Spring Quarter

2.2 GNSS Applications and Market

Module: 2.2
Period: Spring Quarter

Responsible: Adjunct professor

Credits: 3
Total hours: ~30

Course Objectives

The course aims at providing the students with basic elements of applications and services dependent on the GNSS and to help them to identify the characteristics of several applications of GNSS in different environments.

Course Syllabus

The course will be organized in several seminars, each one focusing on a specific technological application that relies on the use of the GNSS. Additionally, a 10-hours seminar will be devoted to marketing aspects and elements of business modelling. Each application will be described at user level, service level and technological level, leveraging on the knowledge gained by the student in the previous courses and pushing them to adopt an application/business-level perspective.

Contents:

- Introduction and methodology
- Principles of business modelling and planning
  - Introduction to innovation management
  - Business models: concepts & tools
  - Basics of strategy
  - Fundamentals of business planning
  - Examples with GNSS applications
- Focus on the road transports domain
- Focus on the maritime domain
  - Overview of the different maritime applications domains (e.g., constricted waters, open waters, seaports)
  - Introduction on Ship Reporting Systems: regulations and technical aspects
  - Overview of the on-board equipment related/dependent on the GNSS receiver
  - Possible threats and vulnerabilities of ship reporting systems: general overview of jamming and spoofing attacks, possible countermeasures
- GNSS signal authentication for specific applications:

  - General overview of the GNSS signal authentication concept
  - Target applications in road transport for the signal authentication
- Focus on leisure applications
- Focus on aviation domain: Unmanned Aerial Vehicle (UAV) applications
  - Case study: attitude determination of an ultra-light UAV using multiple GPS receivers
  - Example with INS application
- Opportunities in Europe: the University Challenge

2.4 Environmental applications of GNSS technology

Module: 2.4
Period: Spring Quarter

Responsible: Marco Piras (Politecnico di Torino)

Credits: 5
Total hours: ~50

Course Objectives

Lessons of the part 1 aim at providing an introduction to Remote Sensing principles. They are focused on topics related to the processing workflow of satellite multispectral images for thematical map production .
Lessons of the part 2 concern GIS :the objective is to provide basic information useful to represent, manage and query digital geographical data..
Lesson aim of part 3 and 4 is to provide geodetic elements for GPS survey in territorial applications (survey monitoring and other). The topics addressed in this course are focused on the high precision techniques based on relative ad differential approach. Techniques whit metric accuracy with low cost GPS receivers are also treated. Practice survey on the field and data processing, with specific geodetic software is also given, to complete theoretical lessons.
For each topic theoretical principles will be investigated giving, during lab hours, an overview of the main environmental applications.

Course Syllabus

Part 1. Introduction to Remote Sensing

- Physics fundamentals
- Digital Images Processing
- Platforms and sensors
- Environmental applications
- Envi software overview

Part 2. Introduction to Geographic Information Systems (GIS)

- Digital Map Overview
- Reference systems
- Attributes and entities
- Database principles
- Environmental applications
- ArcGis software overview

Part 3.

- Observation's equations code and carrier phase
- Stand alone positioning
- High precision carrier phase positioning
- Relative approach: single, double and triple phase differences
- Differential positioning (DGPS) code and phase
- Correlation between phase difference
- Code and phase linear combinations and noise propagation
- Computational strategies
- Zero differences approach: positioning one way
- Real time kinematic survey (RTK) and research of integer solution in OTF approach
- GNSS permanent stations and network RTK
- DATUM: reference system and frame. ITRS/F and ETRS/F
- 3D DATUM transformation: Helmert and Molodensky equations

Part 4.

- Standard GNSS data format (RINEX, NMEA, RTCM 2.X & 3.0)
- GNSS receivers classification
- Acquisition's techniques (static and kinematic)
- Mobile mapping system: introduction.
- GNSS session planning
- GNSS campaign: static, kinematic and RTK survey on the field
- GNSS data processing (with commercial software) and fitting in reference systems
- Visit at GPS permanent station and RTK network control centre (DIATI)

2.5 Fundamentals of Time and Frequency Metrology

Module: 2.5
Period: Spring Quarter

Responsible: Adjunct professor

Credits: 3
Total hours: ~30

Course Objectives

The course aims to provide the students with elements to understand the basics of time and frequency metrology, including definitions, international organization and standards, methodology and tools for clock metrological characterization, fundamentals of time transfer techniques for comparison of remote clocks and timescales.

Course Syllabus

- Definitions and general concepts in Time and Frequency
- Metrological organization, international standards and glossary
- Clock models
- Statistics for clock characterization and GUM
- Clocks and Time scales comparison using GPS
- Clocks and Time scales comparison using TWSTFT

2.6 Integration between Satellite Navigation and other Positioning Technologies

Module: 2.6
Period: Spring Quarter

Responsible: Fabio Dovis (Politecnico di Torino - DET)

Credits: 3
Total hours: ~30

Course Objectives

Lessons aim to provide basic elements for the understanding of the important issue of integration among navigation systems and other positioning technologies.

The first part of the course is focused on the integration with inertial navigation systems (INS). The basic concepts of INS technology are provided. The key point for GNSS and INS integration is the Kalman filter, whose basic theory is provided in the course together with a brief description of the INS-GNSS integration methods.

In the second part of the course positioning methods based on terrestrial communication systems are considered. The course provides a background on the positioning strategies which can be employed on the stand-alone terrestrial communication networks, and in particular some emerging technologies, such as Wireless Ad-Hoc and Sensor Networks are addressed.

Course Syllabus

Part 1. Integration of different localization systems

- Localization with non-GNSS methods
- INS technology
- Kalman filter: basic theory
- Accelerometer principles
- Navigation equation based on INS measurements
- Reference frame and frame mechanization
- GNSS-INS integration

Part 2. Terrestrial Localization methodologies

- Localization and synchronization in terrestrial wireless systems
  - Introduction to wireless positioning principles

- Time Of arrival, Differential Time of Arrival, Angle of Arrival and Received Signal Strength method
- Positioning in cellular networks
- Positioning based on Signals of Opportunity
- Integration with ad-hoc and sensor networks

Part 3. Nav/Com Hybridisation

- Classification of hybridisation techniques
- Assisted GNSS
- Cooperative and Peer-to-Peer positioning

3-A Atmospheric effects for navigation and remote sensing

Module: 3-A
Period: Spring Quarter

Responsible: Letizia Lo Presti (Politecnico di Torino - DET)

Credits: 3
Total hours: ~30

Course Objectives

Propagation effects induced in the GNSS signal by the terrestrial atmosphere (Neutral Atmosphere and Ionosphere) may affect GNSS receiver performance and, if not properly taken into account, they may cause large errors in the final position estimate. Several techniques, generally based on the use of atmospheric models, are applied to compensate pseudorange and carrier phase measurements for these effects. On the other hand, knowing GNSS satellites and receiver positions with a high degree of accuracy, and compensating for the Ionosphere, we can extract from the Navigation Solution the total phase delay experienced by the signal in crossing the Neutral Atmosphere. The systematic measurement of this quantity, together with its inversion, opens the door to the remote sensing of the Neutral Atmosphere using GNSS. After the theoretical basis which will be introduced in the first part of the course and which are necessary to better understand atmospheric effects on GNSS signal propagation, several practical topics will then be treated. Solar activity inducing ionospheric threats will be analyzed and impacts on GNSS receivers and on GNSS signal propagation will be described. After that, some aspects related to GNSS remote sensing will be addressed: measurement of scintillation indexes to evaluate ionospheric disturbances, the GPS Radio Occultation Technique for the extraction of temperature, pressure and humidity vertical profiles from observations carried out from a Low Earth Orbit satellite, a GNSS tomography for the three dimensional characterization of water vapour fields. Methods for the Total Electron Content (TEC) evaluation will be described and discussed, with the focus on the TEC estimate through GNSS measurements.
The Earth's surface can also be monitored processing the GNSS radiation scattered off by land and oceans. In particular ocean altimetry, ocean surface winds retrieval, ice monitoring, soil moisture content determination are the possible applications. Techniques applied to this innovative remote sensing method will be described in the last part of the course.

Course Syllabus

Part 1. The Terrestrial Atmosphere: physics and effects on RF propagation

- Physics of the Ionosphere
- Physics of the Neutral Atmosphere
- Propagation effects induced by the terrestrial atmosphere on Satellite Navigation signals
- Techniques for the compensation of propagation effects

Part 2. Impact of Solar activity on Ionosphere and on GNSS systems

- Physics of the problem and examples
- Amplitude and Phase Scintillation Indexes: definition and examples
- Impact on GNSS receivers

Part 3. Remote sensing of the atmosphere using GNSS data

- GNSS observables and evaluation techniques
- GNSS Radio Occultation: atmospheric profiles using GNSS measurements from LEO satellites
- Integrated Water Vapour/Precipitable Water evaluation and tomographic reconstruction.

Part 4. Surface Remote Sensing through GNSS Reflectometry

- GNSS reflectometry receiving systems
- Signal processing techniques
- Soil parameters retrieval
- Altimetry measurements
- Measurements calibration and resolution
- GNSS reflectometry applications

3-B Laboratory of Time and Frequency Metrology

Module: 3-B
Period: Spring Quarter

Responsible: Adjunct professor

Credits: 3
Total hours: 30

Course Objectives

The course aims to provide students with elements to approach the instrumentations for time and frequency applications. After a short recall of definitions and general concepts for time and frequency applications, the main purpose is to conduct specific laboratory experiences for calibration, traceability and characterization of frequency reference standards as quartz and atomic clocks on which the navigation systems are based on.

Course Syllabus

- Definitions and general concepts in time and frequency
- Noise analysis in quartz and atomic clock
- Experimental laboratory measurements for time and frequency
- Clocks noise analysis and characterization
- Use of the spectrum analyzer for oscillators noise investigations
- Understanding instruments specifications
- Automatic measurement systems

3-C GNSS Applications to Traffic Management

Module: 3-C
Period: Spring Quarter

Responsible: Adjunct professor

Credits: 3
Total hours: ~30

Course Objectives

This course introduces the use of GNSS technologies in different transportation domains. The first part of the course is dedicated to the road sector and examples of LBS will be discussed, with an overview of the state of the art of vehicle tracking systems. The course also presents the use of GNSS in maritime, providing an overview of current European legislation and describing modern ship reporting systems.

Another objective of this course is to increase students awareness of the Civil Aviation issues through a description of ATM basics and RNAV/RNP concepts, then to provide them the elements to understand the many implications of the use of GNSS for Civil Aviation applications and finally to present the GNSS applications in ATM.

The course includes lab sessions, students will be asked to work on real data and comment the results critically.

Course Syllabus

Part 1: Use of GNSS in the road sector

- Overview of GNSS applications in road (i.e.: Pay as You Drive, smart parking, etc.)
- Description of a generic vehicle tracking systems. Challenges in urban scenarios and limits of current technology;
- LBS standardization activities
- Lab exercise

Part 2: Introduction to ATM and related Civil Aviation navigation aspects

- ATM basics
- ATM technical facilities general architecture
- Navigation and the different phases of flight
- PBN concept (Performance Based Navigation): RNAV and RNP overview and operation benefits

Part 3: GNSS for Civil Aviation

- ICAO requirements
- GNSS concepts for Civil Aviation
- GNSS augmentations for Civil Aviation

Part 4: GNSS applications to ATM

- GNSS approach and landing procedures
- GNSS applications to the Surveillance concept
- Use of GNSS time dissemination
- Future: 4D trajectory, Auto-taxi

Part 5: Use of GNSS in the maritime sector

- Overview of the current European legislation and IMO requirements;
- Description of common ship reporting systems (e.g.: AIS, Satellite-AIS, VTMS);
- Vulnerabilities (i.e.: intentional GNSS jamming, RF spoofing, cyber attacks on AIS)
- Lab exercise