Modern GNSS Technology Implementation in Study Courses Targeting Engineering Survey, Field Mobile Worker and Precision Agriculture Areas

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SUMMARY

Land is the nonrenewable resource that supports the existence and development of the human kind. The current status of land use and the ability to utilize more effective methods of its management and cultivation are the important base of an overall plan of land use and macro decision-making of whole country economy development. The technology application into areas such as smart city, smart electricity, intellectual transportation systems, GIS/big data integration is also crucial to meet the increasing demands of 21st century.

In recent years, the global positioning systems (GPS, GLONASS, BEIDOU, GALILEO, QZSS, IRNSS) and satellite based augmentation systems (SBAS) have widely been applied in the land survey areas, such as engineering, cadaster, resources management, urban planning, landscape construction, high precision agriculture, monitoring and so on. Keeping up with the times, the Moscow State University of Geodesy and Cartography focused onto providing the high-class specialists in these areas.

Starting from last decade, GNSS positioning had become one of the main subjects of higher educational study courses thanks to the rapid development of satellite-based positioning and to the appearance of GNSS mass-market receivers and antennas.

This presentation describes the progress on application of new GNSS-RTK/PPP technology study courses in Russian Moscow State University of Geodesy and Cartography, which are focused on cadastral, fieldmobile worker andprecision agriculture areas. During the study,the students get not only additional knowledge in application of single-base Real-Time Kinematic (RTK), Network Real-Time Kinematic (NRTK) and PPP methodologies of GNSS measurements, but also curtain practical skills in cross-disciplinary subjects. Considering that fact,the work demonstrates the feasibility and practicality of the courses applied.

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1. INTRODUCTION

Global Navigation Satellite Systems (GNSS) have revolutionized consumer product industries and their applications have become irreplaceable in today's society. In the near future, more satellites and constellations, more broadcast frequencies, more advanced signal structures, and better ability to take into account the impact of the earth's upper atmosphere will allow unprecedented accuracy and open the door to even more uses. Currently operational GNSS constellations include the United States' Global Positioning System (GPS) and the Russian Federation's Global Navigation Satellite System (GLONASS). Two other global GNSS systems are expected to be fully operational in 2020: the European Union / European Space Agency satellite navigation system (Galileo) and China's global navigation satellite system (BeiDou/Compass). France, India, and Japan are in the process of developing regional navigation systems. Once all these regional and global systems are working, the GNSS technology will provide a user with access to positioning, navigation and timing signals from more than 100 satellites. The impact of the new capabilities will extend from basic science to more practical engineering and technology including geophysical exploration, airline and spacecraft tracking, surveying and cadastre, precision agriculture, and unmanned vehicles. As a result, a growing number of employers are seeking hires with understanding and experience of GNSS. The emerging nexus between education, research, and industry in this critical area presents an opportunity for a joint effort to help prepare the next generation of engineers advanced in GNSS science and technology. A relatively broad range of engineering and science disciplines is required to understand the GNSS-associated technologies that enable this spectrum of applications. These include orbital mechanics, signal processing and communication system theory, computational mathematics, statistics, radio wave propagation, upper atmospheric space physics, and even relativity theory.

Not only has GNSS revolutionized modern technology, it has begun to be used effectively for a broad range of educational purposes. Moscow State University of Geodesy and Cartography educational courses on GNSS have been developed to teach fundamental science and engineering concepts, the principles of engineering design, and the impact of modern technology on society.

The training of engineering students at the undergraduate level in GNSS technology, the general subject of this report, has seen a variety of teaching approaches. These have often been based on application training within specific engineering disciplines rather than acquisition of detailed first principles understanding. The training is often provided as needed in a module within the offering of a core course. For instance, in Civil and Environmental Engineering, GNSS technology is incorporated into construction engineering for training students to use spatial construction data for various applications that include surveying, construction planning, and

scheduling. Aerospace Engineering curricula place emphasis on technology applications related to air and space navigation, traffic control, and pilotless aircraft and aerospace technologies, such as atomic clocks, that enable GNSS. In general, undergraduates appreciate applications of GNSS and design projects that are effective in giving some insight into fundamental GNSS principles. These approaches, however, do not address learning GNSS from first principles and so do not convey the depth of understanding that is necessary to work with a broad spectrum of GPS technologies and to design new applications.
Educational approaches that utilize GNSS signals collected at the raw level and which replicate the detailed computations performed inside actual GNSS receivers have begun to be more commonplace. This latter approach is very effective at teaching fundamental principles and is considered in the following discussion. We report on our experience in teaching a laboratory and field practical GNSS courses on GNSS theory and design applications. The course has been taught for the past 10 years at Applied Geodesy department of Moscow State University of Geodesy and Cartography and has evolved with advances in GNSS technology and on-going assessment of instructional effectiveness. The range of technical disciplines associated with GNSS provides a rich interdisciplinary educational experience that can be used to effectively train a broad range of engineering students. The GNSS learning experience brings together fundamental concepts utilized in many lower division engineering courses and therefore strengthen the students' understanding of working on real world engineering problems and systems that require multiple disciplines. The courses has benefited a broad cross-section of students from a number of engineering departments outside of Survey Faculty that include aerophotogrammetry, cadastre and adjacent specialists. It consists of a theoretical component that explains the inner workings of GNSS and an innovative hands-on laboratory and field practical component that uses modern equipment to give students practical training and the opportunity to work on more extensive design projects. Students are trained in how to operate GNSS receivers, decode data and to into getting necessary practical skills, as described below.

2. MAIN COURSE CONTENT

As previously described, competencies over a relatively broad range of engineering and science topics are required for understanding GNSS. The course contents are listed in Table 1 for a fourteen-week semester course. The theory of GNSS is presented during lectures that occur one to three times a week depending on specialization chosen, for 90 minutes at a time. A seminars with laboratory or field practical work take place each week that reinforces understanding of the theory. During the seminars in-class discussion are the key point. The laboratory component is open-access with on-site tutorial help available. Each student team (generally consisting of three students) is assigned a personal job with their own GNSS equipment for the duration of the semester.

	Subject	Lectures/seminars, hours
1	Fundamental Concepts, Coordinate and Time Systems	6/3
2	Satellite Orbit Theory	6/3
3	Concept of Ranging and GNSS Observables Determination	3/3
4	Navigation Solution Calculation	4/8
5	Error Sources and Accuracy Determination	6/12
6	Atmospheric Effects and Associated Scientific Measurements	3/3
7	Signal and Communication System Theory	4/4
8	Discussion of Course Projects	6/4
9	Differential GPS (e.g., SBAS/WAAS)	2/4
10	GNSS Modernization	2/2
	Total	42

Table 1. Standard GNSS course contents

It can easily be seen that the conceptual basis of the course extends over many engineering and science topics including vector analysis, linear algebra and matrix theory, probability and statistics, Kepler orbit theory, radio wave propagation and electromagnetics, and signal and communication system theory. Concepts of atmospheric science (ionosphere and troposphere) are also discussed and applied including Total Electron Content (TEC), scintillations ($S4$, $\sigma\phi$), and occultation. Typically few undergraduate students, even upper level ones, have strong capabilities across all these disciplines. For instance, aerophotogrammetry engineers may have a solid understanding of satellite orbit theory but not electromagnetics or signal theory while electrical engineering students may have contrasting skills. Some students may have competencies in vectorial and matrix mathematics but not in probability and statistics theory. We have found that teaching GNSS using a first principles approach is highly effective for imparting functional competencies across this broad range of topics for both upper level undergraduates and beginning graduate students.

3. SPECIAL COURSES CONTENT

4. LABORATORY AND FIELD CLASSES

5. CONCLUSION

Opportunities will continue to grow for well-trained engineers in the area of GNSS design and application of GNSS technology for the foreseeable future. Here, we have described a comprehensive course for senior undergraduates and beginning graduate students that integrates theory and laboratory instruction to promote first-principles understanding of GNSS and competencies in related technical areas and in GNSS analysis and design. As described

here, a state-of-the-art laboratory component greatly enhances the instructional value of such a course.
The ongoing modernization of GNSS includes the development of a number of new satellite constellations and their accompanying frequency bands and signal structures. This will require an even broader scope of training involving large, international engineering systems. Teaching programs will need to expand to take into account the new GNSS constellations and the applications associated with the expanded services. The new opportunities and teaching requirements will encompass K12 education as well as education and training at the university level. In summary, just as GNSS has revolutionized our society through technological advances over the past few decades, the future is bright for instructors and students to transform education and research experiences with GNSS.

REFERENCES

BIOGRAPHICAL NOTES

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