Navigation: Machines v humans

who will win?...

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Primary navigational safety requirements

- Avoid collisions with:
  - Other vessels
  - Fixed above water structures
  - Dangerous floating debris
- Avoid groundings and striking any underwater danger/facility
- Take best care to avoid dangerous natural disturbances, eg:
  - Weather-based
  - Hazardous sea states
  - Ice
- Adhere to all rules and regulations relevant to the voyage
- Take best care to avoid contact with malevolent humans

In effect:

Keeping the evolving track and speed consistent with the safe and legal passage of the specific vessel in the immediate and evolving circumstances

But equally important:

Ensuring the best possible compliance with the reasons for the passage, eg:

- **Meeting place and time-of-arrival objectives**
- **Minimising total costs**

$$$ **€€€**

£££

Requirements driven by:

Modern human society seeking to ever-improve:

- Safety
- Environmental protection
- Availability of products to end users
- Value for money
- Acceptable freedoms

... Which dominate the direction of much of our evolving world

Vessel navigation and control

Combines the three essential elements of navigation:

- **Technical**
- **The laws and rules**
- **The ‘art’**

Technical – fundamental science

Over 1000's of years of involvement humans have developed:

- Detailed understanding of the relevant sciences, such as:
  - Dynamics, materials, mathematics, electronics, computation
- Detailed knowledge of the Globe's geometry and features and the specific mathematics relevant to calculations in 3D + time
- Growingly accurate prediction of relevant natural events:
  - Tides and currents
  - Sea state
  - Wind
  - Precipitation
  - Visibility
  - Solar, lunar and celestial cycles

Technical – engineering

The basic science has developed into:

- Detailed knowledge of vessel construction, powering, dynamics, control, etc
- Affordable and accurate determination – and integration – of navigational parameters:
  - Magnetic sensors for bearing
  - Acoustic sensors for underwater depth, etc
  - Inertial sensors for bearing, velocity and positional changes
  - RF systems for target detection, position/range/velocity determination and communications over distance
  - Mechanical sensors for STW, bearing, wind speed, etc

... and ever more importantly:

Improving the interface between humans and machines

- To display information that aids decisions
- To ease the control of functionality

Increasing the accuracy and integrity of decisions and actions

The HMI is a highly important element of e-navigation

The laws and rules of navigation

(not just the Colregs ...)

- Constructed to enhance safety, environmental and national protection
- The level of international agreement achieved is a compliment to the working of the United Nations
- The rules naturally assume that humans are involved at every level

BUT - they are sometimes not definitive enough in complex situations – simply because we have difficulty in improving them and keeping them understandable

The *art* of navigation

Maximises the strengths and overcomes the limitations of humans

- Embraces the fact that humans need suitable tools to enable the fundamental science of navigation to be readily applied
- Enables the ready assessment of most situations – including the prediction of the outcome of decisions
- Provides a method of working in an environment where the rules and laws are extensive but are not definitive in all situations
- Provides humans with ‘mind tools’ that can successfully tackle extremely complex situations
- Provides help in dealing in situations where the laws and rules are being ignored, ‘bent’ or misunderstood by others

“The situation was very complex but I seemed to be able to do the right things, in part, by following my instincts”

Humans have many limitations for nav

- Limited natural sensors
- Limited brain ability in key areas:
  - For instant computation of complex navigation-related equations
  - To fully memorise all details from past experience and formal learning
  - To always take into account all the details of a complex situation
  - To be sure at all times of all the applicable rules and laws
  - To be able to develop totally effective rules and laws
- Even when assisted by the latest technology have a ‘higher than acceptable’ error rate
- (As a race) are prone to distraction and aberration
- Brief “between-service” intervals – we quickly get tired

The *art* helps overcome our limitations

- We gain an ‘adequate’ understanding of the science, rules and laws
- We are taught *best practice* in the classroom and on simulators to tackle real life situations
- We evolve and make good use of:
  - Approximations
  - Charted and tabled representations
  - Sensors
  - Computing devices and MMIs
  - Sources of detailed information

Courtesy Warsash Maritime Academy

- We keep learning ‘on the job’ – from others and in noting the consequences of our own decisions
- We become aware of the situations when extra vigilance is required

However, machines – ever more capably:

- Provide highly sophisticated sensing
- Solve highly complex equations virtually instantly
- Have a large, accurate and fast recall of memory
- Can make consistent decisions based on available data and ‘pre-programmed’ behaviour
- Do not get tired and can be made to be highly resistant to failure

Advancing navigation-related technology

- Robust absolute position fixing using intelligent integration of multiple sources, also providing good (rms) error estimates:
  - eg GNSS, other RF, inertial, quantum
- Robust and accurate detectability of all fixed, floating and underwater features using optical, sonar and RF sensors
- Ever improving accuracy and timeliness of charted data – eased by auto collection of data by UAVs
- Autocorrelation of charted and sensor detected data
- Detailed digital knowledge of own vessel's behaviour in all conditions and vessel settings
- Affordable high integrity broadband digital communications
- Extremely low failure rates (high MTBF) of navigation and other vessel systems

Growth in artificial intelligence

A rapidly expanding processor-based science:

- Driven by continuing exponential advancement of affordable computation power
- Vessel automation intelligence being generated by a mix of:
  - Traditional programming of the clear-cut rules and laws
  - Research systems developing computer-based rules by following good human practice in complex situations – real life and simulator based (Synthetic Environment) analysis
  - Programming of moral and financial decisions to be followed in an emergency (who/what gets hurt ...)
  - Continuous shared learning from all systems in the field
- Decisions take into account the calculated knowledge integrity of the situation
- Improved legislative rules will inevitably result
- Human navigators may need machine assistance to meet such rules

Some important automation requirements

- Must respond intelligently to human errors made on manned vessels – ‘behavioural analysis’
- Must respond appropriately to instructions and warnings given in arising emergency and critical situations
- Must be able to detect any anomalous behaviour of own-ship and react appropriately

Must not rely on humans trying to take over instantly when an urgent problem occurs

Parallel activity – ‘The Connected Ship’

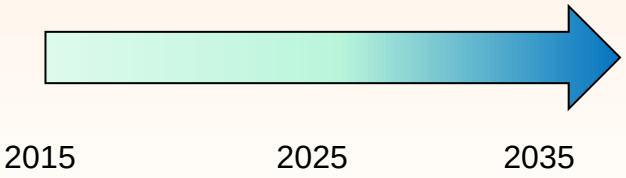
Freight transport is becoming increasingly integrated

- Will eventually be totally driven by individual ‘vendor-to-customer’ transactions
- Will involve cost/time/availability computer optimisation of all involved transport facilities
- ‘Improved asset management’ is the business phrase of interest
- In maritime world obviously taking into account:
  - Port capacity
  - Optimised use of suitable and available vessels

Highly consistent with full automation

Drivers towards autonomous vessels

- The ever-growing capability of emerging technology
- The increasing belief that any accident is unacceptable
- The continuing evidence that most accidents are caused by incorrect actions by humans
- The striving for cost reduction and better service



It will take time ...

Phase 1

- Introduction of improved capability navigational equipment with concentration on human interface issues (as part of e-nav)
- Greatly increasing use of autonomous small vessels (mainly remote pilotage)
- Development of legislation for autonomous vessels

Phase 2

- Remote pilotage of larger vessels based on shore-based control centres, perhaps using familiar e-nav-like tools
- Increasing use of small fully autonomous vessels

Phase 3

- Fully autonomous use of large and small vessels with potentially many vessels being managed by a small number of humans

Machines are ever-evolving, but ...

Like humans

- They will never be 100% reliable
- They will cause accidents
- They are prone to malevolent attacks and use
- They need constant updating to retain their capability
- They need evolving legislation

The world is facing a real upheaval

Many other tasks of the future are also likely to become highly automated, such as:

- Health diagnosis, prescriptions and surgery
- Financial
- Legal
- Building and road construction
- Farming
- Manufacturing (much more than now...)

What will most humans be doing?

So finally...

Humans must fully explore the sociological implications of this and other advances in machine intelligence

What will most humans be doing in the new world?

Will a few be super rich and powerful?

... and the rest be very poor?

Seemingly, a risky time ahead for the human race...