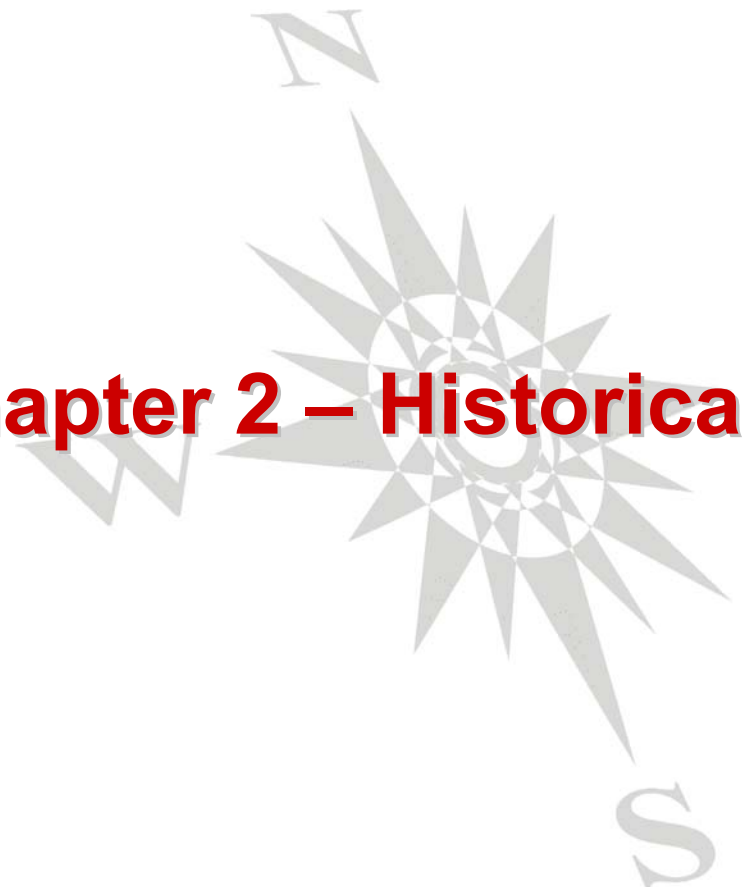
TUG

Navigation

SS 2004



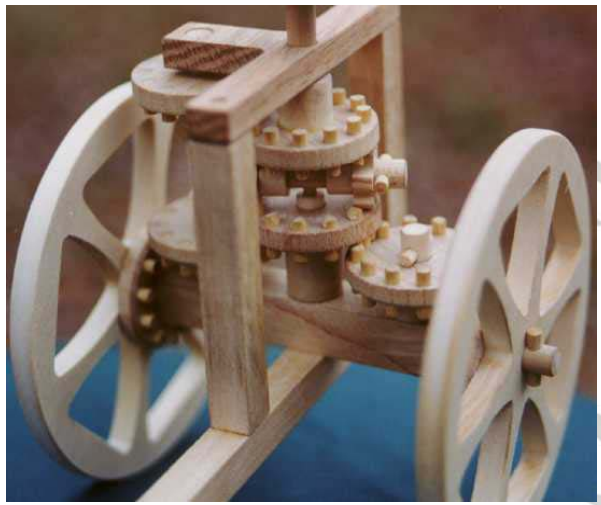
Chapter 2 – Historical review

2 Historical review (1)

2.1 Origins of navigation

- For **6000 years**, ingenious ways for navigating to remote destinations have been developed
- Ancient times: Lack of instruments ➔ **visual navigation**, e.g. celestial bodies, characteristic coastline features
- 2600 BC: **Chinese drum carriage** ➔ odometer (legend?) measurement unit “li” (about ½ km); a set of gears connected to the wheels of the cart caused one figure mounted on the carriage to strike a drum every “li” and a second figure to ring a gong every ten “li”
- 2000 BC: Sailing directions (**coastal and river maps**)

2 Historical review (2)



South-pointing chariot

– A figure with an outstretched arm pointed to south independent of the changes of the chariot heading (principle of differential odometer)

http://www.odts.de/southptr/richard/chariot.htm

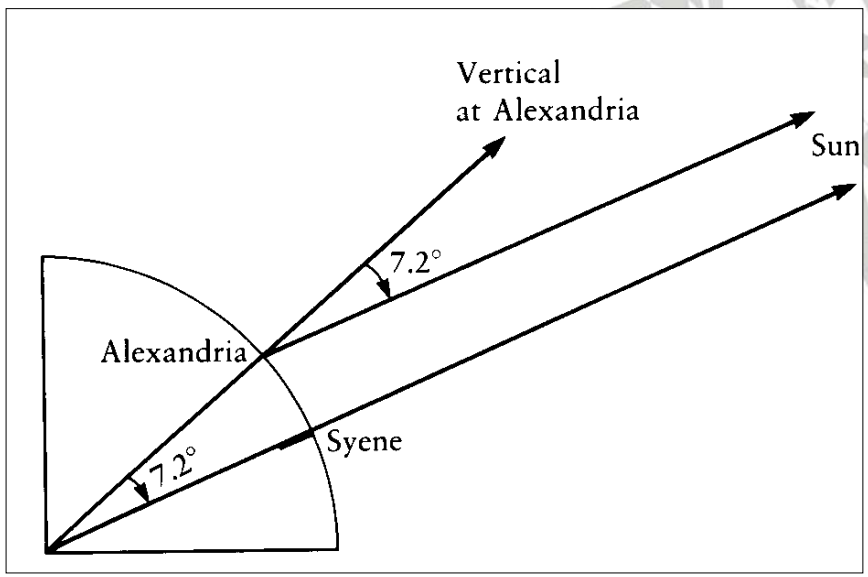
2 Historical review (3)

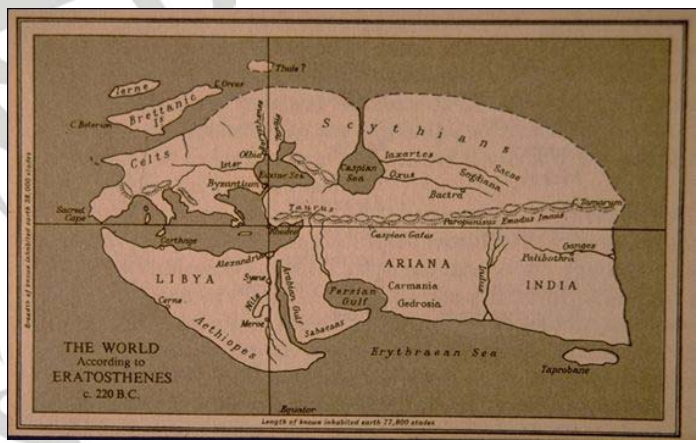
2.2 Hellenistic period and Roman Empire

- Hellenistic period: 400 BC – 100 BC
- Roman Empire
  - Early: 27 BC – AD 284
  - Late: AD 284 – 476
- Greek astronomy
  - Wandering of **planets** against fixed stars detected
  - **Heraclides** (4th century BC): assumed interior planets and guessed earth rotation
  - **Aristarchus**: stated not only earth rotation, but also revolution around the sun (basically the same idea as proposed by **Nicolaus Copernicus** 2000 years later!)
  - **Eratosthenes** (geodesist!) determined the circumference of the earth

2 Historical review (4)

– Determination of earth circumference by **Eratosthenes**
  - At **Syene**: Sun reflected in the bottom of a well at noon on a certain date
  - At **Alexandria**: At noon on the same date the zenith distance of the sun was a fiftieth part of a circle (7.2°)
  - A camel train took 50 days from Alexandria to Syene
  - Assuming that the camels travel 100 stadia (a length measure) a day
  - Earth circumference is 50·50·100 = 250 000 stadia





http://www.henry-davis.com/MAPS/

2 Historical review (5)

- 100 BC: **Hero of Alexandria** and the Roman architect **Vitruvius**:
  - First detailed western description of the **odometer** (From Greek: "*hodos*" = way, "*metron*" = measure)
  - Principle: Counting revolutions of a wheel of known diameter
- 2nd century BC: **Hipparchus** proposed the system of latitude and longitude. (Some 350 years later: **Ptolemy** produced the first "world" map.)
- **Ptolemy**
  - Wrote the famous Almagest
  - Explored special properties of spherical triangles
  - Calculated a table of sines

http://www.henry-davis.com/MAPS/

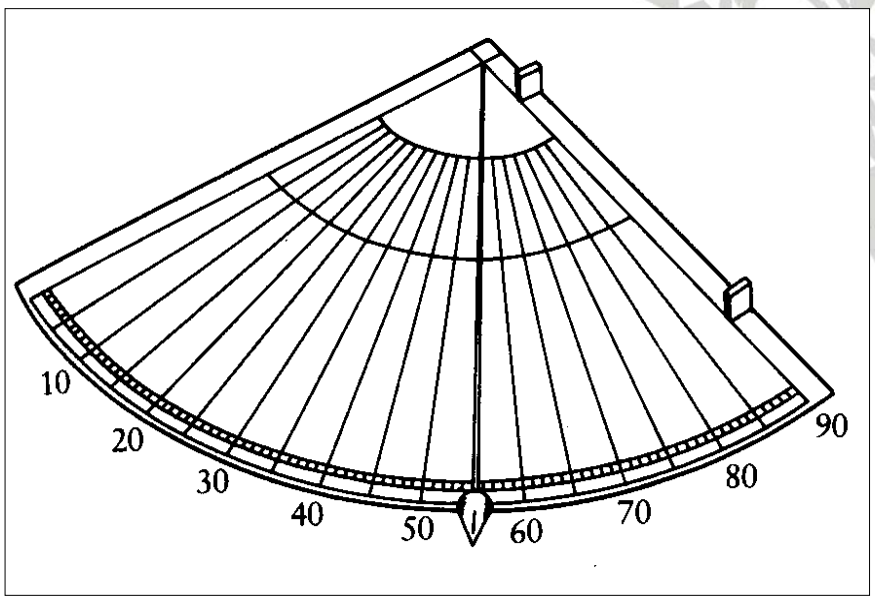
2 Historical review (6)

2.3 Middle Ages

- Period AD 500 up to 1350 (sometimes 1450 or 1500)
- 700-900: **Sailing directions** extended from Korea to East Africa
- 12th / 13th century: Invention of the **magnetic compass**, probably independently in:
  - China: South-keeping
  - Italy: North-seeking
- 13th century: **Quadrant** for measuring the altitude reintroduced in Europe by Leonardo of Pisa (Leonardo Fibonacci)

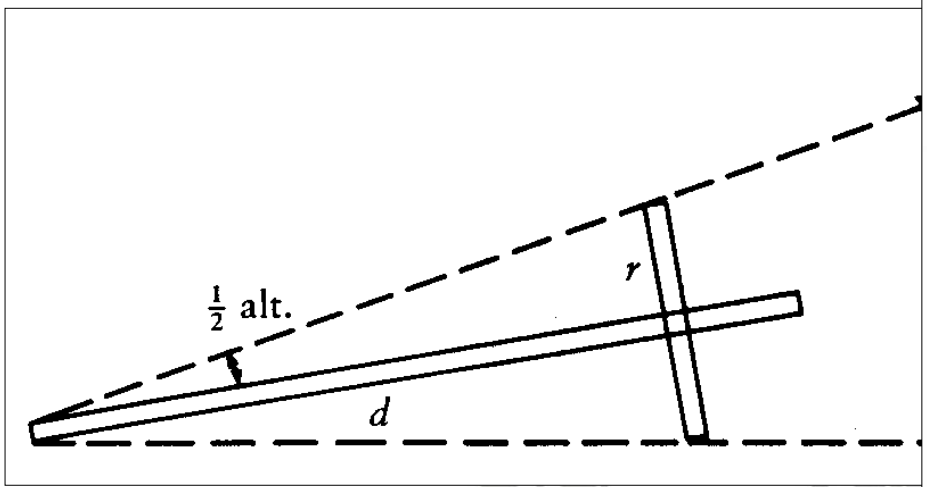
2 Historical review (7)

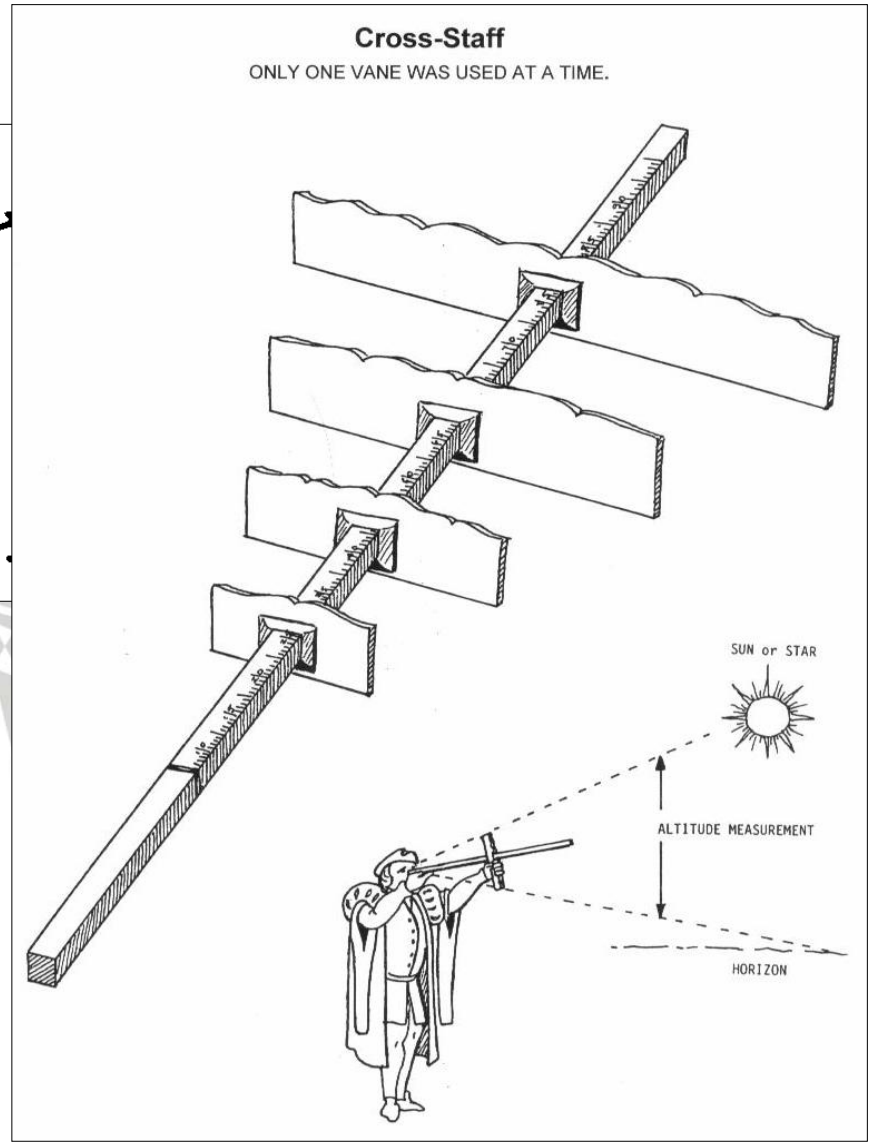
– **Quadrant**
  - Two pinholes along one edge
  - Arc graduated 0-90°
  - Plumb line suspended from the center
  - Observer sighted the pole star (or the sun) through the pinholes while his assistant read the alignment of the plumb line



2 Historical review (8)

– Cross staff, back staff

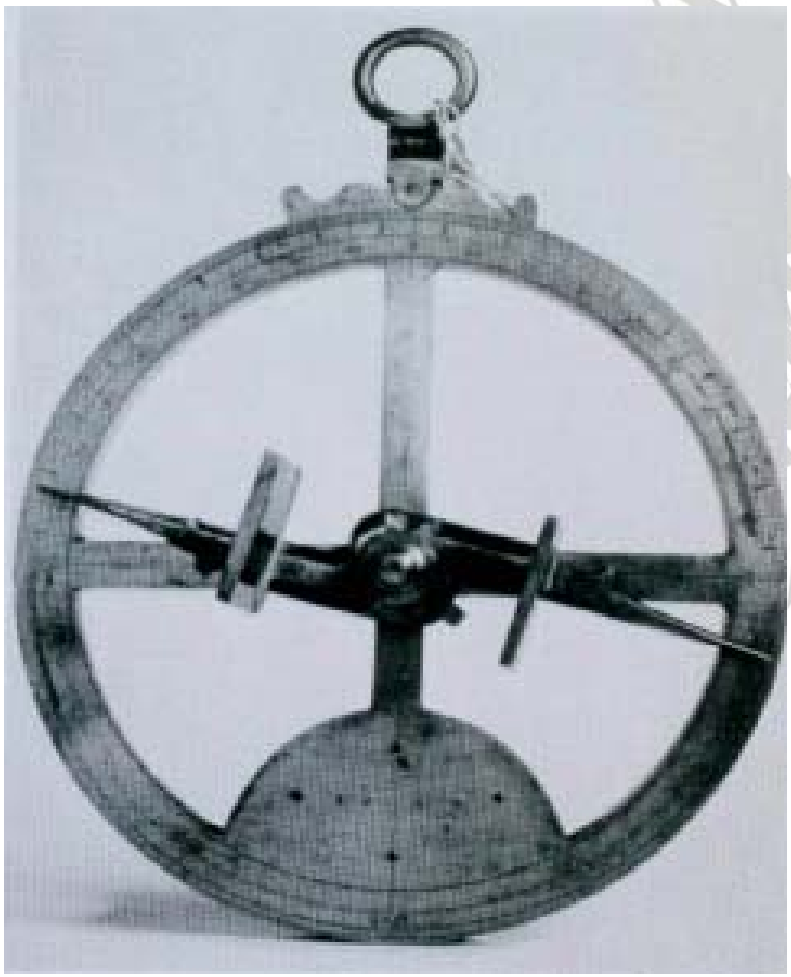


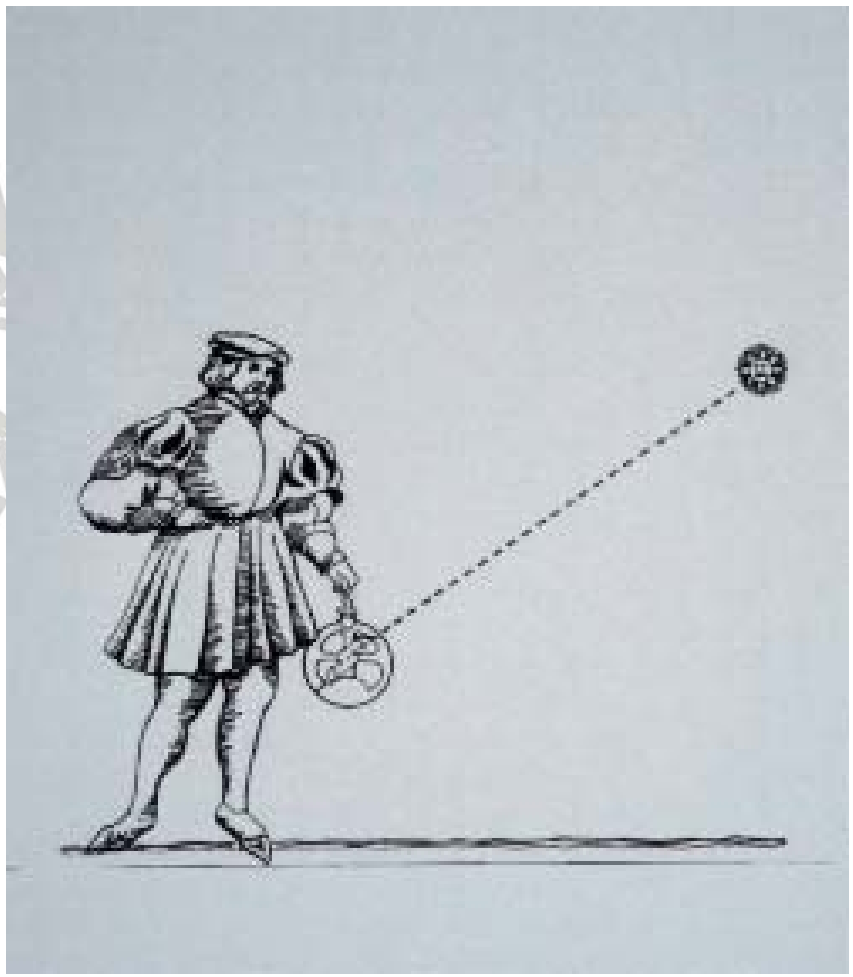


2 Historical review (9)

– Astrolabe

More details: http://www.mat.uc.pt/~helios/Mestre/Novemb00/H61iflan.htm





2 Historical review (10)

- **Speed measurement**
  - Throwing a piece of wood or a **log** from the bow
  - The time it took to pass the length of the ship was an indicator of speed
  - Later: Piece of **chord** with a series of knots was used
  - Today: Speed is still measured in **knots** (one knot corresponds to one nautical mile per hour)

2 Historical review (11)

- 15th/16th century: Cruises
  - 1492: **Christoph Columbus** detected America
  - Same year: **Martin Behaim** produced the first globe
  - **Amerigo Vespucci** (1451-1512) explored the east coast of South America
  - **Ferdinand Magellan** (1480-1521) started towards South America; he was killed by natives in the Philippines, but the vessel Victoria under the command of **Sebastian Elcano** returned ➔ first vessel having circumnavigated the globe
  - Equipment of Magellan: Sea charts, a terrestrial globe, wooden and metal theodolites, wooden and wood-and-bronze quadrants, compasses, magnetic needles, hour glasses, a log to be towed astern
  - Mercator projection: **Gerhard Kremer** (latinized **Mercator**) invented the conformal projection

2 Historical review (12)

2.4 Seventeenth and eighteenth century

- Trigonometry: Ptolemy´s Almagest – Regiomontanus – **John Napier** (also Neper) ➔ rules for spherical triangles
- **Johannes Kepler** (1571-1630): Three laws of planetary motion (1609 the first two, 1619 the third)
- **Galileo Galilei** (1564-1642): Founder of mechanics (force, momentum, inertia), pendulum clock, moons of Jupiter
- **Isaac Newton** (1642-1727): Three laws of motion, mass of earth, spheroidal form of the earth (centrifugal and gravitational forces)

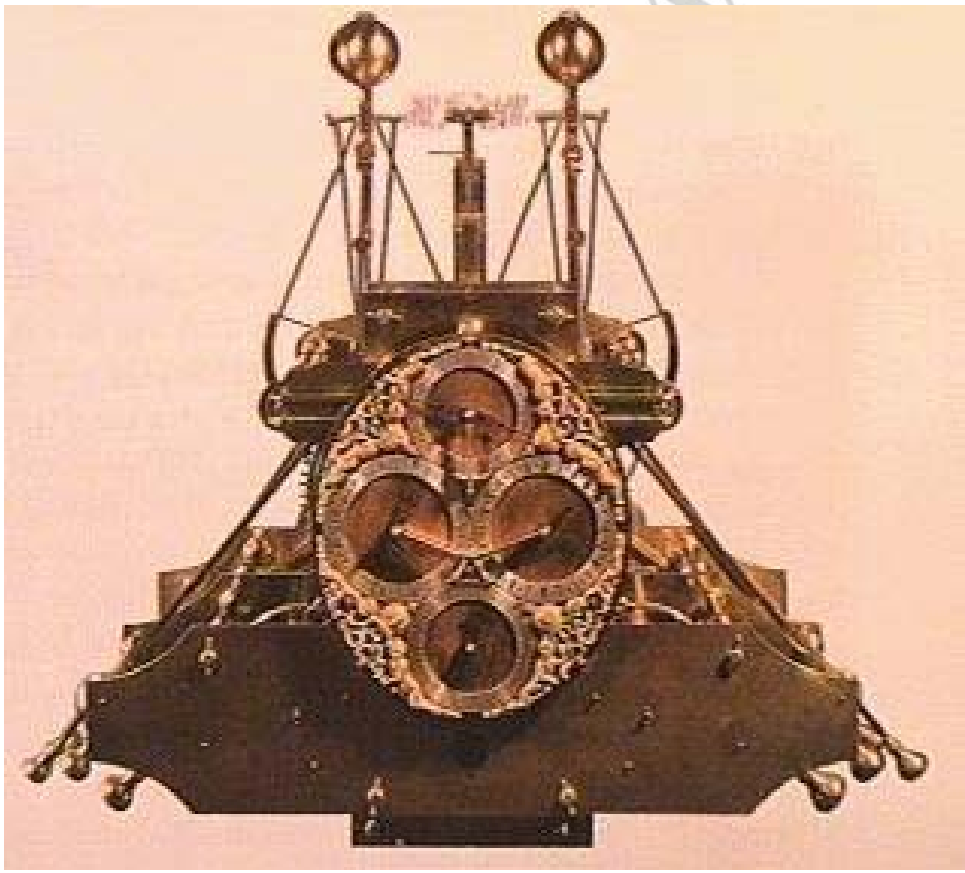
2 Historical review (13)

– **Determination of the longitude**
  - Giovanni Domenico Cassini and Christian Huygens pioneered the determination of longitude on land
  - England: royal warrant of 1765: “so as to find out the so-much desired longitude of places for the perfecting the art of navigation” ➔ foundation of **Greenwich observatory**
  - Large prize held out by the English parliament (200 times the annual salary of an astronomer)
  - **John Harrison** received the prize for his chronometer (H4)
  - Conference 1884: establishing **Greenwich** as the **prime meridian** and **Greenwich Mean Time** as the standard
  - **Sextant** (latitude) and **chronometer** primary tools for seamen

2 Historical review (14)

– **Harrison´s Chronometers** (left: H1, right: H4)

http://rubens.anu.edu.au/student.projects97/naval/



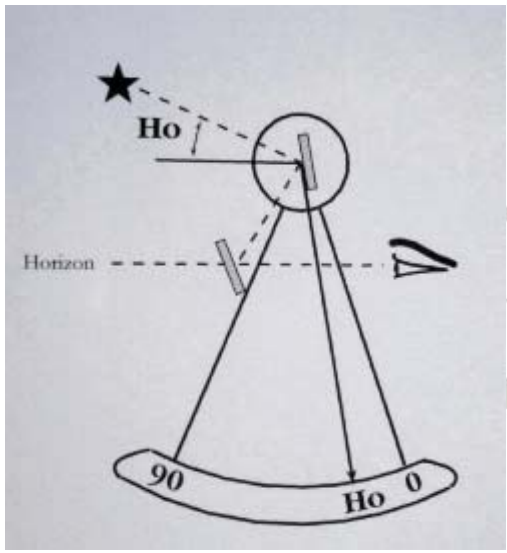
several decimeters

a few centimeters

2 Historical review (15)

– **Sextant**

http://www.mat.uc.pt/~helios/Mestre/Novemb00/H61iflan.htm



2.5 Nineteenth and twentieth century

- Diversity of research
  - **Alessandro Volta** (1745-1827): Electric battery
  - **Michael Faraday** (1791-1867), **André Marie Ampere** (1775-1836) investigated the magnetic field and electricity
  - **James Clerk Maxwell** (1831-1879): Equations describing the electric and magnetic fields
  - **Heinrich Rudolph Hertz** (1857-1894): Apparatus producing radio waves

2 Historical review (17)

– Magnetic compass

- **João de Castro** (16th century): Referenced the deviation of the magnetic compass by ferrous material in the ships
- **George Airy** (1801-1891): Investigation of induced and permanent magnetism ➔ compass compensation in ships and aircraft
- **Earth inductor compass**: Produces electrical currents proportional to the component of the magnetic field ➔ used by Charles Lindbergh (1902-1974) on his flight over the Atlantic Ocean

2 Historical review (18)

- The bowl of water with edge markings (to the left) shows a simple mariner´s compass, with a floating magnetized needle pointing north and south.
- A further refinement in the box compass (to the right) is from about 1200 CE, and is much more suitable for navigation.

(http://www.computersmiths.com/chineseinvention/compass.htm)

2 Historical review (19)

- Gyroscope, gyrocompass
  - Definitions
    - **Gyroscope**: Consists of a rotating wheel so mounted that its rotation axis can turn freely in all directions, and capable of maintaining the same absolute direction in space (in spite of movements of the mountings and surrounding parts)
    - **Gyrocompass**: Navigational compass containing a gyroscope rotor that, when adjusted for the latitude and speed of the vehicle, indicates the direction of true north along the surface of the earth
  - Difference
    - **Magnetic** compass: Points to **magnetic** north
    - **Gyro**compass: Points to **geographic** north

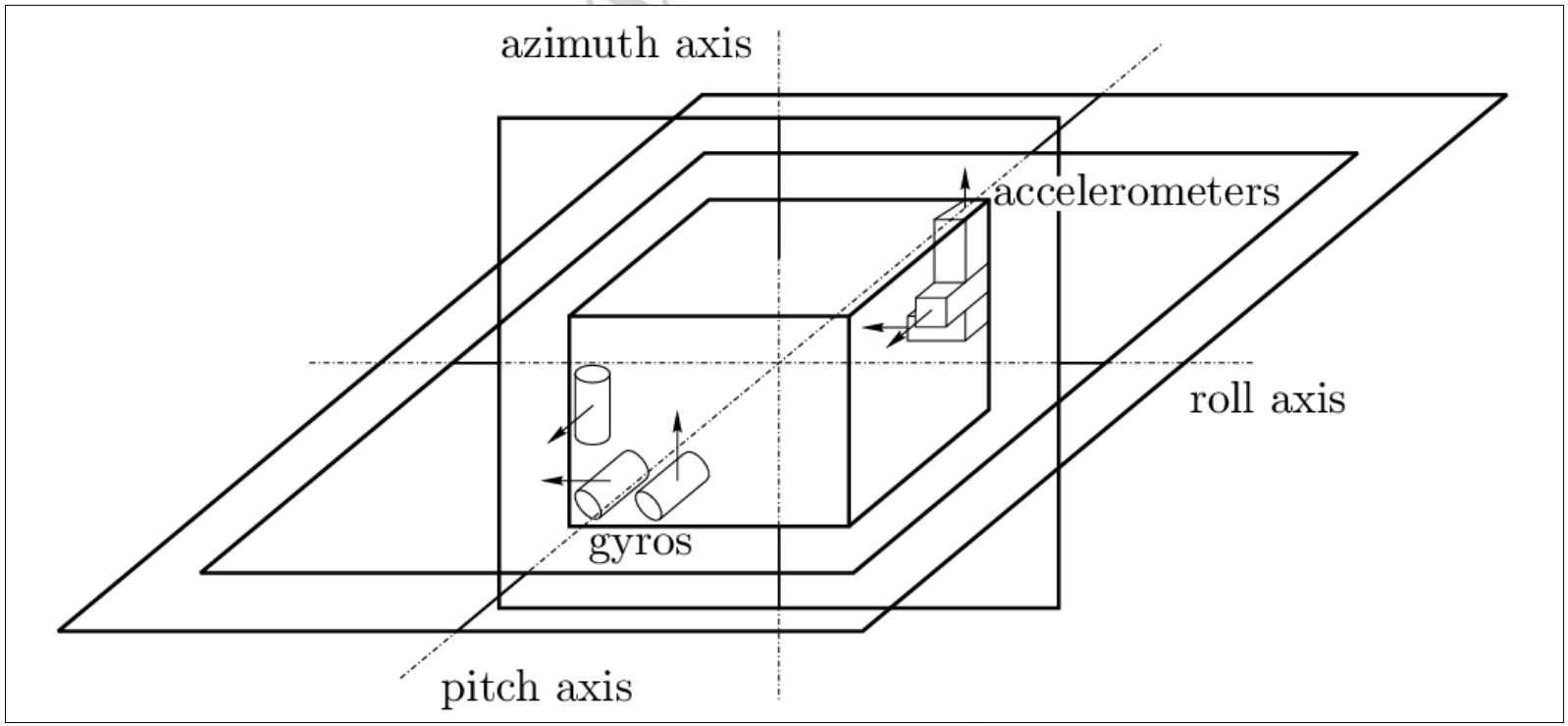
2 Historical review (20)

- **Gyroscope**: Johann Gottlieb Friedrich Bohnenberger (1765-1831) and Jean Foucault (1819-1868) demonstrated the gyroscope principle
- **Gyrocompass**: First mature model developed by Hermann Anschütz-Kaempfe (1872-1931) and Elmer A. Sperry (1860-1930)

  (**Problem**: The term gyro is used as an abbreviation for gyroscope and gyrocompass as well)
- Designs for **inertial navigation systems** (INS): Three accelerometers mounted orthogonally on a platform stabilized in space by gyroscopes (not necessarily in the mechanical sense)

2 Historical review (21)

Principle of INS



2 Historical review (22)

– **Vehicle and traffic guidance** (1/2)
  - 1895 first **road map** and first road signs in USA
  - 1900 **photo route guides**: Text + photos of landmarks + arrows to indicate turns
  - 1910 onwards: Many mechanical route guides (real-time instructions) ➔ **Jones Live map**, Chadwick road guide
  - U.S. army in World War II: Combination of odometer and magnetic compass
  - Late 1960s: Modern **intelligent transportation system** (ITS) ➔ ERGS in USA: Traffic control center ➔ traffic routing based on current traffic situation, two-way communication

2 Historical review (23)

- **Vehicle and traffic guidance** (2/2)
  - Vehicle navigation system (VNS): On-board digital maps + dead reckoning + map matching ➔ trajectory
  - Mid 1980s: Digital map stored on CD-ROM
  - 1990: VNS included GPS receiver
  - **Systems**
    - Navigator of ETAK, Oldsmobile Guidestar (USA),
    - Toyota´s Electro-Multivision, Nissan´s Multi AV (Japan),
    - CARIN of Philips, Travelpilot of Bosch (Europe)

2 Historical review (24)

– **Radio navigation** (1/2)

- **Loop antenna**: Use of radio waves for direction finding
- **Guglielmo Marconi**: Antenna development ➔ 1897 communication over 20 km, 1901 he bridged the Atlantic
- 1920s: Aircraft navigation by very high frequency (VHF) omnidirectional range (**VOR**) and distance measuring equipment (**DME**): bearing and distance
- 1948: International Civil Aviation Organization (ICAO) adopted standard for the instrument landing system (**ILS**), 1978 the microwave landing system (**MLS**)
- **Christian Hülsmeyer** (1881-1957) initiated the radio detection and ranging (radar) development

2 Historical review (25)

– **Radio navigation** (2/2)

- 1920s: **Distance** by phase and run time measurements
- 1945: Long range navigation (**Loran**) established in USA, Loran-C operational in 1957 (Soviet Union: **Chayka**): Radio frequency pulses are used
- Hyperbolic systems: **Decca**, **Omega**. In 1970s, Omega became effective; first global system radio navigation system comprising a total of eight transmitter stations
- Sound waves (**Doppler effect**): Under-water measurements

2 Historical review (26)

– **Satellite-based navigation**
  - October 4, 1957: Soviet Union launched **Sputnik**, the first satellite ➔ U.S. scientists computed its orbit from Doppler shifts
  - Inversion of this principle: Use of known orbits to determine the position of a receiver
  - 1967: U.S. Navy navigational satellite system (NNSS) **TRANSIT** fully operational
  - USA: Global Positioning System (**GPS**): Fully operational since 1995
  - Soviet Union (Russia): Global Navigation Satellite System (**GLONASS**): Fully operational in 1996
  - Europe: **Galileo**: Fully operational by 2008

2 Historical review (27)

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