DYNAMIC POSITIONING CONFERENCE
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SENSORS SESSION

Sensing Autonomy

By Arne Rinnan

Kongsberg Seatex AS

Abstract

A certain level of autonomy is already present in a DP and DP requirements have been a driving force in the development of a diversity of high reliability reference systems. Today there is a strong drive for autonomous concepts and solutions in several market niches (e.g. short sea shipping and ocean-based aquaculture). At the same time, the market downturn in traditional oil and gas leads to a reduced implementation of new reference system solutions.

A development towards higher levels of autonomy in novel operations drives the development from traditional reference systems towards solutions capable of proximity awareness and connectivity. The existing reference system technologies comprise a good platform in this development, but new technology elements like sensor fusion, machine learning, artificial intelligence and extended connectivity are considered.

The paper presents ongoing developments within microwave, laser, GNSS and inertial based reference systems and discusses likely future developments. Connectivity will be a native feature of future reference systems, and is also discussed.

Current development is running at a much higher pace than legislation and regulation can adapt. Some input to regulation challenges and trade-offs are outlined.

Introduction

KONGSBERG is a leading technology company being the market leader in offshore, subsea and merchant marine applications, a player in the growing defence and aerospace niches and is building up a strong activity within digital solutions.

KONGSBERG already has a strong position within autonomy in different applications and is expanding the autonomy technology platform by the engagement in some of the most ambitious maritime domain projects.

Autonomy

Autonomy is about systems that, to some extent, can operate independently with a varying degree of human intervention. There are many definitions of different levels of autonomy but it is important to note that autonomy not necessarily means unmanned. Autonomy is achieved by using technology elements like algorithms, software, hardware, interaction with humans and legislation. With a low degree of autonomy humans manually controls all actions and with a high level of autonomy systems make decisions and carry out actions with the human in a monitoring and supervisory role.

Autonomy involves a range of interested parties and elements including:

- Vessel
- Mission
- Developer
- Project manager
- Commander
- Director
- Board of directors
- Society

Autonomy is, in other words, about a lot more than technology even if technology provides enablers for autonomy.

Some important technologies comprising enablers for autonomy are:

- Sensors for measuring surroundings and conditions
- Perception for analysis of signals and data generating proximity awareness
- Communication for interaction and meeting security challenges
- Cognition for planning, learning and adaptation
- Localization and mapping relative to the operating environment
- Human-machine interaction for remote monitoring or control and to keep humans in-the-loop

The development within many of these technology areas is very fast due to strong development towards autonomy within driverless cars. It is still important to be aware that autonomy in the maritime domain in many aspects is different from road and land based autonomy. The maritime domain will require solutions and technology that might be different from what is being developed for driverless cars.

Dynamic Positioning and Autonomy

DP operations already represent a level of autonomy and have been around for decades. Under normal conditions, the DP operator can leave the manoeuvring of the ship to computers and machinery in most situations, has the opportunity to intervene when the technology reaches its limits. In such situations, it can be questioned if the operator also meet his limitations.

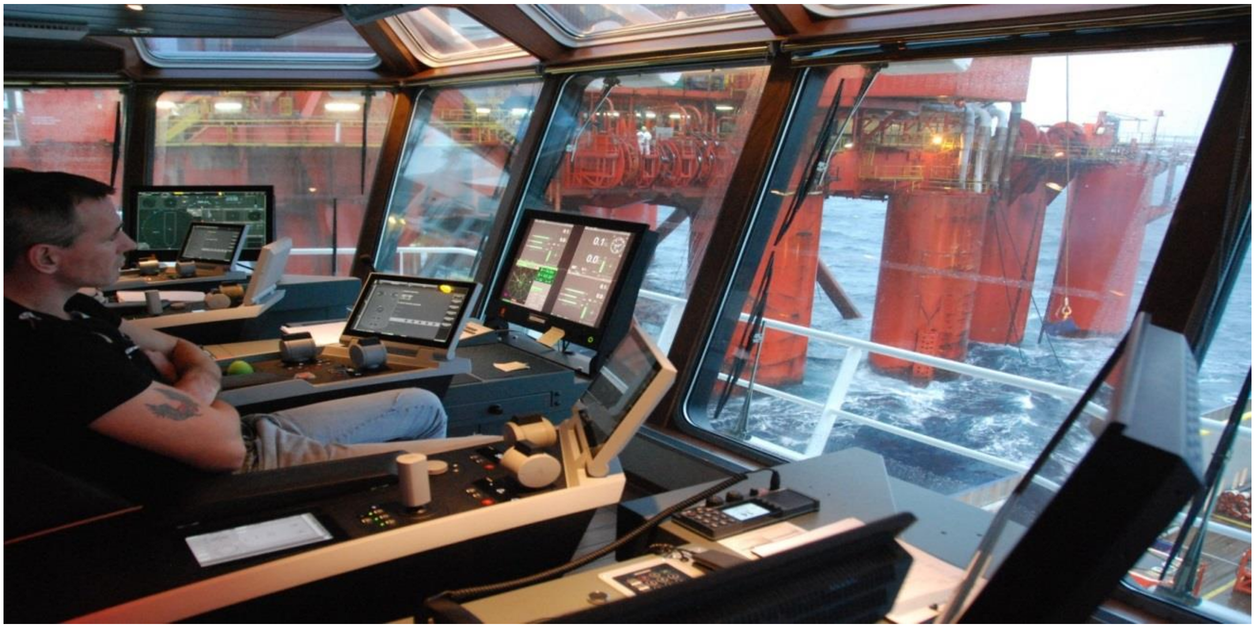

Figure 1: Autonomous manoeuvring of a vessel by using DP

The DP uses input from several sensors and reference systems to replace and improve the senses of the operator. The DP uses sensor fusion to obtain a picture of what is going on and what kind of forces that are affecting the vessel, before power is allocated to the thrusters. To avoid propagation of errors from the reference systems to the power allocation it is usually required to use at least three reference systems simultaneously, when at least two should be based on different measurement principles according to class regulations given by e.g. ABS and DNV-GL.

New Concepts

There are strong drivers for moving transport from roads to sea, and strong ambitions to develop more cost-effective solutions for maritime operations. To reach these ambitions, and be able to develop new solutions, the cost levels need to be reduced. In combination of the strong drivers and the development of enabling technology, several new concepts are develop pointing into a possible future where more activity can take place at sea or on the oceans. A few examples where KONGSBERG plays a strong role are:

- Offshore support vessel (Hrönn)
- Exposed aquaculture (Ocean Farming I)
- Autonomous container feeder (Yare Birkeland)

These examples represent first-mover opportunities that can potentially lead to full scale developments of radically new solutions. Even if traditional solutions will exist for decades, it is also foreseen that solutions developed to reach the ambitions of these projects will flow into traditional operations.

Figure 2: Hrönn - light duty, offshore utility ship

Figure 3: Ocean Farming I - new construction for salmon farming in exposed locations

Figure 4: Yara Birkeland - zero emission container feeder

All examples represent full scale, operating constructions that are built or will be built shortly.

Proximity Awareness

Traditional DP reference systems usually provide position measurements relative to earth-centred or relative co-ordinates in X, Y, Z or as range/bearing measurements. The traditional reference systems have limited capabilities of handling non-cooperative targets. Even if some capability of lever arm compensation usually is provided, they also have limited capacity of representing the positions of the entire hull for collision avoidance or optimal manoeuvring.

Vessels with a higher level of autonomy will require features exceeding those provided by current reference systems, to provide significantly better proximity awareness compared to what is available today.

It is interesting to look at sensors and sensor integration in a modern car in order to get an impression of the functionality that is required.

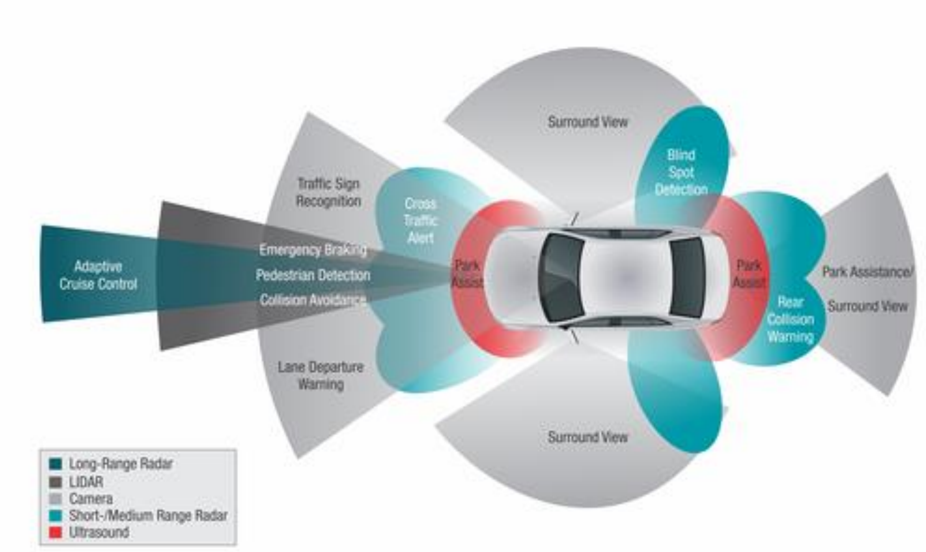

Figure 5: Sensors and sensor integration in a modern car

There are some important differences between a modern car and a vessel operating in a maritime environment:

- The size and variation in size of vehicles – it is questionable if it will be possible to equip a ship with the same density of sensors per meter as in a modern car.
- The environment – weather conditions are expected to be worse in a maritime environment than on roads.
- The masses involved in a maritime operation limit the manoeuvrability of the vessels
- At sea it is usually not possible to pull over and stop if something goes wrong.

The point is not to define a complete list, but point at some major differences between road and maritime applications. These are influencing technology requirements and solutions that makes it difficult to make a direct transfer of solutions from one application to another.

Solutions for higher levels of autonomy also require connectivity to be addressed in a more comprehensive way. Sensors and systems need better interaction on-board but digital communication channels also need to be available for ad-hoc connection between vessels involved in the same operations, or operating in the vicinity of each other. It is also necessary to reconsider traditional solutions for connectivity between sea-going vessels and land based infrastructure.

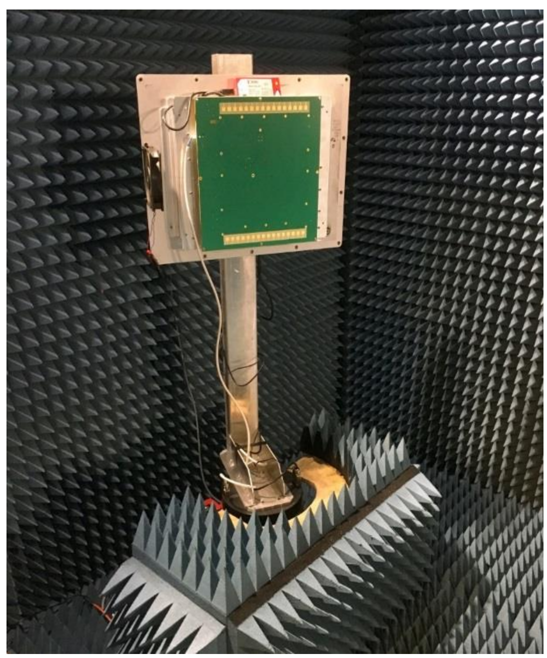

Figure 6: Beam-forming microwave reference system

Technology developments

DP reference systems based on microwave signals, usually in the 5 GHz or 10 GHz bands, are well-known. Modern, solid state technology makes it possible to improve the performance of such systems to avoid moving parts completely and to increase the resolution and accuracy of current solutions.

Phased array antennas and powerful signal processing are important features of this technology. Systems can consist of active nodes for extended range and accuracy, the combination of active and passive nodes or even providing radar type images for proximity awareness and detection and identification of non-cooperative objects.

There are new on-going developments of LASERs operating in the infrared band (1 550 nm wavelength) making it possible to provide long range LIDAR functionality required in maritime operations with night vision capabilities. LIDARs are essential in autonomous cars, but the range and visibility requirements are much stricter in maritime environments.

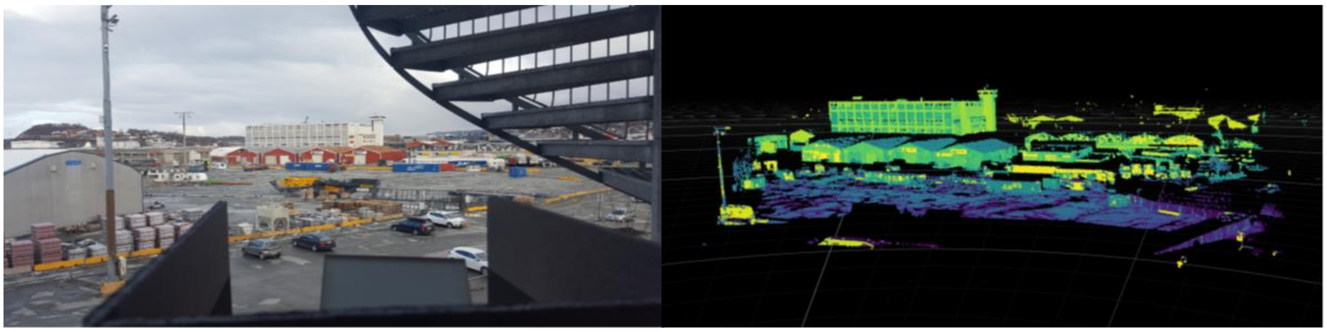

Figure 7: Daylight camera and LASER image

The deployment of new navigation satellites in the four global constellations: GPS (US), Galileo (Europe), Glonass (Russia) and Beidou (China) has been increasing over the last few years. Today (September 2017) there is a total number of 98 such satellites in orbits, and 83 out of these are operational.

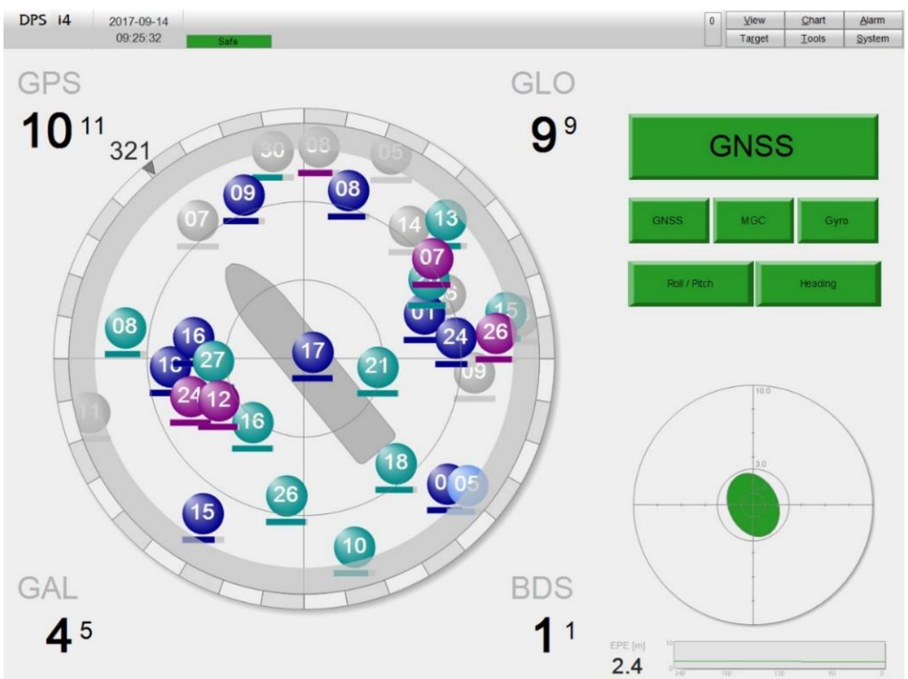

Figure 8: Multi-constellation GNSS

The use of inertial solutions is increasing and also the development of new solutions which provide north seeking capabilities and inertial navigation performance. There is a trend towards integration between GNSS and inertial solutions to reduce the need for costly differential solutions even in some DP operations. Solutions for real-time transfer of attitude data between vessels are emerging, for e.g. relative heave compensation between vessels.

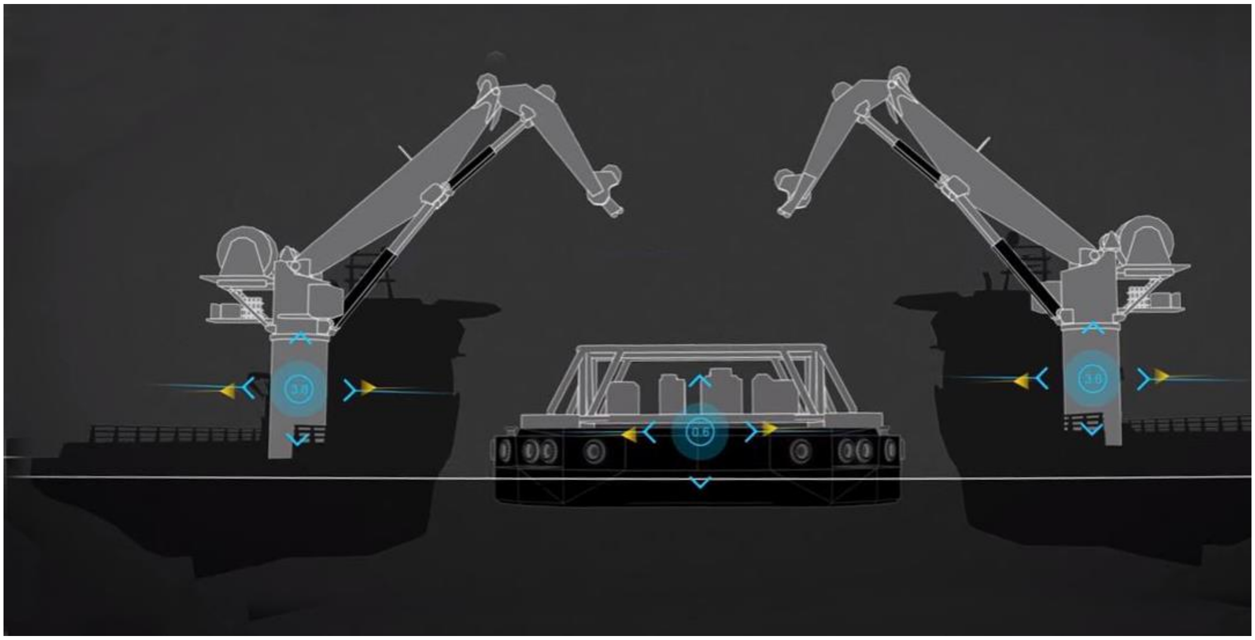

Figure 9: Relative heave compensation

The needs for digital and reliable connectivity between vessels are an essential part of the development towards higher levels of autonomy. It is no longer sufficient to communicate high level data as decisions and to co-ordinate information. Autonomy also requires communication of sensor data in real-time between vessels and objects. Connectivity is expected to be automatic and instantaneous.

Fusion and beyond

As mentioned in earlier chapters, sensor fusion has been going on in the DP for decades. Fusion of different reference system technologies such as GNSS and inertial measurements are also well-known.

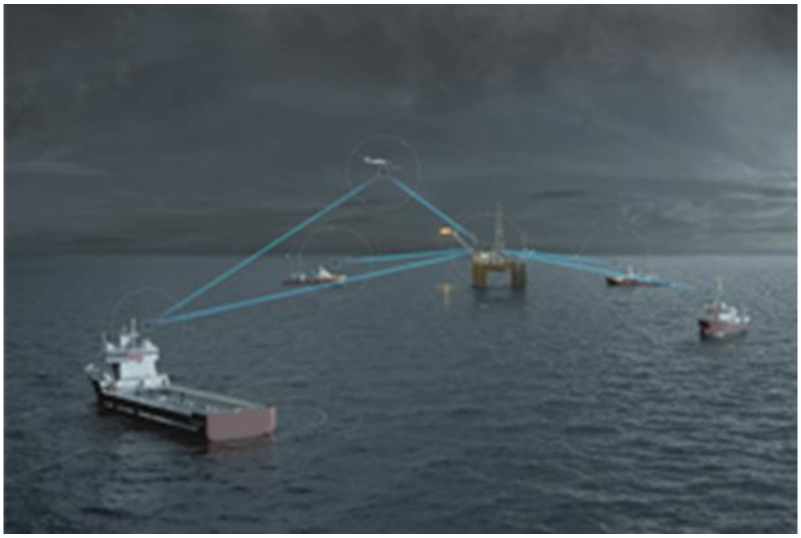

Figure 10: Maritime connectivity for autonomy

Autonomy requires fusion to take place at a completely new scale compared to traditional DP and DP reference systems in order to achieve true proximity awareness. Data driven methods like machine learning are already used in the development of driverless cars, and these technologies will also be available to maritime applications. Data driven methods are well-known in science but the amount of data and the capability to process and handle these data are new, not at least to traditional maritime operations. Machine learning techniques can be used to recognize, identify, classify, comprehend, learn, predict, decide and act in an autonomous operation.

One large concern related to machine learning is the black box problem. It is hard (at least for a human) to really know what is going on in a machine learning process. It is also hard to know if the data-set used to train the machine learning algorithm is representative and faultless. These challenges need to be addressed, especially in safety critical applications and by regulations and legislation. Machine learning is usually associated with Artificial Intelligence (AI). It is worth noting that Artificial Intelligence, like human intelligence, can fail.

Another development enabled by Moore's law (the exponential growth of number of transistors per mm^2 silicon) is the possibility to solve computer intensive tasks closer to the data source or the sensors (Edge Computing). It is even possible to use the increasing processing power of the sensor, or networks of sensors, to make computations usually belonging to centralized computers. Machine learning and sensor fusion do not necessarily require more processing capacity of the centralized computer system, but might be solved directly in the sensor network.

Sensor fusion at a level required by autonomy, also requires a comprehensive platform for massive processing and rapid deployment of new algorithms and solutions. A typical platform task is to provide a consistent platform for Cyber Security as connectivity increases and the opportunity for manual intervention is reduced. Advanced analytics of huge amounts of data also require access to the combined processing power of large processing and storage plants to e.g. training of machine learning algorithms.

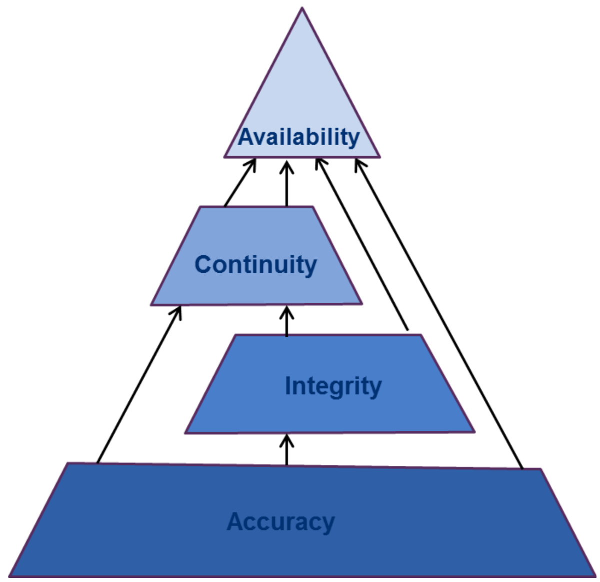

Figure 11: Performance trade-off pyramid

Regulation Challenges

The challenges to regulations and legislation are huge because of the rapid technology development and the development of completely new, full scale concepts. Regulations and legislation are not expected to drive the development, but it is important to change the pace of this kind of work.

Even if technology is changing rapidly, the fundamental trade-offs between different performance parameters still apply. These trade-offs cannot necessarily be derived from existing applications and operations into new, autonomous applications. It is necessary to carefully analyse the basic, operational requirements and derive a new set of operation specific requirements. It is also necessary to collect data at an early stage in the development cycle to be able to verify new solutions and approaches.

Figure 12: Digital twins and regulations

The development of digital twins and simulations can be a valuable tool in this work. A digital twin of a new concept can potentially be developed much faster than the physical construction of a new vessel.

Conclusion

The development towards a higher level of autonomy in maritime operations and the development of new concepts is potentially a game-changer also for DP operations. Technology and solutions are expected to flow from the new concepts into more traditional applications. New concepts are drivers and technology seems to be an enabler.

Sensing and connectivity are core elements in this development and the features provided by new solutions can increase efficiency, reduce costs and increase safety. This development will eventually feed back into the development of even better and more versatile sensors.

The opportunities in data driven methods such as machine learning, will enable new levels of sensor fusion but it is important to address the pitfalls of these technologies, especially in safety critical operations.

The rapid development of new concepts and technology comprise substantial challenges to regulation, and legislation, but digitalization technology also offers tools that should be considered in these processes.