Introduction to Navigation & Guidance

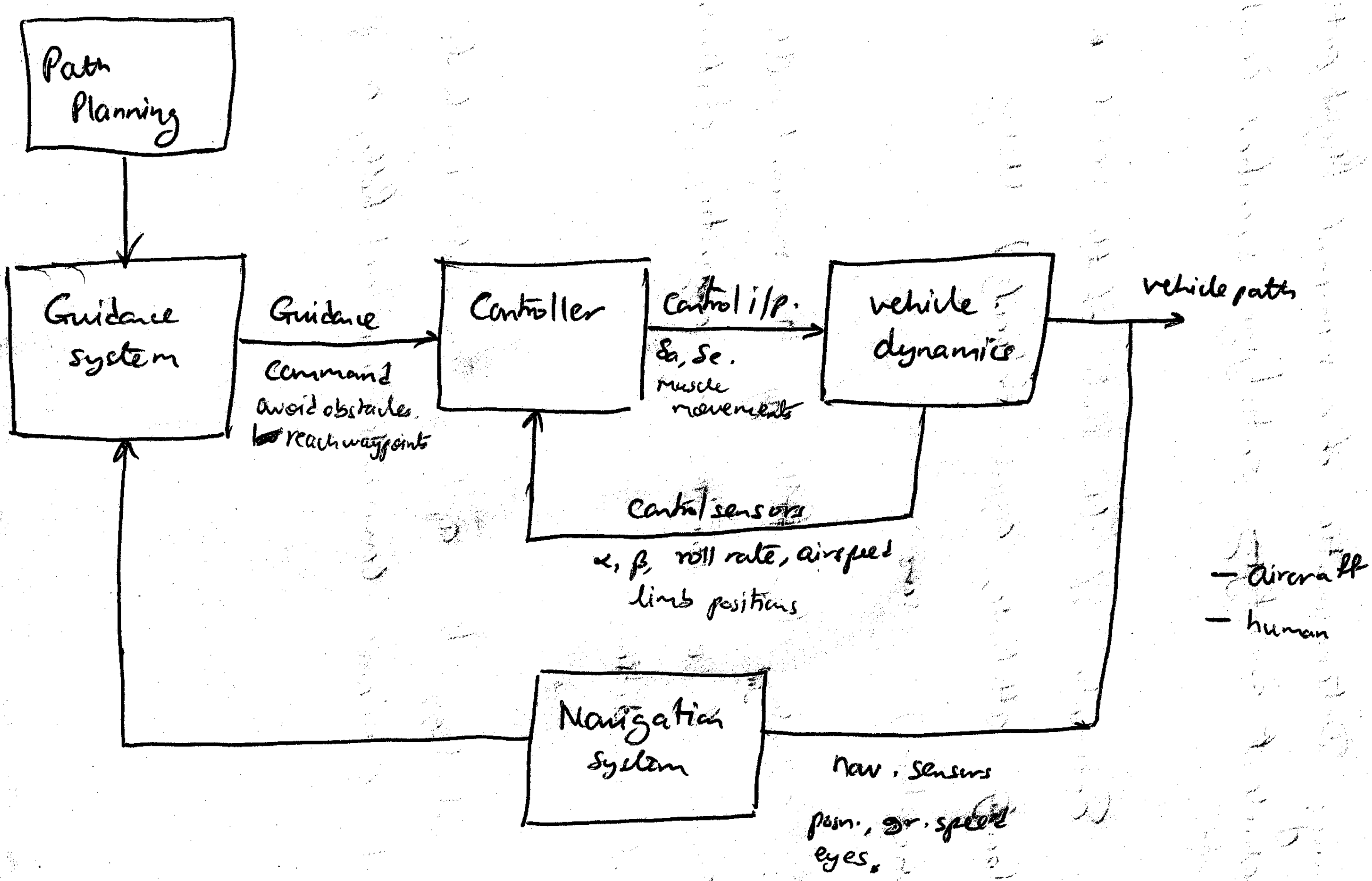
Functions required to steer a vehicle from one place to another.

- Path planning: Determination of a nominal flight path for the vehicle ~~to specifying~~ satisfying specified constraints

- Navigation: Estimation of the state of the vehicle (posn., velocity, attitude, angular velocity) using (possibly uncertain) sensors.

- Guidance: Strategy for following the nominal path in the presence of uncertainties in navigation, disturbances, off nominal conditions

- Control - Strategy for applying available inputs to implement guidance commands as faithfully as possible.



- all 4 systems may not be independent

History of navigation closely linked with the history of seafaring.

~~Polynesian~~ Early sailors kept to the coast.

Polynesians - sailed long distances (>2000 miles)
using currents & seasonal winds for navigation

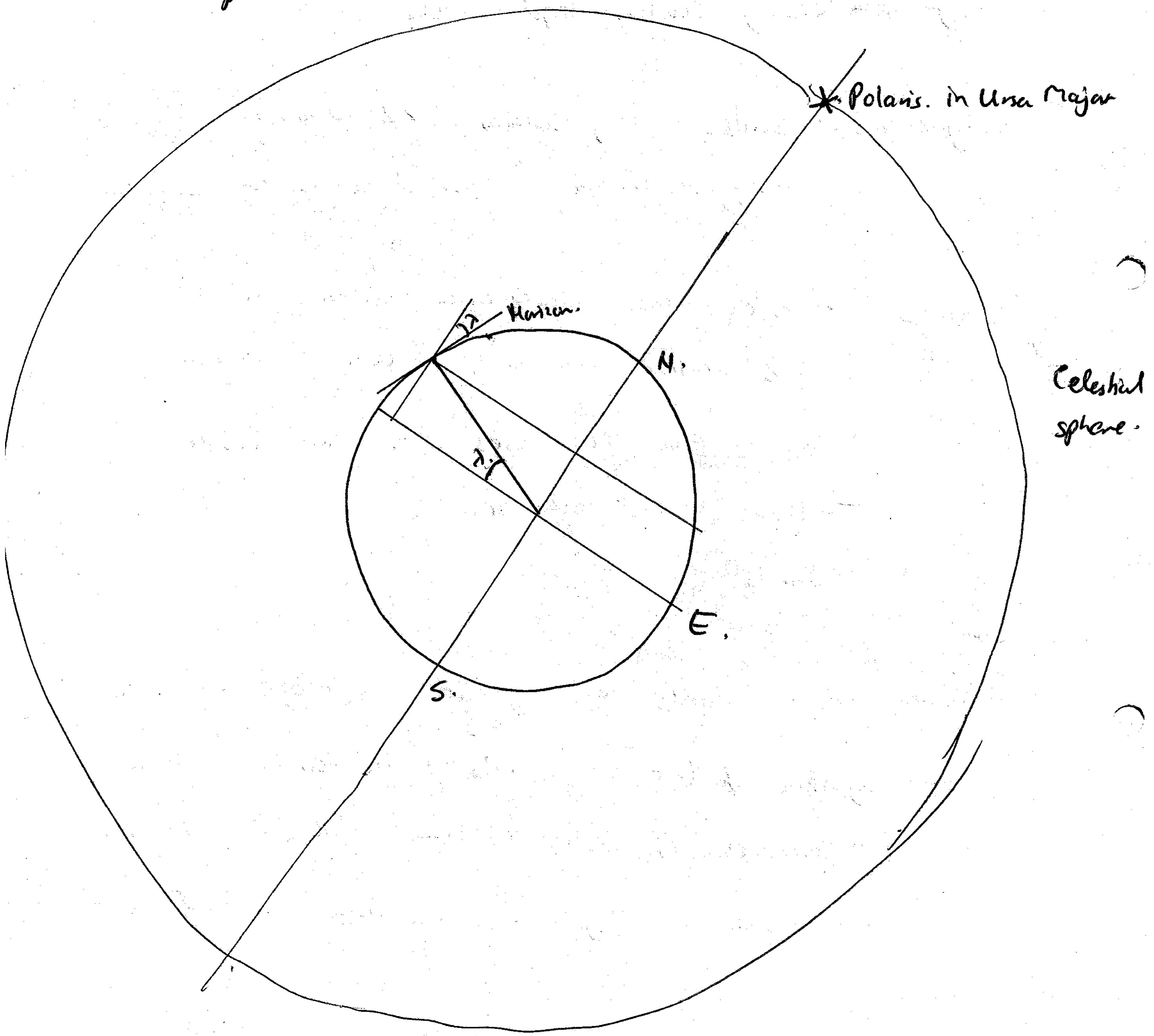
Vikings (800-1000) — sailed from Scandinavian countries to GB, Iceland, Greenland, & even N. America
- used sun compasses & shadow boards
- tide & wind direction.
- birds

Sailors need latitude, longitude & maps.
- system of lat, long related to earth's rotation.
  - parallels of latitude from −90° S to +90° N.
  - meridians of longitude ~~from~~ from 0 to 180° E & 180° W

- Ptolemy 1st maps in 2nd century showing lat & long.

How to measure latitude?

Night time: Elevation of the pole star in the northern hemisphere.



latitude in N. hemisphere = elevation of Polaris above the horizon.

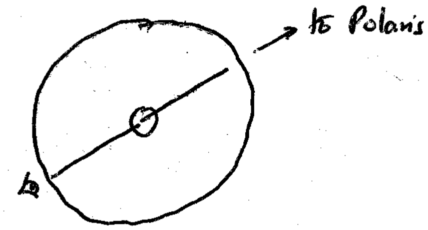
Techniques ~~o~~ for measuring latitude:

Arab sailors: ~~o~~ knotted string with a piece of metal at the other end.

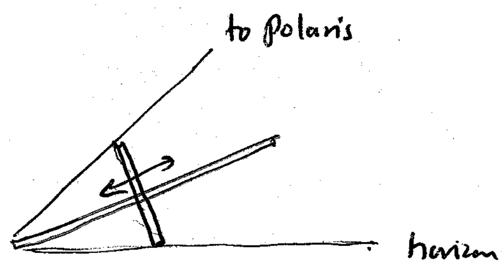
possible to return to home port by sailing down the latitude.

Other techniques

— Astrolabe (10th century).



— Cross staff.



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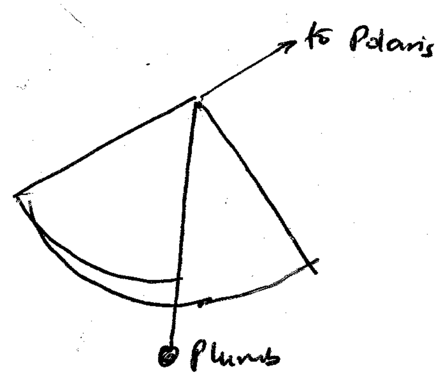
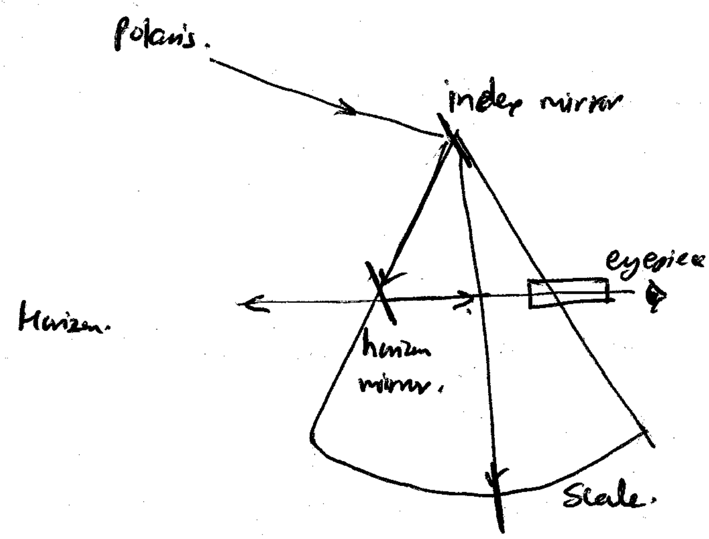
Quadrant.



– Sextant. in 1730s



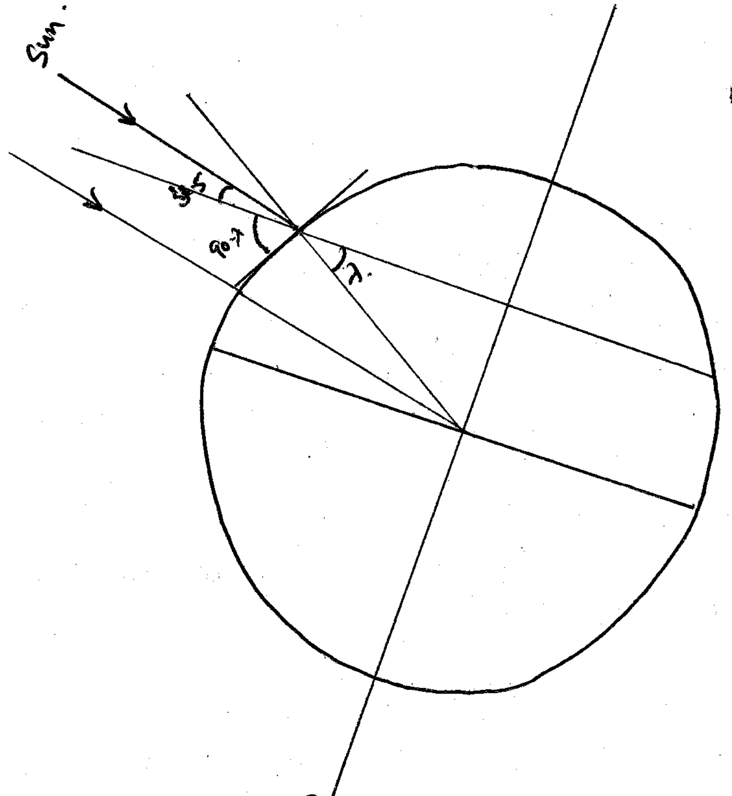
Combined with artificial horizons, developed upto WW II.

Problem: Daytime? Southern Hemisphere?

In late 15th century, Portuguese sailors sailing south to find a sea route to the east.

– Elevation of midday sun.

– needs to be corrected for the time of the year.



Summer solstice.

elevation $= 90 - \lambda + 23.5$

~~in[illegible]~~

At ~~the~~ winter solstice, elevation $= 90 - \lambda - 23.5°$.

Backstaff to measure elevation of sun.

<u>Problem:</u> How to measure ~~length~~ longitude?

In 16 century, the wealth of European nations came to depend on captain's ability to navigate. Feverish competition between maritime powers (Britain, France, Holland & Portugal) to find a way of precisely measuring longitude at sea.

Accuracy is vital because each ° corresponds to 68 miles at the equator.

To determine longitude, need to ~~meas~~ find local time & compare with the time at some reference longitude

Problem reduces to finding the local time at some distant place while at sea.

Soln. 1: Lunar tables prepared ~~at~~ by an observatory at a ref. place. (Royal Obs. at Greenwich, 1675).

In 1714, offer of £20,000 for a solution.

Between 1768-1771, James Cook navigated thru the uncharted Pacific Ocean to reach New Zealand, Australia, Tasmania using lunar tables.

Soln. 2: Accurate chronometers were invented around 1760.

Other techniques:

Dead reckoning:

- measure course (magnetic compass)
- measure speed
  - throw a chip of wood, time its passage across the length of the ship.
  - throw overboard a log tied to a rope having knots tied at intervals. Count the knots in a certain time. gives the speed in knots. 1 knot = 1 n.m/hr.
- estimate new posn. at the end of a certain period of time.

Piloting:

- Find ~~relative~~ true bearing to two visible landmarks having known position

Each bearing gives a line of position (LOP), on which the observer lies. The intersection of the two LOPs gives a position fix.

Ex. True bearings 30° & 330°, True course 90°