DYNAMIC POSITIONING CONFERENCE
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SENSORS SESSION

Sensor fusion and proximity awareness in DP

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Abstract

A certain level of autonomy is already present in dynamic positioning (DP), and DP requirements have been a driving force in the development of a diversity of high-reliability reference systems. There is a strong drive for autonomous concepts and solutions in several market niches like short sea shipping and ocean-based aquaculture. A development towards higher levels of autonomy in novel operations drives the evolution from traditional reference systems to integrated solutions capable of complete proximity awareness. The existing reference systems are a good platform for this development, but other sensors like RADAR and cameras are also demonstrating value in sensor fusion concepts. These concepts include the use of break-through achievements within Artificial Intelligence by using methods like Machine Learning and Neural Networks. The value of large and representative data sets is crucial to develop such solutions. There are exciting developments combining traditional physical models with data driven methods that are relevant to mission critical operations. The paper presents the concept of sensor fusion and proximity awareness as parts of this development in a DP context, and includes some initial results based on large data sets recording during a Winter season at the Norwegian coast.

Introduction

Dynamic positioning (DP) is an automated system for controlling the heading and position of a vessel by using thrusters and propellers. Position reference systems, wind sensors, motion sensors, and gyrocompasses provide input to DP about actual heading and position and the magnitude and direction of environmental forces affecting the vessel's movement.

There are some important challenges to DP operations that need to be addressed:

- Better energy optimization and reduction in emission of NOx/SOx
- Hybrid power plants combining e.g. diesel-electric generator sets and battery banks
- New vessel concepts like unmanned container feeders (e.g. Yara Birkeland)
- New operational concepts like maintenance of offshore wind parks or fish farms
- Improved adaptation to changing environments like single waves
- Operating unmanned vessels either autonomously or remotely
- An increased level of automation of vessels and operations
- Decision support either for on board crew or remote operators

There are on-going technology developments enabling solutions to some of these challenges in novel and innovative ways. This paper addresses such technologies related to sensor fusion and proximity awareness in a DP context.

Autonomous operations

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

The most important technologies comprising enables for autonomy are the following:

- 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 to actual situations and conditions

- Localization and mapping relative to the operating environment
- Human-machine interaction for remote monitoring or control by keeping humans in the loop

The development within many of these technologies is moving quickly due to a strong advancement 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. An example is the delivery of Yara Birkeland, the World's first zero-emission container feeder, which eventually will operate fully autonomously with no people on-board. The development of vessels like Yara Birkeland is expected to drive the development towards sea-born autonomy.

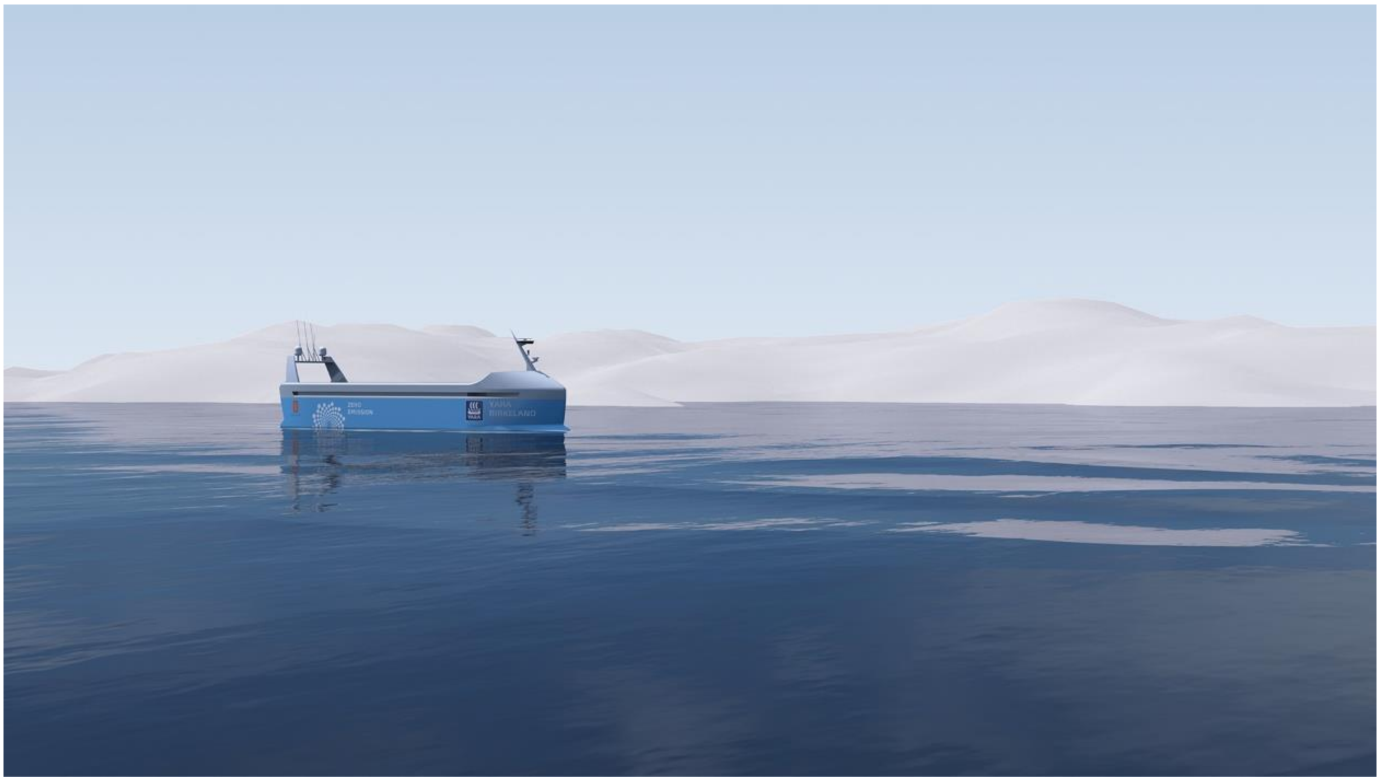

Figure 1: Yara Birkeland - zero-emission container feeder

The human role in DP operations are usually not as a direct element in the loop controlling the vessel. The human role is rather monitoring and supervising during the operation. This role is sometimes described as 99% boredom and 1 % panic. Situational awareness is usually based on the same sensor input as the automatic control of the vessel and additional use of human sensors like vision, hearing, feeling of vibrations etc. When weather is bad the human sensors will be of limited value and there might be a need both for better situational awareness and decision support. A human intervening in an autonomous operation will usually need a certain period of transition to be able to handle the situation.

Situational awareness is about more than just knowing the readings of different DP reference sensors, motion measurements and weather conditions. It also requires awareness of what is going on in the close proximity of the manoeuvring vessel. Like for autonomous cars, the proximity awareness might also depend on the specific operations undertaken. A modern car is using different sensors for functions like cruise control, anti-collision, lane control, cross traffic alerts, park assistance, blind spot detection and rear collision warnings.

Figure 2: Human monitoring and supervision in a DP operation

Increasing levels of digitalization as an enabler for autonomy also increases the need for proper strategies addressing possible cyber security threats. Some main elements in such a strategy will be:

- Secure communication with protection against eavesdropping, jamming and spoofing
- ID management both for personnel and equipment
- System security and architecture with resilience against cyber security threats
- Secure logging and monitoring
- Device management including protection against tampering and using defined levels of trust
- TEMPEST protection including precautions regarding signal jamming and spoofing

There is a long range of benefits implementing autonomy at higher levels, but cyber security threats are the reverse side of the coin.

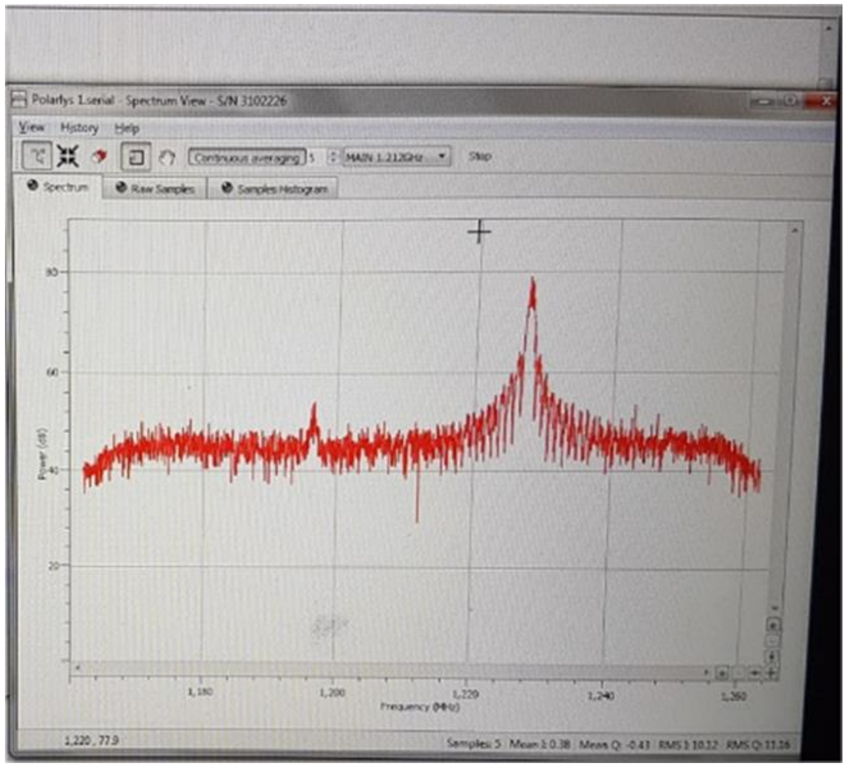

Figure 3: Experimental jamming of GPS L2 in Trondheimsfjorden

Traditional solutions for remote assistance and remote monitoring can be used to support operations going on anywhere and at any time in the World. It is expected that these solutions will be developed further into more integrated parts of operational concepts. Technology enables a transition from remote to virtual management, monitoring, supervision and control. Solutions need to capture the value of capturing data from operations to be able to make data driven decision support. Digitalization also enables a separation of operational functions across a fleet rather than covering all functions of one vessel at a time. Autonomy at any level will require some kind of human interaction and the development of solutions for virtual control and monitoring will enable new ways of defining the boundary between humans and machines.

DP and autonomy

Implementation of all-speed functionality in DP or autopilots represents new, autonomous manoeuvring concepts altering the traditional DP role of station keeping. An example application is automatic docking of ferries. A combination of traditional DP reference systems and target less sensors like cameras, is used to support automatic manoeuvring during transit, approach and docking phases. The operation is supervised by the crew and Augmented Reality solutions are used to transfer proximity awareness from sensors to humans.

Combining the use of traditional reference systems with sensors providing pictures or point clouds requires a new reference system concept. The need for processing power by using Machine Learning (ML) algorithms makes it natural to use a separate processing unit. The output to the DP, or other systems, will in addition to position, heading, attitude, velocity be proximity awareness and decision support information.

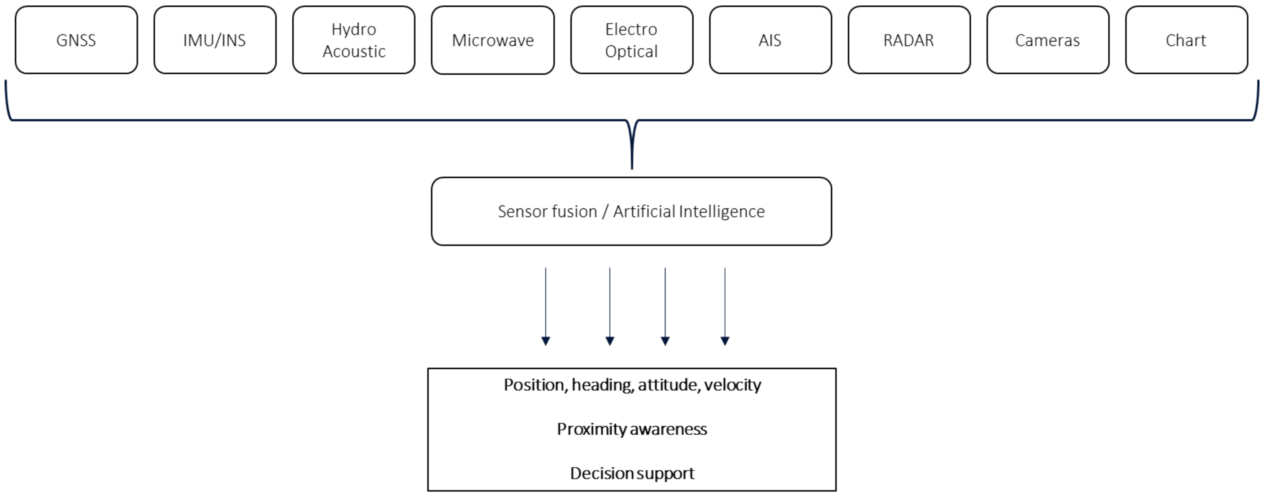

Figure 4: A new Reference System concept

Proximity awareness

The basis for proximity awareness will be a consistent "World Model" adopted by all sensor-providing input to sensor fusion and AI algorithms. Even at sea, this needs to be a 3D model. Reducing the "World Model" to 2D will mean an over-simplification where a lot of useful information will be lost, like the shape of the hull, location of sensors at different points at the vessel, compensation for vessel movement etc. The "World model" also needs to contain both references to the Earth (geo-referencing) and the vessel. In some situations, it is even necessary to take into account movements of objects on the vessels (e.g. cranes).

When the "World model" is established it will be meaningful to do picture recognition and point segmentation of data from dedicated sensors or RADAR and cameras. Picture recognition has been known for many years, but the new element in this process is that AI represented by Machine Learning and Deep Learning have become a valuable tool for this task. Machine Learning has dramatically improved the performance of detection, classification and identification compared to conventional picture recognition algorithms.

Machine Learning has demonstrated superiority in avoiding false detection and missed detection of objects at sea as long as sufficient and representative data sets are used for training these algorithms. It should be noted that it is an increasing interest in combining Machine Learning algorithms with traditional, physical models like Kalman Filters, to overcome limitations in the data sets. A key term evolving since 2015 is hybrid analytics.

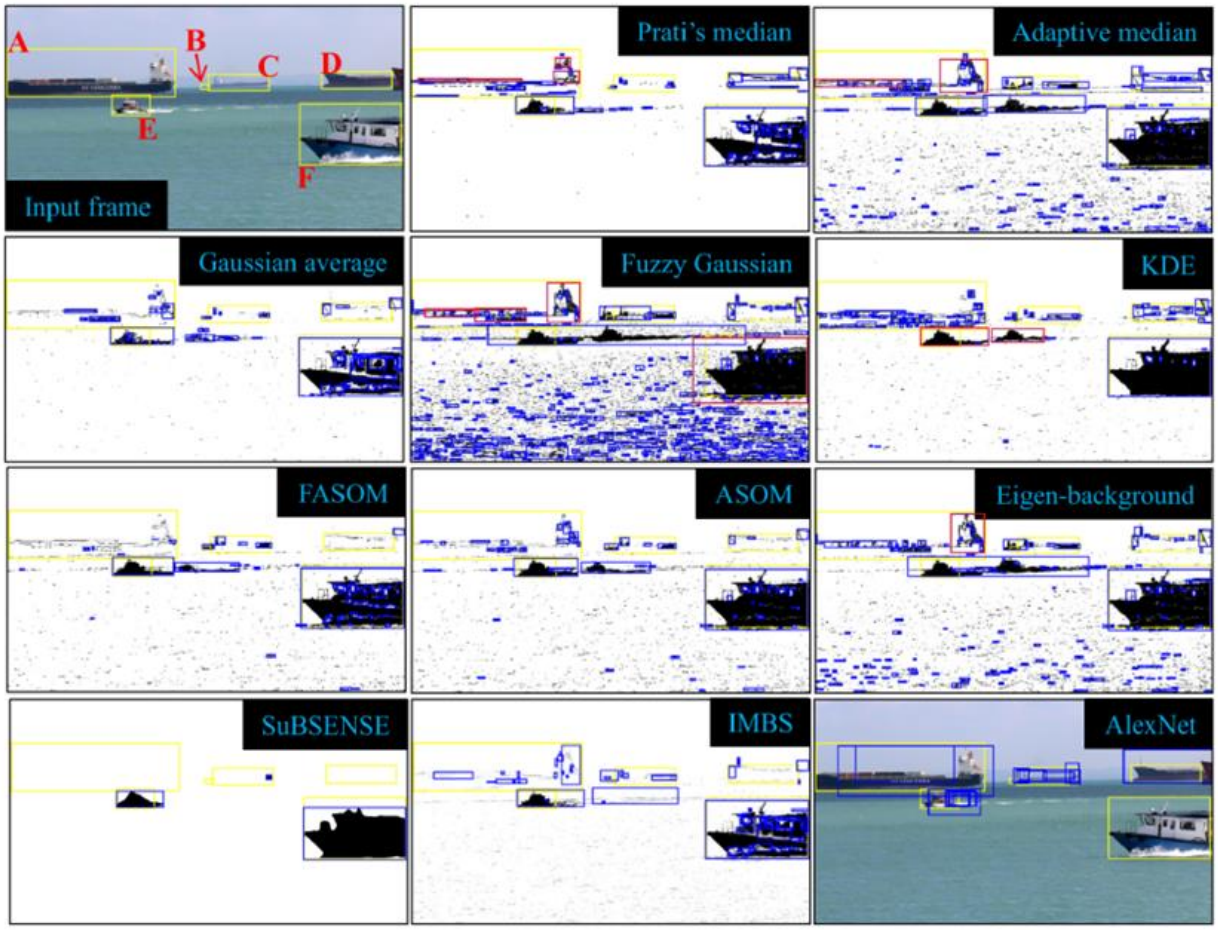

Figure 5: Dilip K. Prasad et al: Conventional vs. Machine Learning (AlexNet) picture recognition

Results from a pilot installation

Since the data sets for training of Machine Learning algorithms are crucial an experimental data collection project has been running at the coast of Norway since Autumn 2017. So far (per September 2018), more than 200 Tera Bytes of sensor data have been collected during all kinds of weather and light conditions.

The sensors used for data collection are:

- 2 x high precision GNSS (position and heading)
- 1 x IMU/INS
- 2 x X-band RADAR
- 1 x S-band RADAR
- AIS
- 12 x surveillance cameras (360 degree coverage)

The comprehensive data set, makes it possible to experiment with different sensor fusion algorithms and methods. The data set is also sufficient for effective training of Machine Learning algorithms.

An early take-away from the data collection project is establishing a proximity view of the vessel by fusing the different sensor data. This can further be used as a docking aid to the captain.

The next level take-away is:

- Fusing sensor data and a 3D model of the vessel and the surroundings
- Detection and classification of objects in the vicinity of the vessel (e.g. navigation marks)
- Improving the accuracy and integrity of proximity sensors
- Providing improved decision support for the DP

Conclusion

Autonomous operations are strong drivers for technology development in the maritime domain, and will challenge conventional solutions also in mission critical operations. The evolution of radically new concepts, like Yara Birkeland, are pushing this development at an unexpected pace, both in the technology domain and legislation and regulatory domain.

It is expected that elements as sensor fusion and proximity awareness will be key elements of future DP reference systems and some of the achievements within this field are in the transition phase from experimental to early operation for certain operation.

Figure 6: Automated docking by sensor fusion and human supervision