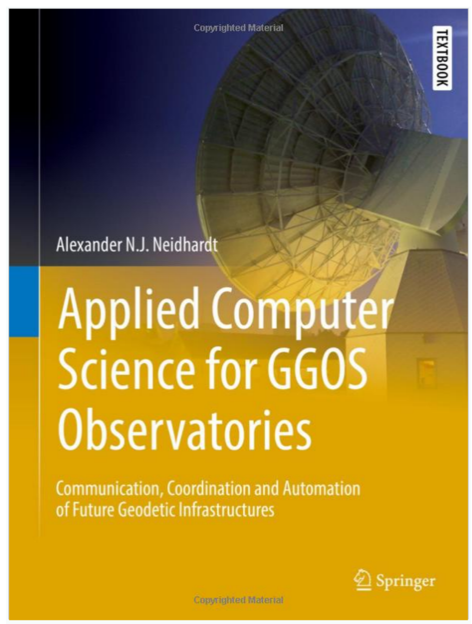

Fig. 1 The cover of the textbook.

2 Content of the Book

The book has seven chapters. After a short introduction, the second chapter explains aspects and solutions for writing safe and stable code in the field of scientific environments. Programming languages are discussed. The style (coding layout and code policies) which is used for writing the source code is essential to keep the programs comprehensive. A big issue is the inclusion of existing legacy code using suitable converter classes with clear interfaces to keep “older” code more manageable. Automatic document generators help to implement an agile documentation landscape. High-quality, test-driven developments use unit tests, static inspections, and dynamic analysis to get a suitable test coverage. Test metrics provide quantitative classifiers for software quality. Continuous integration offers daily overviews. Code repositories use version management systems to track all changes and updates. This ideally supports agile development.

The third chapter shows methods to create code toolboxes as re-usable code basis. Software is decomposed into modules and components partly using generative ways to support parametrized applications. This splits a development into domain and application engineering, so that most of the engineers can use predefined, parametrized domains, e.g., for communication over network, for specific tasks to implement their own applications. Remote procedure calls standardize this communication and also all related tasks. The results are remote function calls which look similar to local calls. They organize data conversion, implement call semantics, and guarantee safety and security. The result is a middleware for the controlling of distributed systems.

The fourth chapter puts the focus on operating of geodetic antenna systems showing the aspects of a controlling system on the example of a laser ranging system. Designing of control tasks means a mapping of real structures to software units. An intelligent management of hardware includes different layers of feedback loops which use data from sensors to make decisions for the commanding of actuators. Every hardware is represented in form of standardized software stubs. Autonomous production cells using autonomous software cells provide techniques for planning, controlling, user interfacing, hardware driving, and failure managing. A coordination cell uses metrics for static and dynamic planning. Separate autonomous hardware cells control the individual hardware. All data are organized in a hybrid, autonomous data management cell. A parallel system monitoring is used to fulfill safety criteria and to show state overviews.

The fifth chapter extends the local control systems with remote functionality and access using the existing software “NASA Field System” controling radio telescopes as an example. It is feasible to extend such an existing system with functionalities for remote access to support orders from external partners and offer reports to them. Because worldwide networks do not guarantee continuous access, systems have to increase their ability to run completely autonomously. This can be implemented using multi-agent systems where each agent uses an internal feedback loop. An agent can control existing software, like the NASA Field System, as legacy code. Additional requirements, like Web cameras, remotely controled switches, and a suitable graphical remote interface, extend the local architecture to replace the senses of an operator at the system. Remote access requires network security using role-based access control and ciphering algorithms, restricted network enclaves, and different types of firewalls.

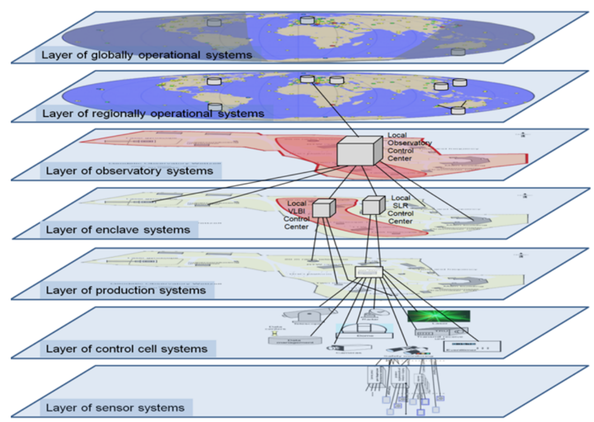

Fig. 2 Communication and coordination layers for GGOS products [Neidhardt(2017)].

A final, sixth chapter before the outlook section summarizes all techniques to a world-wide method of coordination, communication, and automation of GGOS workflows. It names the operational deficits having the GGOS products as parallel workflows without operational interaction. A layered hierarchy is explained to interact between the systems of the different services. Finally, statistics are shown to explain the essential need of automation for the realization of continuous operations with different world-wide telescopes.

The outlook shows that GGOS networking between autonomous agents explained in the book can be compared to Internet-of-the-Things or Industry 4.0 where cyber-physical systems are a consequence of modern workflows in industry.

3 VLBI-related Topics

Especially chapter five has a strong relationship to VLBI-relevant tasks. It describes the idea of multi-agent systems, which might be the future for automated computer auctions to automatically plan and assign resources to an optimal offer. While this is more or less future, concrete implementations extend the existing software "NASA Field System" to read, control, and manipulate the lower-level communication to the hardware devices as well as the higher-level interaction with the operator. It is like creating a control "parentheses" around the NASA Field System which can also be used to bypass it but especially to monitor all levels of the interaction. Using such an environment enables the access to the data and control from remote over computer networks. Therefore, an important aspect is security. Security touches different levels using different methods from simple user accounts with passwords to specified operator roles and access rights to higher level control tasks. It also requires methods for the architecture of networks and secure sub-networks.

Besides implementations around the NASA Field System, monitoring aspects also touches the field of VLBI. VLBI is currently the only GGOS technique which strongly requires a tight cooperation of telescopes around the world. Therefore, coordination of such networks and a real-time status during the observation is more and more an essential requirement. Industrial-like monitoring techniques with centralized archives are explained in Section 4.7 of the book, where the starting point was a white paper created at the beginning of the discussions about a Monitoring and Control Infrastructure (MCI) (see also [Ettl(2010)]). Meanwhile, different systems were developed and are in use. This means that the focus turned to a centralized collection and archiving of monitoring of seamless, auxiliary data from different sources ([Neidhardt(2015)]). This task is touched by the "Jumping JIVE" project, funded by the European Union, where a centralized monitoring infrastructure has to be established for the European VLBI Network (EVN).

4 Conclusions and Impact

The book is an interesting combination of applied computer science with the applications of geodesy. It is helpful for students, but also for engineers at the observatories. A valuable aspect is the impact to other disciplines. Meanwhile, the chapters of the book were downloaded over 4,600 times while computer scientists build the largest group of readers [Bookmetrix(2018)]. The projects described in the book are still ongoing. For example, the follow-on of the monitoring system is currently funded by the European Union's Horizon 2020 research and innovation program. The implementations of the designs are also under finalization for the laser ranging system and the automation of the VLBI system of the Geodetic Observatory Wettzell. Therefore, there is a huge relation to real applications of different fields.

Acknowledgements

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