TUG

Navigation

SS 2004

Organization

- Lecturers
  - B. Hofmann-Wellenhof, K. Legat, M. Wieser
- Division
  - 2 lectures + 2 labs (block)
- Dates
  - Tuesday, 14:15-15:45, A111
  - Wednesday, 08:15-09:45, A111
  - Thursday, 08:15-09:45, A111
  - Friday, 08:15-09:45, A111

  } see detailed schedule

- General contents
  - Encyclopedic knowledge in navigation

Preamble (1)

- *"Navigare necesse est, vivere non est necesse!"*

  Plutarch, Greek philosopher

- Motivation
  - Increasing **importance** of navigation in daily life
  - Differences between **surveying** and **navigation** are disappearing
  - Foundation of the **Austrian Institute of Navigation** (OVN), 1998
  - Book "**Navigation** – Principles of positioning and guidance", 2003
  - Institute name: **Navigation and Satellite Geodesy**, 2004

Preamble (2)

- Main goals
  - Presentation of present navigation systems and techniques
  - Focus on principles rather than on details
- Difficulties
  - Limited practical experience of the lecturers in certain topics
  - Missing equipment at the Institute
- Examinations
  - Oral examination on the lectures (typically 30 min)
  - Permanent controlling and program elaboration in the labs

Contents (1)

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Lecture

1. Introduction
2. Historical review
3. Mathematical fundamentals
4. Physical fundamentals
5. Maps
6. Terrestrial navigation
7. Terrestrial radio navigation
8. Celestial navigation
9. Satellite-based navigation
10. Outlook

Contents (2)

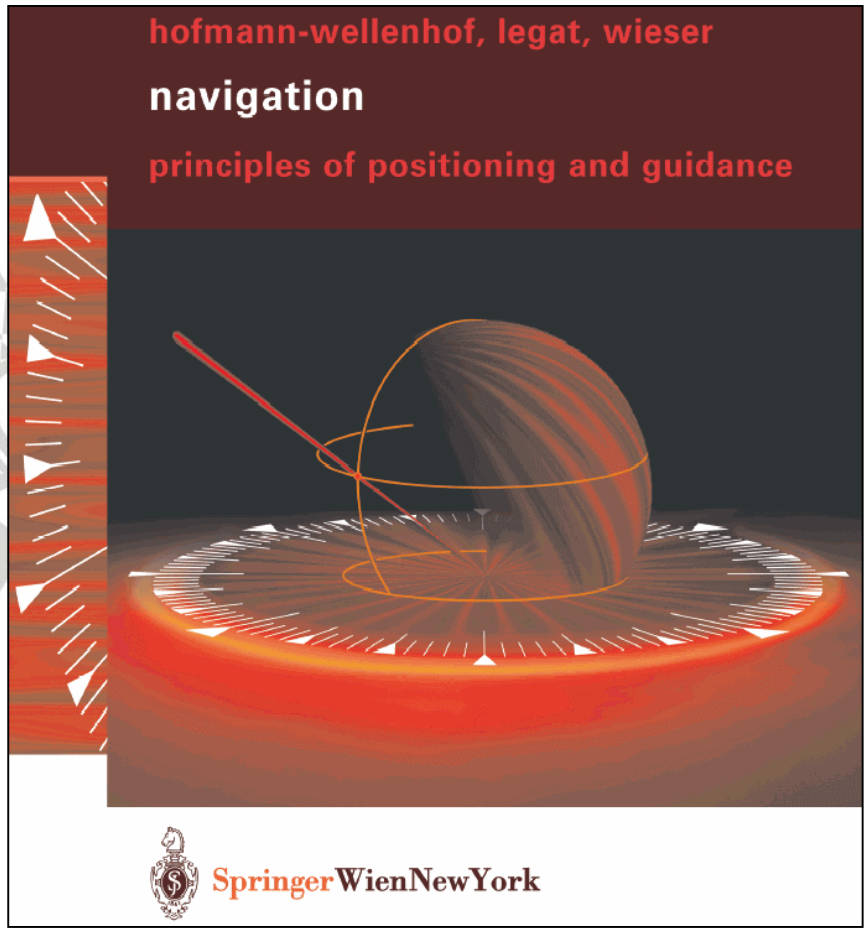
Labs

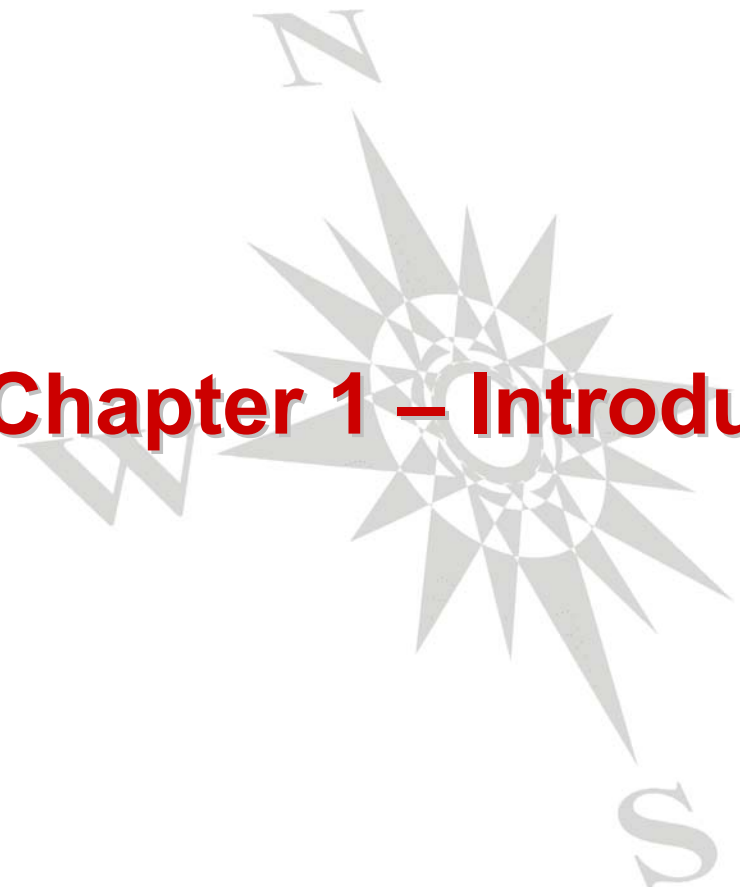
1. Terrestrial navigation
2. Satellite-based navigation
   - Hand-held GPS receivers
   - DGPS experiments
   - Data exchange formats

- Programs
  1. Orbit computation
  2. Single-point positioning
  3. DGPS / Atmospheric models / Carrier-phase smoothing

Literature

- Structural script (www.posnav.tugraz.at)
- Book "**Navigation**"
- List of specific references for each chapter





Chapter 1 – Introduction

1 Introduction (1)

1.1 Goals of the course

- Lectures
  - **Encyclopedic view** of navigation (Book: Chaps. 1-10)
  - Extension of geodetic knowledge towards **real-time applications**
- Labs
  - Experiments
  - Emphasis on **satellite-based navigation**
    - Single-point positioning (navigation solution)
    - Differential positioning
- Advanced course: "**Navigation Systems**" (➔ Master studies)
  - Other navigation systems
  - Integrated navigation (sensor fusion)

1 Introduction (2)

1.2 Definitions and terms

- **Position**
  - "Where am I?" … answered by a set of coordinates
  - Related to a well-defined coordinate reference frame (definition of origin and coordinate axes is required)
  - Distinguish: Absolute vs. relative positions
  - Position determination ≅ positioning
- **Location**
  - "Where am I?" … answered in terms of topological relations
  - Location determination ≅ localization ≅ detection
- **State vector**
  - Position, velocity, attitude (➔ 3D objects)
  - Parameters are usually time-dependent (➔ kinematics)

1 Introduction (3)

- **Routing and guidance**
  - Route planning: “Where to go?”, “How to go?”
  - Guidance: “What to do next?”

- **Navigation**
  - Deals with moving 3D objects (mostly vehicles)
    Note: positioning usually deals with points
  - **Components**
    - Trajectory determination
    - Guidance
  - Origin: Latin “*navis agere*”
  - Similar: Greek “*nautics*”

1 Introduction (4)

- Additional definitions
  - **Types of positioning techniques**
    - Self-positioning vs. remote positioning
    - Autonomous vs. dependent
    - Real-time vs. post processing
  - **Types of navigation techniques**
    - Navigation vs. surveillance
    - Autonomous (onboard) vs. nonautonomous (dependent on a communication facility)

1 Introduction (5)

– Traditional relations

Characteristic	**Surveying**	**Navigation**
Positioning accuracy	high	low
Observation technique	static	kinematic
Processing	offline	online

➔ Differences are diminishing

1 Introduction (6)

– **Terms of navigation**

Trajectory	A polygon connecting subsequent positions of a vehicle determined by a navigation system
Route	A detailed list of maneuvers to be performed by a vehicle to reach a destination
Leg	A segment of a route between to consecutive maneuvers
Waypoint	A distinct point on a route that usually corresponds to a change of course direction

1 Introduction (7)

1.3 Quality parameters

- Accuracy: Degree of conformance with the true position
  absolute (predictable) vs. repeatable vs. relative
- Availability: Percentage of time that the system is usable
- Capacity: Maximal number of simultaneous users
- Continuity: Ability to perform a function without interruption
- Coverage: Surface area or space volume where the system can be used
- Dimension: 1D, 2D, 3D
- Integrity: Provision of timely warnings in case of failures
- Reliability: Frequency of system failures
- Update rate: Number of independent fixes per time unit

1 Introduction (8)

1.4 Applications and phases of navigation

- General remarks
  - Restriction to marine applications over centuries
  - Today: various types of transport and nontransport applications (on land, at sea, in the air, in space)
  - Many different types of navigation systems and techniques have been developed

  - **Current trends**
    - Integration of individual navigation systems into complex information systems (➔ **sensor fusion**)
    - Integration of navigation with communication systems and contextual databases (➔ **location-based services**)

1 Introduction (9)

- Phases of navigation
  - **Land navigation**
    - No well-defined phases
    - Transport vs. nontransport
  - **Marine navigation**
    - Oceanic
    - Coastal
    - Harbor approach and in-harbor
    - Inland waterways

1 Introduction (10)

- **Aeronautic navigation**
  - En route (domestic, oceanic, remote)
  - Terminal areas
  - Approach and landing (nonprecision vs. precision)
  - Surface operations (off-runway)
- **Space navigation**
  - Launch
  - On-orbit
  - Re-entry and landing

1.5 Examples of user requirements

– The requirements strongly depend on the application and phase

Application	Accuracy [m]
Land navigation	
• Private transport	50 – 200
• Public transport	20 – 50
• Emergency	5 – 20
Marine navigation	
• Oceanic	≥ 200
• Coastal	20 – 100
• Harbor	5 – 20
Aeronautic navigation	
• En route	≥ 100
• Landing (position / height)	5 – 20 / 0.5 – 5

1 Introduction (12)

- Availability: 99.0 – 99.999%
- Continuity: Mainly related to aeronautic navigation (depends on the phase of flight)
- Coverage: Global / continental / regional / local
- Dimension: Depends on the application and phase
- Integrity: Typically, between 1 and 15 s (time to alarm)
- Reliability: Usually defined at the 95% probability level
- Update rate: Often around 1 Hz or more

1.6 Miscellaneous

– Navigation alphabets

Letter	Phonetic	Morse	Letter	Phonetic	Morse
A	Alpha	·–	N	November	–·
B	Bravo	–···	O	Oscar	–––
C	Charlie	–·–·	P	Papa	·––·
D	Delta	–··	Q	Quebec	––·–
E	Echo	·	R	Romeo	·–·
F	Foxtrot	··–·	S	Sierra	···
G	Golf	––·	T	Tango	–
H	Hotel	····	U	Uniform	··–
I	India	··	V	Victor	···–
J	Juliet	·–––	W	Whiskey	·––
K	Kilo	–·–	X	X-ray	–··–
L	Lima	·–··	Y	Yankee	–·––
M	Mike	––	Z	Zulu	––··

1 Introduction (14)

- Examples of navigation organizations
  - **Standardization**
    - International Organization for Standardization (ISO)
    - American National Standards Institute (ANSI)
    - Comité Européen de Normalisation (CEN)
  - **Application-specific interests**
    - International Civil Aviation Organization (ICAO)
    - International Maritime Organization (IMO)
    - International Hydrographic Organization (IHO)
    - National Aeronautics and Space Administration (NASA)
    - European Space Agency (ESA)

1 Introduction (15)

- **Other organizations**
  - International Association of Institutes of Navigation (IAIN)
  - International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA)
  - International Telecommunication Union (ITU)
  - U.S. Federal Aviation Administration (FAA)
  - U.S. Coast Guard (USCG) Navigation Center
  - European Organisation for the Safety of Air Navigation (Eurocontrol)

1 Introduction (16)

References

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