Intelligent Ships - Intelligent Ports

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Once a new technology comes rolling along, you are either part of the steamroller or part of the road.

Without a vision, there is no research

The Intelligent Ship – A Vision for the 21st Century

Volker Bertram, TU Hamburg-Harburg

Self-driving cars, trains and planes are developed

Computers take over controls in cars, trains and planes:

- Intelligent highways and self-driving ‘seeing cars’

Self-driving cars are not a new concept. “Indeed, a working model of an automated highway was the hit of the General Motors pavilion at the 1939 World’s Fair in New York City. During the late 1950s and 1960s, researchers at General Motors went on to refine various driveless vehicles. They showed, for example, how robotic trucks could work in open-pit mines. Although these early attempts at automation were valuable research exercises, the results proved too crude to be truly workable. Yet by the late 1980s, advances in microprocessors, wireless communications and various electronic sensors prompted many people to rethink the idea of automated highways. One group, which originally called itself Mobility 2000, convened in 1988 to consider the possibilities. It subsequently formed the Intelligent Vehicle Highway Society of America (later named the Intelligent Transportation Society of America), which now has more than 1000 organizations as members. Its mission is to foster the introduction of various ‘intelligent’ transportation systems, including automated highways,” Rillings (1997). In 1997, a prototype system for an automated highway on a stretch of the California freeway showed how automation might allow existing highways to accommodate a larger number of vehicles, while ensuring a higher degree of safety. The developers target the year 2002 for a commercial introduction of the system.

While the Americans base their system on sensors and signals embedded in the freeway, guiding cars along electronic tracks, German developments of ‘seeing cars’ are even more spectacular. Researchers around Prof. Dickmanns have developed self-driving cars that use video and pattern recognition to supply a computer with the necessary data to ‘model the world outside’, Maurer and Dickmanns (1996). The actual control – based in part on a knowledge-based systems for traffic rules and other rules for driving a car – is then rather simple as cruise-control has long been established in cars. By 1994, the ‘seeing car’ drove automatically in Paris on a three-lane freeway at speeds of 130km/h changing lanes and passing other cars. Also in 1994, the ‘seeing car’ mastered the problem of turning into intersections. By 1997, the ‘seeing car’ recognized street signs and potholes in the street and could drive 180km/h safely. Remaining problems for a commercial introduction will be overcome as computers become smaller and more powerful. It is estimated that in 20 years the necessary computer power to allow automated driving by ‘seeing cars’ will have the size of a football and be installed in cars on a standard basis. Simpler systems, that automatically reduce speed if getting too close to the leading car, are already on the market.

- Automatic trains

Trains appear to be particular simple to automate, as the tracks supply automatic guidance leaving mainly the speed control as task. In France, automatic trains are already reality. In Lille, a fully automatic metro has been operated since 1983. In Paris, the ‘Meteor’ started service in summer 1998 on a 7km track in the Paris metro system. In Germany,
the Deutsche Bahn AG is testing on the track Salzgitter-Braunschweig the first self-driving motor coach SST (Selbsttätig signalgeführtes Triebfahrzeug), a train intended to deliver supplies to the Volkswagen factory in Wolfsburg.

- Automatic planes

Prof. Dickmanns, who developed the ‘seeing car’, has also applied his technology to planes and helicopters. Cargo and passenger planes are already most of the time flown by an autopilot. The pilots take over controls during take-off and landing, because here visual input is vital. Even during emergencies autopilots usually are superior in flight-handling to human pilots nowadays. Prof. Dickmanns demonstrated that in principle by now also machines can see well enough (during good weather) to supply the necessary information to an autopilot during a landing approach. In fact, a European research programme intends to use related techniques to improve the safety of helicopters in bad weather conditions (e.g. snow storms) supplying ‘super-human’ vision (outside the bandwidth of wavelengths perceived by humans) to guide the Eurocopter.

Unmanned planes have been in use for a long time for military purposes. Remote-controlled ‘drones’ have been used for surveillance and cruise missiles fly automatically long-distance with claims of reaching an intended target with a few meters accuracy. Now Lockheed Martin develops an unmanned fighter plane modifying the aging F-16 A Falcon into F-16/UCAVs (Uninhabited Combat Air Vehicles). The idea is to give the plane ‘electronic brains’ so that it can carry out missions on its own or as directed by land-based ‘pilots’ via satellite. The plane will also have ‘eyes’, smart sensors that can detect e.g. missiles and shoot them down. The F-16/UCAV could be flying in little more than a year. More advanced UCAVs with stealth capabilities are under development by Northrop Grumman. These UCAV will be operated by ‘pilots’ sitting in command centers controlling the planes wearing virtual reality headsets. “By 2025, the US Air Force may be flying [these unmanned] craft that move at Mach 12”, Patton (1998).

Is the unmanned ship in sight?

In view of these spectacular projects, naturally questions arise if there are comparable developments for ships. Are there equivalents to the ‘unmanned car’ or the ‘intelligent highway’ on the water? Indeed, unmanned ships have been envisioned more than two decades ago, Schönknecht (1973): “In this age of rationalization and automation it would not be difficult to imagine a ship without a crew. [...] It is indeed quite possible that at some distant future date the captain will perform his duties in an office building on shore. In his place he will leave a computer on board ship which will undertake all the tasks of the navigator’s art, [...] controlling the ship, and will in fact perform the task much more effectively.”

The German RelationShip project has made this vision to a large extent reality. In June 1998 a sailing trimaran started for a journey around the world. The trimaran was remote controlled from Furtwangen in southern Germany, far away from any ocean, but within 12-mile zones of land and in pirate-endangered areas crews were taken onboard. The project was intended to demonstrate the possibility of unmanned shipping and remote control around the globe. The FH Furtwangen sees the project as an avantgarde demonstration for unmanned, computer-guided cargo ships. The rector of the FH Furtwangen praises the endeavor as a symbol of entrepreneurship which is opposed to encrusted ways of thinking.

In general, the proposed unmanned ship concepts found in the literature can be classified into:

- ‘Shore Captain’ concept
  This is the concept outlined in the quote above. The control system is transferred ashore. The ship retains only a largely self-regulating propulsion plant together with the equipment
needed for reception, transmission, and decoding of the control signals received from the shore and supervision of onboard systems.

- ‘Captain Computer’ concept
  The ship is equipped with sufficient hardware and software to perform all tasks and decisions autonomously using Artificial Intelligence.

- ‘Master/Slave’ concept
  Convoys of unmanned ‘slave’ ships remote-controlled from a highly automated ‘master’ escort ship have been proposed in Japan, Germany and the USA. While such a concept poses the least technical problems, one large ship with the same crew as the master ship would be simpler and more economical. (However, this concept makes sense if explosives or other dangerous cargo shall be transported apart from the crew.) However, the concept is investigated by navies for mine-sweeping, e.g. in the American Picket Hydrofoil Autonomous PHA, and related projects where a mother ship, typically of frigate size, will remote-control smaller unmanned ships for short-term, short-range highly dangerous operations.

In practice, usually a mix of local and remote control will be employed with redundancy for vital systems in case the communication link breaks down or local systems fail. Even if such a system could cope with all normal conditions the repair of defects is unlikely to be handled satisfactorily. But failures in the ship machinery occur now about once in 100 hours. Approaches to increase reliability include the increased use of electronic sensor and control technology, new materials, and condition-based maintenance. Condition-based maintenance and fault-diagnosis are the foremost applications of expert systems in marine automation, as surveyed by Kaeding and Bertram (1996), Bertram (1998). All large diesel manufacturers offer such systems by now. Despite the expected considerable improvements of engine reliability, onboard maintenance and occasional fault repair will most probably still characterize future machinery operation – at least for cargo vessels – as reliability conflicts with economy. Fuel consumption and prices are decisive for purchase in actual business. Therefore engines are likely to use poor-grade fuel and will not be engineered to ‘space technology’ level. The automatic diagnosis of faults appears quite feasible, the automatic repair of faults not. As long as there are failures, there must be someone to fix the problem which includes manual work like exchanging filters and valves. Some see the solution for the 21st century in robots with sensors, ability of movement and “judgment similar to or better than those of man”, Katagi and Hashimoto (1990), or “robotic arms equipped with binocular viewers will provide virtual presence in machinery spaces”, Ditizio et al. (1995). But robots with sufficient agility and sensoric capability will not be available for some time to come and then the first such robots would probably be more expensive than humans. Redundant capacities for machines and units that are likely to develop faults would be an alternative, but this is at present to be too costly for cargoships, Kaeding (1996). The trend is rather to make maintenance and trouble-spotting easier rather than avoiding faults at all cost. The system of the future will have a self-diagnosis function which instructs the operator how to repair the malfunction. This will drastically reduce time needed to find the reason for malfunction and allow multi-purpose crews to perform jobs now requiring experienced specialists.

Unmanned ships, while technically quite feasible, thus do not make sense at present for commercial shipping. The concepts discussed within the framework of an unmanned ship are nevertheless interesting also for commercial shipping, even if future ships will still feature crews. The issue at present is not the unmanned ship, it is the ‘intelligent ship’.

Let machines do what machines can do

If we focus on the ‘intelligent ship’ that thinks and supports the crew far more effectively than today’s ships, the discussion becomes immediately less emotional and the concept is far
more acceptable to a wide variety of persons involved in shipping. A rational approach to ship automation appears to be:

- Machines should do what machines do better than humans.
- Humans should do what humans do better than machines.
- Machines should support humans.

The technological progress will (or should) shift more and more tasks from humans to machines. However, ship owners are largely ignorant about the technological developments and legal frameworks do not keep pace with the technological change. As a result, more tasks than necessary or economically optimal are performed by humans.

Machines are superior to humans in the following aspects, Schneiderman (1992):
- perform repetitive preprogrammed actions reliably
- exert great, highly controlled physical force
- monitor pre-specified events, especially infrequent
- perform several activities simultaneously
- count or measure physical quantities
- make rapid and consistent responses to input signals
- operate in life-threatening environment

Humans are (at present) superior to machines in the following aspects:
- act in unanticipated and novel situations (common sense)
- reason inductively: generalize from observations
- take actions for self repairing
- interact socially with other humans
- perform acts of fine motorics
- detect patterns, especially using vision

The last two points will be the first to change as technology progresses. Vision and pattern recognition are actively researched and research groups for these topics are growing exponentially worldwide. Eventually, also robots with sufficient motoric skills will become available at a reasonable price.

Based on machine capability today, the crews could and should be supported in (or sometimes completely relieved of) the following tasks:

- Monitoring of machinery and ship
  The monitoring of engines and the ship itself involves the automatic observation of a flood of data which has to be checked against acceptable or expected values. For the machinery, early detection of deviations from standard values is already used to support predictive maintenance and fault diagnosis. Similar tasks are involved in detecting fires or the risk of a collision in dense traffic. The individual tasks are simple and the amount of data and the need for constant vigilance make it clearly a task better handled by computers. An exception is the diagnosis of a collision risk. Here, the computer is handicapped because its ‘vision’ is so far limited to using radar input to generate ARPA data. But ARPA’s automatic target acquisition reliability is limited. Small ships/boats are sometimes not detected. Furthermore, ARPA cannot diagnose the type of ship, e.g. sailing ship, which is a vital information for certain rules of collision avoidance. Earlier Japanese attempts to use video cameras and pattern recognition were not successful. The recent successes with ‘seeing cars’ described above may re-open the discussion about the feasibility of this approach. However, more likely the problem will be solved by making transponders mandatory, Müller (1997). Transponders would allow determination of ship types, detection of