Uncertainty Zones and Relative Distance/Speed for Objects in Simultaneous Operations

Dynamic Data Exchange for Autonomous Functions

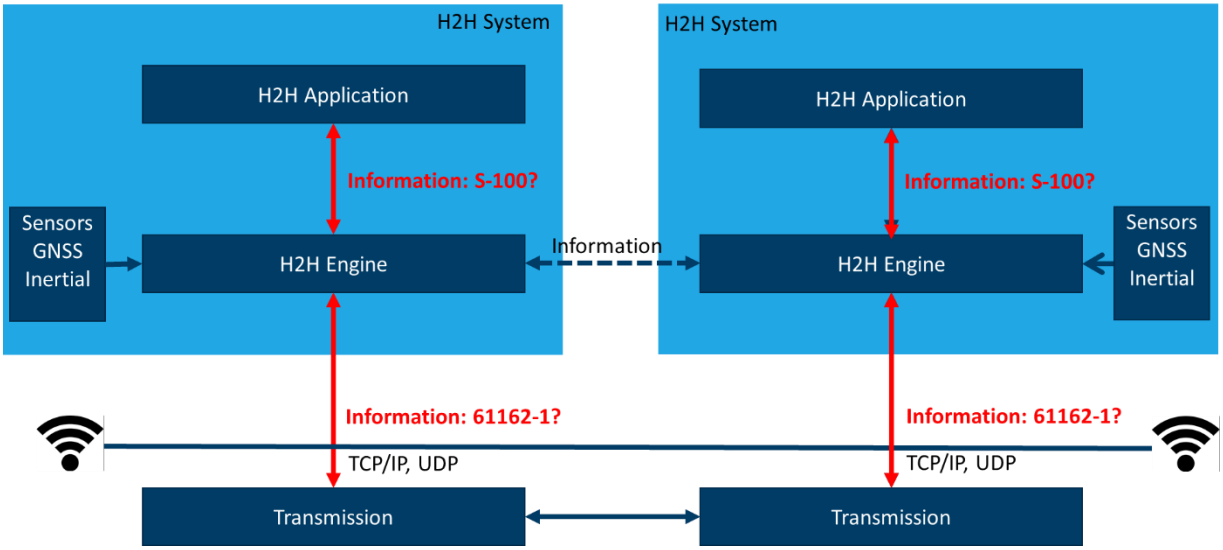
Marianne Hagaseth[1], Svein Peder Berge, SINTEF OCEAN.

Introduction: Dynamic Data Exchange for Autonomous Functions

This input paper briefly presents those parts of the work done in the Hull-to-Hull (H2H) project[2] that is relevant for standardization in the S-100 Framework. It focuses on the standardization of dynamic exchange of data between ships and between ships and land-based infrastructure, for instance quays, to be able to support autonomous functions and single-handed operations and also to support simultaneous operations.

About the Hull-to-Hull project

The idea behind Hull to hull (H2H) is to provide navigators with precise distance and relative velocity at any point on a vessel's hull relative to other vessels. To do this, it is necessary to know the location of the hull relative to the other hull. This is achieved by locating a 3D model representing the vessels, using precise position and orientation measurements.



In addition to vessel to vessel distance, the H2H concept is generalized to include arbitrary objects, where one object is moving, and the other objects could be moving or stationary. Examples of stationary objects are quays, lock walls and land masses.

Position and orientation might be measured by any available means. In the project, we focus on using the European GNSS systems Galileo and EGNOS in combination with the other GNSS and inertial systems. Since we are interested in distance and relative velocity, we use Galileo in relative mode.

[1] Marianne.Hagaseth@sintef.no

[2] https://www.sintef.no/projectweb/hull-to-hull/

It is crucial for navigators to know what level of trust can be put on navigation information. This is also part of the H2H project, where an uncertainty zone (see further below) around the vessel will indicate the uncertainty in the location of the hull.

The H2H concept was proposed by Kongsberg Seatex, and it is now being implemented in a demonstration project. The project has received funding from the European GNSS Agency under the European Union's Horizon 2020 research and innovation programme grant agreement No 775998.

The Uncertainty Zone Concept

The concept of **Uncertainty Zone (UZ)** is used to assist navigators and operators to perform safe navigation of objects (ships) in proximity to other objects (other ships or fixed objects as quays or locks).

*The **Uncertainty Zone (UZ)** represents the uncertainty in the outer boundary of the geometry of a ship or a fixed object within an operational area, at a given time, see two examples of UZs as red shaded areas in* Figure 1.

Each Uncertainty Zone is calculated based on data from position sensors (GNSS data[3]), inertial sensors onboard the ships, range-and angle sensors, and geometry models (2D or 3D) of the objects. Each UZ is calculated based on data from **all objects** that participate in the simultaneous operation. Each object is responsible for calculating all uncertainty zones, that is, both its own UZ and the UZ of all objects participating in the operation.

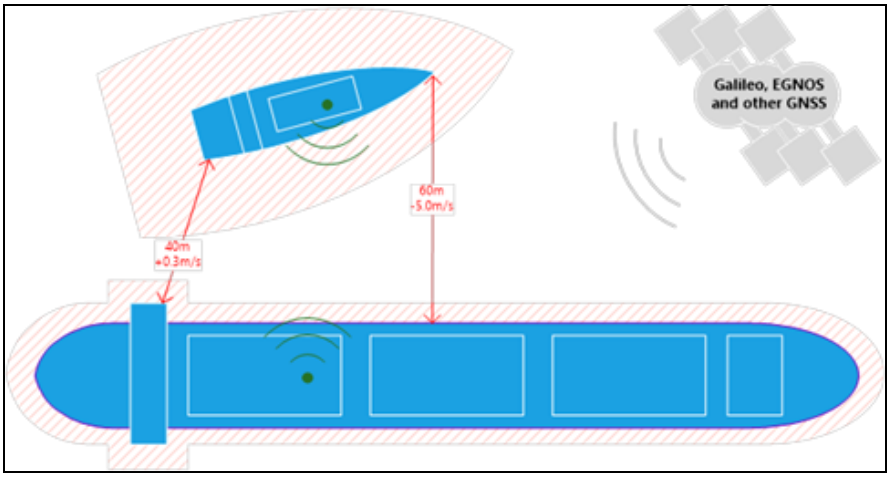


Figure 1 Uncertainty Zone (red, shaded area) for to ships in a simultaneous operation

An example is shown in Figure 1 where the large ship calculates its own UZ and also the UZ of the smaller ship that participates in the operation. And similarly, the small ship calculates its own UZ and the UZ of the larger ship. This means that the UZs may look different onboard each of the ships, dependent on the information available for doing the calculations. It also means that data must be shared and communicated amongst the ships and other objects to be able to perform these calculations. Work will be done to propose this as a standardized protocol, for instance how to extend

[3] Including Galileo and EGNOS

the IEC 61162-standard, to ensure that any equipment implementing Uncertainty Zones will be compatible, independent of the actual provider.

The size of the uncertainty zone is based on the selected integrity requirement *p*, where *p* represents the probability that a point on the hull is inside the uncertainty zone. Typically, *p=95%,* in line with maritime accuracy figures.

If less data is available for the calculation of an UZ, for instance, only position data from AIS, the UZ may be simplified to be a circle and the ship may be presented as a point or a rectangle representing the length and breadth of the ship, Figure 3.

Several sources of uncertainties are handled when calculating the UZ, Figure 2. This includes:

- The installation error, $\varepsilon\_installation$, that is, the difference between the physical location of a sensor and the location in the geometrical model, expressing the accuracy of the sensor installation.
- The error in the actual data received from the sensor, ε_sensor, that is, the sensor data accuracy.
- The error in the geometrical model compared to the physical object (ship or fixed object), $\varepsilon\_3Dmodel$, that is, the sensor.

This means that the total error can be expressed (simplified) as

$$\varepsilon\_hull = \varepsilon\_sensor + \varepsilon\_installation + \varepsilon\_3Dmodel.$$

The calculations will ensure that the hull is inside the Uncertainty Zone with *p* (for instance 95%) probability.

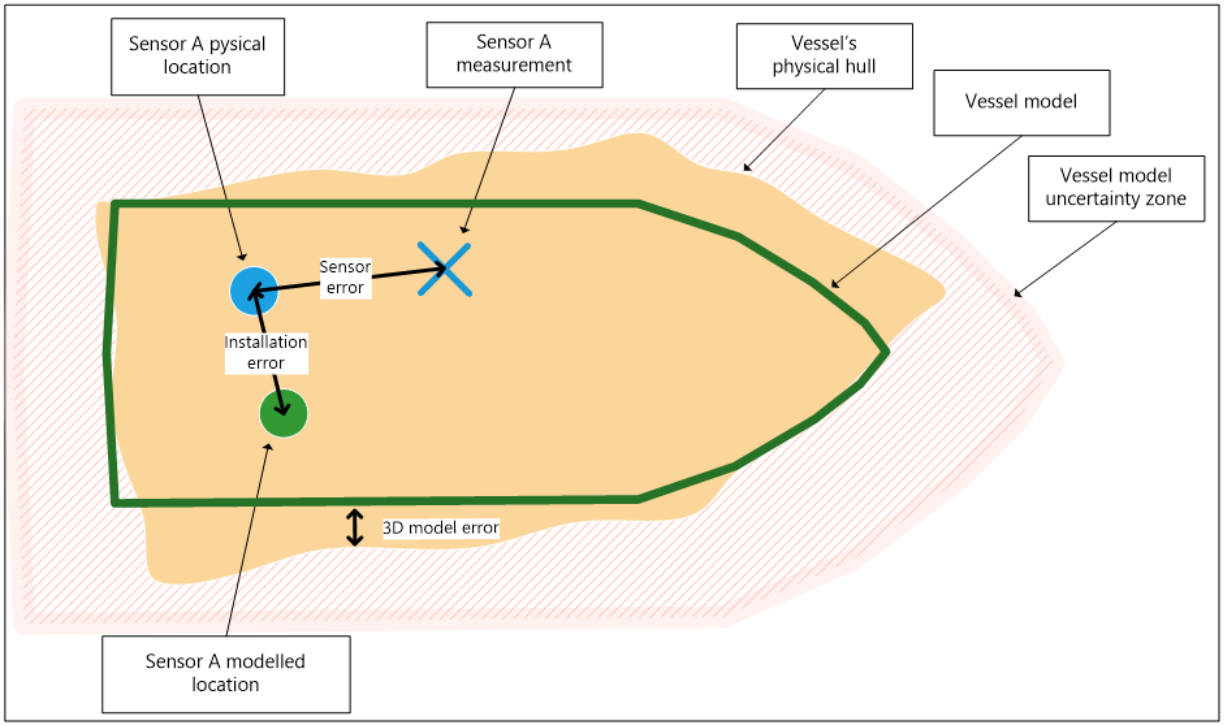


Figure 2 Error factors in the Uncertainty Zone

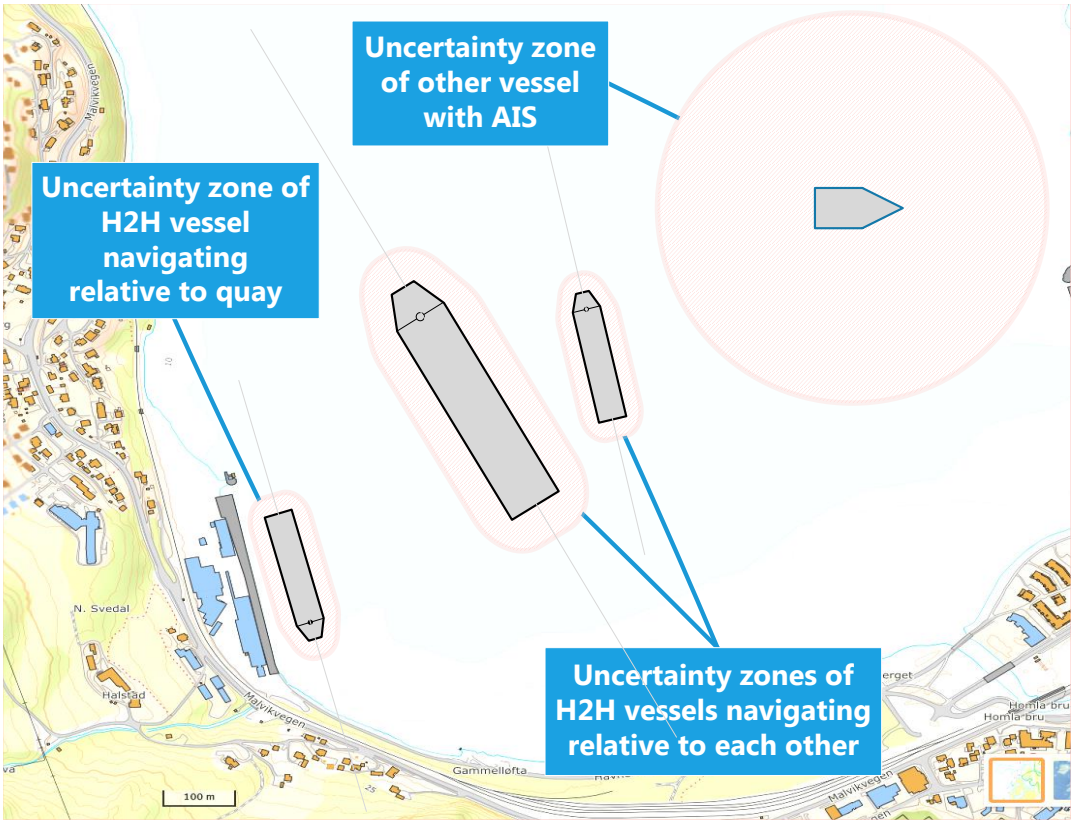


Figure 3 Examples of Uncertainty Zones

Display of Uncertainty Zones and Ships/Objects

The display of the uncertainty zones must be updated each time the underlying data describing this UZ is updated, and also each time the UZ itself is updated. Especially, if communication to at least one of the other ships/objects in the operation is lost, the UZ may suddenly get larger due to an increased uncertainty. This must be reflected in the presentation of the UZ.

If the geometrical model of the ship/object is available, this model, either 2D or 3D, can be used in the presentation. If only the ships/objects dimensions are available, this can be used to present a simplified view of the objects. Zooming of UZs and ships must be handled accordingly.

Distance and Relative Velocity

In addition to have a picture of the UZ, the operator can also select a point on his own ship's/object's geometry and another point on a target ship's/object's geometry. Then, the calculated relative speed and distance between these two points must be presented. Figure 1 shows the relative speed and distance between two points on each of the ship's outlines.

Draft Class Definitions

Figure 4 shows the draft class for describing an uncertainty zone. The UncertaintyZone:Geometry-attribute includes the LAT/LON for each point on the UZ, in the datum used for the presentation. The Sigma attribute represent the probability of having the ship/object fully inside the UZ, where 1 sigma is 68% probability and 2 sigma is 95% probability.

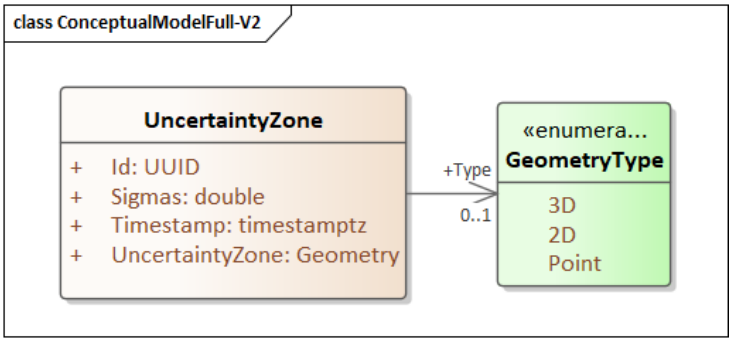


Figure 4 Draft Class for Uncertainty Zone

Figure 5 shows the draft classes for the object geometry, reference points and relative distances and speeds between two points related to a ship or fixed object. Each reference point is related to the physical dimensions of the object and the calculated sensor values in that point (a virtual sensor represents values in a certain point calculated based on sensor values from physical sensors). The relative distance and speed are related to a start and end reference point through the class VirtualSensorMontionState, since the relative distance and speed is dependent of the actual measurements for the start and end points. New measurements in at least one of the start and end point will require new calculations of the relative distance and speed.

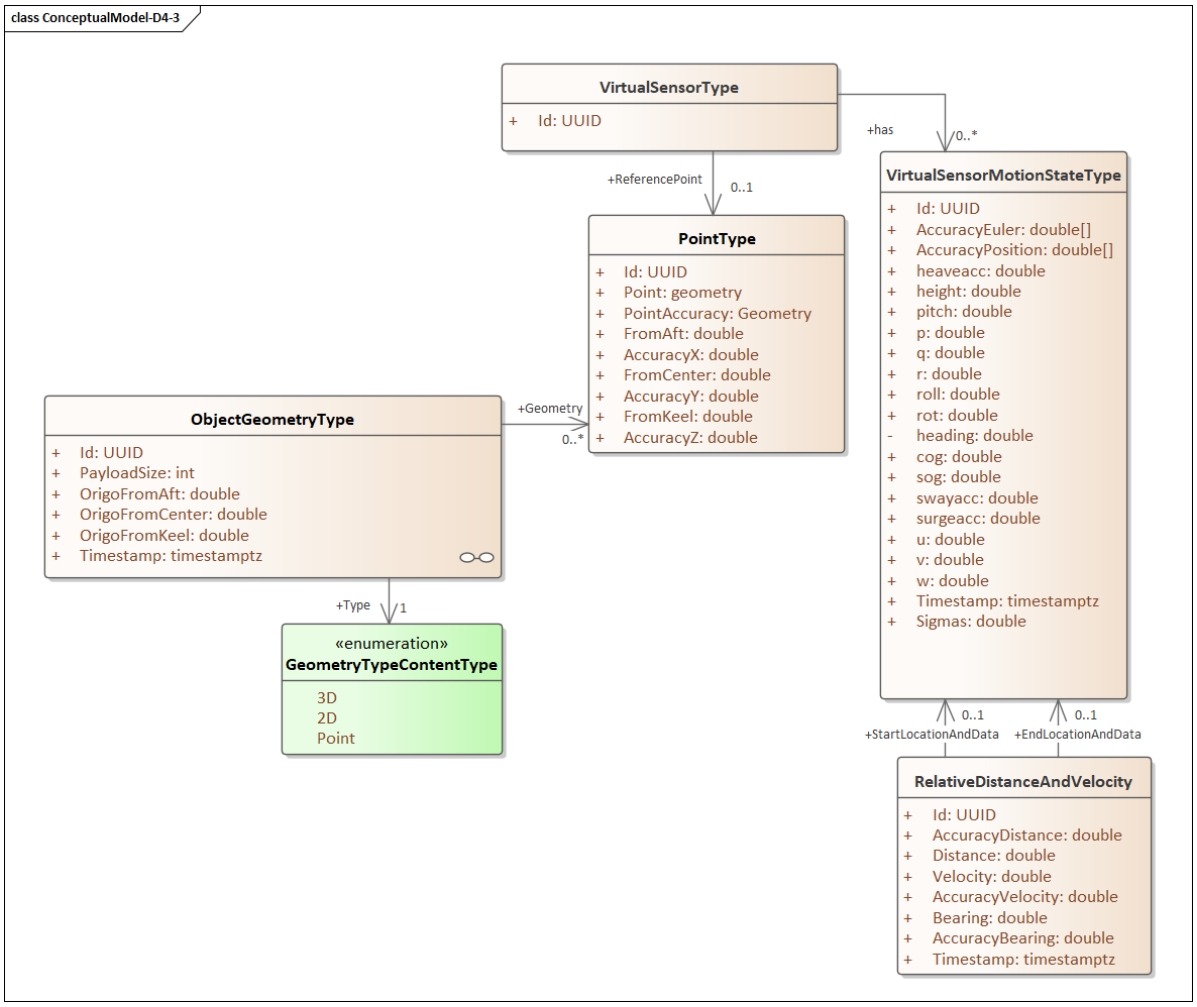


Figure 5 Draft Classes for Object Geometry and Relative Distance/Speed

Questions

- Taking into account the dynamic nature of the information related to Uncertainty Zones, and also that this is closely linked to autonomous functions, what considerations should be taken when integrating this into the S-100 framework?
- Which working group/forum is most appropriate to continue this work?