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Survey on Autonomous Surface Vessels: Part I - A New Detailed Definition of Autonomy Levels

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Abstract. Autonomous Surface Vessels (ASVs) have been involved in numerous projects since the 1990s. Many ASV projects have been successfully realized, and as many are still under development. Together with the development of those new autonomous vessels, the research on classification about ASVs has become important. The classifications provide clarity to researchers, designers, shipbuilders, equipment manufacturers, ship owners and operators, enabling accurate specification of the desired level of autonomy in design and operations. Moreover, the involved research paves the way to a clearer understanding of the opportunity and challenges of research on autonomous vehicles.
In this paper, we introduce the emerging concept of autonomous vessels. A multi-layer multi-agent control architecture of cooperative transport systems from the perspective of ASVs is proposed. Moreover, we provide an overview of existing research on the classification of autonomy. Based on the analysis, a detailed definition and categorization of autonomy levels for ASVs is proposed starting from the characteristics of ASVs and existing classification of autonomy. The proposed autonomy levels categorization assesses the overall autonomy level of a vessel by analyzing the automated sub-systems: Decision, Actions, Exceptions, and Cooperation. This categorization can be used to analyze existing ASV prototypes to gain insight into the status and trend of ASV research.

Keywords: Autonomous Surface Vessels; Autonomy level; ASV; Cooperative transport systems

1 Introduction

Autonomous Surface Vessels (ASVs) have been involved in numerous projects since the 1990s. Typically, the goal is to achieve fully autonomous navigation. The concept of ASV has been well known at an academic level for a while. Recently, industry has began developing full scale vessels for the container and bulk sectors [3, 15, 27, 26]. Together with the development of those new autonomous

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vessels, the research on classification about ASVs becomes important. The classifications provide clarity to researchers, designers, shipbuilders, equipment manufacturers, ship owners and operators, enabling accurate specification of the desired level of autonomy in design and operations. Moreover, the relative research paves the way to a clearer understanding of the opportunity and challenges of research on autonomous vehicles. Lloyd's Register [13], has published a categorization of vessels based on the level of autonomy. This is a step forward in the process to make ASVs a common means of transportation. Other types of categorization have been adopted by different autonomous applications, like the one proposed by SAE International, about the level of autonomy in vehicles [2]. However, above mentioned categorizations are not considering all the aspects subject to automation and the characteristics of vessels.

This paper is organized as follows. An introduction to the concept of ASV and their role in transport systems is given in Section 2. Following this, three existing autonomy level categorizations are explained in Section 3. A new autonomy level categorization is proposed, together with the additional sub-categories in Section 4. The conclusions of this paper are presented in Section 5

2 Autonomous Surface Vessels

An ASV is a vessel that has achieved a level of autonomy in its employment. For example, the human operator is helped or completely replaced by systems on board or at a remote location.

ASVs have started being developed at an academic level in 1993, when MIT presented its first vessel called ARTEMIS [18]. The goal of this ship was to collect bathysphere data along a river. Following this first vessel, many more institutes have started researching the field of autonomy on board of increasingly big vessels, up to the more recent proposal by Rolls-Royce and Man Diesel, to automate cargo and bulk ships [15, 26].

In order to clearly understand the main concept of ASVs, the following part presents the role of ASVs in a multi-agent, multi-layer cooperative transport system. Subsequently, the architecture of an ASV is introduced and the subsystems found on board are explained.

2.1 Cooperative transport system

The existing vessels are currently used to transport any kind of cargo, from bulk material, to containers, to people. Being part of a transportation system means the vessels are not the only actors in the transport environment. The components in the transport systems are controlled by agents. It is therefore interesting to analyze the control architecture with extensive communication and cooperation between the involved agents. Based on the three level planning and control architecture for transport over water proposed by Zheng et al. [29], we design a four level multi-layer multi-agent control architecture. Figure 1 shows those levels, from the point of view of a single agent ASV:

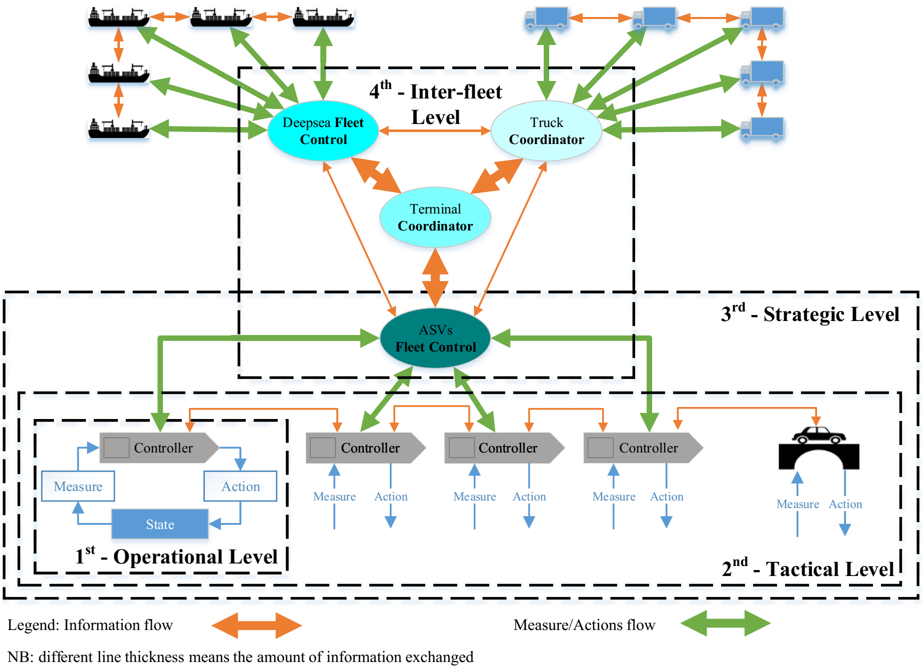

Figure 1. Multilayer environment for autonomous ASVs

1. **Operational level.** This is the single agent level. The autonomy of the vessel is directly related to the dynamics of the vessel. Additionally, it can exchange information, measurements and actions with the agents found in the same layer or in the layers above. There must be an enhanced communications capability.
2. **Tactical level.** This level comprehends a single layer, considering all the agents active in a direct connection. For example, as in Figure 1, information is exchanged between ASVs and infrastructures (locks, bridges, sluices, etc.). The decision control level of the single ASVs can receive important data about future disturbances or incoming conditions, adopting different control strategies based on this information.
3. **Strategic level.** The ASVs fleet control strategy in the second layer is connected to all the ASVs and infrastructures found in the first layer. The entire fleet must be considered and extensive planning must be achieved analyzing the multiple actions of every agent.
4. **Inter-fleet level.** The last level in Figure 1 connects the different coordinators found in the shipping environment. The goal of this level is to actively exchange information, cooperating in order to achieve the optimum controls of every agent involved in the shipping of goods. The first layers are not

considered anymore, so the data exchanged will not directly influence the actions taken on a single ASV. Because the single ASV is not considered explicitly anymore, this last layer is out of scope for the current research.

In this cooperative transport system, the vessels are equipped with sensors in order to autonomously navigate or take decisions. The data from those sensors can easily be shared with the other agents in the same layer or from the layer above. Furthermore, the control inputs from fleet controller or terminal coordinator must not be communicated to humans but can directly be set as input in the autonomous control system.

2.2 ASV vessel architecture

To realize autonomous navigation, an ASV needs different parts that are responsible for different functions. These parts are all supported by the hull, the main element of the vessel. As discussed by [5], [29], and [6], the following subsystems are found in an ASV (see Figure 2):

- **Hull.** The task of the hull is to give stability to the vessel and hold necessary subsystems. The shape of the hull can be different; from simple kayaks [8] to huge cargo vessels [15, 26], moving through many catamarans [7, 10, 4, 28, 11], sailing boats [21, 24, 14, 9, 20] and an unusual "flying saucer" [12].
- **Engine system.** Main component of the vessel, gives the ability to move. Combined with the propeller and the rudder gives direction. The automation

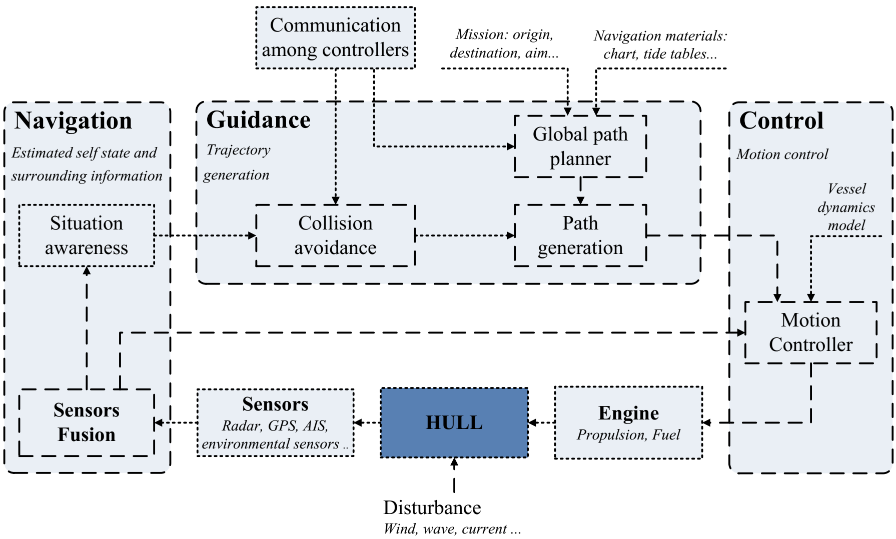

Figure 2. Subsystems in an ASV [6]

of this component is related to navigation, control and guidance system. Further engine monitoring systems can be implemented.

– **Communications system.** The connection between ship and shore or other ships. Key point in the automation of the vessel, gives the ability to remotely control the current situation and act on future states of the vessel. Autonomous exchange of data can be implemented.
– **Sensors.** Sensors are important to retrieve data from environment and the vessel itself. This inputs are elaborated and transformed in following controls of the actuators. Standard sensor found on board of many vessels are the GPS, together with the Inertia Measurement Unit (IMU). Further experiments have been performed using stereo vision cameras, laser vision, LiDARS and Automatic Identification Systems (AIS).
– **Navigation, Guidance and Control system.** The Navigation, Guidance and Control system is mainly software based. The task of the system is to obtain data from the sensors, calculate the desired output that comply with the optimal solution of the algorithm, and send the outputs to the actuators or to another module.

3 Existing autonomy level categorizations

In the previous section, the different components of an ASV have been presented. In this section, the systems and sub-systems will be related to the autonomy levels. The existing categorization of ASVs, introduced by Lloyd's Register [13], is discussed. The solution adopted by autonomous vehicles [1] is then introduced, building on longer development. Finally, the influence of the the interaction between human and machine is discussed, as described by Sheridan [23, 16].

3.1 Lloyd's Register autonomous ship guidance document

According to Lloyd's Register [13], an Autonomy level can be assigned to cyber-enabled ships. Three main tasks have been identified in the levels description: decisions making, actions taking, exceptions handling. The categorization is focused on the cyber safety of the vessel, where the hacking of the communication system is the worst risk. The summary of autonomy levels is given in Table 1.

3.2 SAE International automated driving levels

The SAE Level for autonomous vehicles have been redacted by the Society of Automotive Engineering to define clear boundaries for autonomous drive. The levels have been issued for vehicles on wheels, but the solution can easily be compared with the marine environment. The 6 autonomy levels are characterized by four tasks, each task is performed either by human or by system or by a collaboration of both. The summary is found in Table 2.

	Decision	Actions	Exceptions
AL 0	I. Manual	I. Manual	I. Manual
AL 1	II. Human in the loop (On-board data)	I. Manual	I. Manual
AL 2	III. Human in the loop (On- and off-board data)	I. Manual	I. Manual
AL 3	IV. Human supervision (Ship level)	IV. Human supervision (Ship level)	IV. Human supervision (Ship level)
AL 4	V. Human supervision (Broad level)	V. Human supervision (Broad level)	V. Human supervision (Broad level)
AL 5	VI. Rarely supervised	VI. Rarely supervised	VI. Rarely supervised
AL 6	VII. Unsupervised	VII. Unsupervised	VII. Unsupervised

Table 1. Autonomy Level illustrated as in Lloyd's Register document [13]

	Execution of Steering and Acceleration/ Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
SAE 0	I. Human Driver	I. Human Driver	I. Human Driver	n/a
SAE 1	II. Human driver and system	I. Human Driver	I. Human Driver	Some driving modes
SAE 2	**III. System**	I. Human driver	I. Human driver	Some driving modes
SAE 3	III. System	**III. System**	I. Human driver	Some driving modes
SAE 4	III. System	III. System	**III. System**	Some driving modes
SAE 5	III. System	III. System	III. System	**All driving modes**

Table 2. SAE Level for autonomous vehicles [1]

HIGH	X. The computer decides everything, acts autonomously, ignoring the human.
	IX. Informs the human only if it, the computer, decides to.
	VIII. Informs the human only if asked.
	VII. Executes automatically, then necessarily informs the human.
	VI. Allows the human a restricted time to veto before automatic execution.
	V. Execute a suggestion if the human approve.
	IV. Suggests one alternative.
	III. Narrows the selection down to a few.
	II. The computer offers a complete set of decision/action alternatives.
LOW	I. The computer offers no assistance: human must take all decisions and actions.

Table 3. Different levels of autonomy as suggested by [23] and [16]

3.3 Sheridan types and levels of human interaction with automation

Sheridan and Parasuraman [23, 16] have defined a set of 10 levels of interaction between human and autonomous system, from the computer decides everything to the computer offers no assistance (see Table 3). The levels are based on the classic four control concepts:

- **Information acquisition:** sensing and acquiring input data through the continuous monitoring of the environment around, or through a communication channel.
- **Information analysis:** elaborating received data, trying to create predictive algorithms or integrating different input variables together.
- **Decision selection:** evaluating different proposals, selecting decision and action.
- **Action implementation:** receiving the inputs from the decision made and has the goal to execute the actions.

3.4 Comparison of existing autonomy level categorizations

In the categorizations proposed by Lloyd's Register, SAE International and Sheridan, a system is subdivide in smaller functions or subsystems. Each of these subsystems is analyzed and labeled with a specific autonomy level. SAE International and Lloyd's Register propose an overall classification, based on the smaller subsystems. However, a overall classification can not give an explicit insight into subsystems. For example, Lloyd's register considers the possibility that a vessel has an autonomous decision making system and all the actions are human driven (AL 1 and AL 2). On the opposite side, SAE 1 and SAE 2 leave the decision task mainly to the human driver while taking care of the path following function as most important autonomy parameter. With these categorizations, the existing autonomous vessels usually fall in the SAE 1 or SAE 2 category, having autonomous actions implemented. The current cargo ships are within the AL 1 or AL 2 from Lloyd's Register, since decision making support can already be found on board.

Furthermore, as mentioned in Section 2.2, vessels are not the only actors in the transport environment. The communication and cooperation between agents are important functions that should be realized. The previous classifications are all lacking the explicit concept of cooperation between different agents. Lloyd's Register categorization is the only proposal that considers communications and data coming from the vessel only, or shared by a remote location. This seems like an hint to a collaboration with the central coordinator, but no explicit reference is made. If the communication and cooperation is implemented in the current ASV domain, then information could flow between ships, shore and infrastructures. Connecting those three data sources can lead to the creation of smart collaborating multi-agent networks, where information is exchanged to achieve an overall, more efficient, environment, instead of only optimizing the individual agent [17].

Additionally, the categorization proposed by [23] and [16] is quite flexible, but not directly useful for an overall ASV division.

A key component has been found to contrast between Lloyd's Register solution and SAE International division. The main topic of the former is the decision making task, which must be addressed before being able to rely on an autonomous action subsystem. On the other side, the latter, proposes an autonomy level that only considers the driving part (equivalent to the actions taking) of the autonomous vehicle. Furthermore, [23] and [16] seems to support the choice used in Lloyd's Register document [13]. The scale defined in the two research is considering first the achievement in autonomy at a decision making level, and then further considers the possibility to expand the autonomy by automatically actuating the physical components.

4 Definition and classification of autonomy levels for ASVs

Comparing the previous categorizations proposed by Lloyd's Register, SAE International and Sheridan, when defining the autonomy level for ASVs, we can look in both the subsystems and overall functions. In this section, we propose a new autonomy level categorization that considers both subsystems and overall systems.

Our new categorization system considers four main subsystems: decision making, actions taking, exceptions handling and cooperation. The levels assessed in each subsystem are going from a lack of interaction between human and computer to a full control of the computer that ignores the human actions. The levels of first three subsystems scale from 1 to 10. This scale is taken from [23]. For the newly introduced concept of cooperation in the autonomy scale, the levels are made by giving an increasing level of cooperation based on the number of agents the system is able to communicate with. For example, a vessel that is able to share data (not cooperate) with other agents will have a cooperation level of 2. A vessel that is better interfaced and can cooperate with vessels and a remote coordinator will have a cooperation level of 4. The level of cooperation ranges from 1 to 5. Detailed descriptions are presented in Tables 4 and 5.

The decision making subsystem is the first and easiest to automate; routing and planning tasks can be autonomously optimized, together with the maintenance schedule. *The actions taking subsystem* is more complex than the decision making subsystem, since physically actuated mechanical components are involved in the control loop. *The exceptions handling system* is a key part to obtain an overall high autonomy level, different solutions are being studied to detect and avoid obstacles. Finally, *the cooperation subsystem* considers the cooperation between the vessel and the surrounding environment. Information is exchanged with other vessels, infrastructures or remote control locations.

Once autonomy levels of the subsystems have been determined, the next move is to create a general autonomy level classification for the overall system

Decision making subsystem	
The decision making subsystem is in charge of defining the overall trip (from origin to destination), considering long term data, electronic nautical charts, weather forecast and, if available, the shared information incoming from cooperative vessels.	**1.** The computer offers no assistance: human must take all decisions. **2.** The computer offers a complete set of decision alternatives. **3.** The computer narrows the selection down to a few. **4.** The computer suggests one alternative. **5.** The computer executes that suggestion if the human approve. **6.** The computer allows the human a restricted time to veto before automatic execution. **7.** The computer executes automatically, then necessarily informs the human. **8.** The computer informs the human only if asked. **9.** The computer informs the human only if it, the computer, decides to. **10.** The computer decides everything, ignoring the human.
Actions taking subsystem	
The actions taking subsystem is in charge to interpret higher level inputs and transform those data in actions, directly related to the motion of the vessel.	**1.** The computer offers no assistance: human must take all actions. **2.** The computer offers a complete set of action alternatives. **3.** The computer narrows the selection down to a few. **4.** The computer suggests one alternative. **5.** The computer executes either steering or acceleration suggestion if the human approve. **6.** The computer executes steering and acceleration suggestion if the human approve. **7.** The computer allows the human a restricted time to veto before automatic execution. **8.** The computer executes automatically, then necessarily informs the human. **9.** The computer informs the human only if it, the computer, decides to. **10.** The computer acts autonomously, ignoring the human.

Table 4. Scale used to assess the autonomy level in different subsystems – Part 1

Exceptions handling subsystem	
The exception handling subsystem is in charge of always monitoring the surrounding of the vessel, detect unexpected obstacles and, if implemented, compute a new local path to avoid the impediment.	**1.** The computer offers no assistance: human must detect, decide and act. **2.** The computer offers a reduced set of possible obstacles. **3.** The computer offers a complete set of possible obstacles. **4.** The computer detect possible obstacles and suggests a local rerouting. **5.** The computer detect possible obstacles and executes a local rerouting if the human approve. **6.** The computer allows the human a restricted time to veto before automatic execution. **7.** The computer executes automatically, then necessarily informs the human. **8.** The computer informs the human only if asked. **9.** The computer informs the human only if it, the computer, decides to. **10.** The computer acts everything, ignoring the human.
Cooperative subsystem	
The cooperative system is in charge of exchanging information between the vessel and other agents, acting in the same domain. The data exchanged is then passed and integrated in the decision making, actions taking and exceptions handling subsystems. The communication are always exchanged in an autonomous way. For cooperation is intended the process of working together toward the same goal.	**1.** The vessel does not exchange any information and does not cooperate with any agent. **2.** The vessel exchange information with one or more agents but does not actively co-operate. **3.** The vessel exchange information with one or more agents but does only cooperate with one type of agent. **4.** The vessel exchange information with one or more agents and does cooperate with two types of agents. **5.** The vessel exchange information with one or more agents and does cooperate with three types of agents or more.

Table 5. Scale used to assess the autonomy level in different subsystems – Part 2

of the ASVs. The overall autonomy level is determined by the autonomy levels of the subsystems.

Many different subsystem autonomy combinations are found in prototypes and even more could be defined by combining existing technology and working models. To create a general ASV scale that is able to cover all the possible combinations, we adopt sub-levels to consider different variations. However, some ASVs may have high level autonomy on the decision making system, but a low level on the action taking. Consequently, a priority is given to a certain subsystem. By analyzing the existing ASV prototypes, we find that not all ASVs consider all the four subsystems. For example, the cooperation subsystems have not been considered in most prototypes. Among the four subsystems, decision making or actions taking subsystems can be found in almost all the existing. Therefore, the autonomy level of decision making or actions taking are considered as the candidates of the priority. As seen in [23] and [13], the decision making subsystem can easily be integrated in the existing and future vessels. Hence, the automation of decision making system is considered less important than the one of the action subsystem. For the same reason, the capability of autonomous exception handling and cooperation are also regarded as the sign of higher autonomy.

Besides, many projects and prototypes are considering a variable level of autonomy, depending on the situation or task being executed by the vessel. This concept is called "Dynamic autonomy" in [19]. In the our categorization, the maximum level of autonomy reachable on the vessel will be classified.

In addition, the combination of the autonomy level of the four subsystems is not randomly. The four subsystems are closely linked. Observed from existing ASV prototypes, when one of the subsystems has a high autonomy level, the autonomy level of the other subsystems will not be very low. For example, when the autonomy level of decision making and action taking is 5, the lowest level of cooperation is 1; when the autonomy level of decision making and action taking increase to 6, the lowest level of cooperation is 2. Therefore, when design the sub-levels, we take the possible combinations of subsystems in existing ASV projects.

Table 6 defines the main levels. The name of the levels describes their function. In each levels, there are several sub-levels. The relation between main levels and sub-level of the overall system and autonomy scales of the subsystems are explained in Table 7. With these two tables, the overall autonomy level of an ASV and the autonomy level of its subsystems can be determined. Here, we use an ASV developed by TU Delft, Delfia-1 [25], as an example. It is able to make decisions, take acts and handle exceptions autonomously, and inform human when it is requested. It has the capability to cooperate with other ASVs and infrastructures. Correspondingly, the Delfia-1 reaches decision making level 8, action taking level 8, exception handling level 8, and cooperation level 5. Therefore, it has an overall autonomy level 9, sub-level 2.

Autonomy Level	Name
0.	*Human is alone*
1.	*Human is helped by systems*
2.	*Human is helped by the systems and other agents*
3.	*Autonomous path following vessel*
4.	*Autonomous trajectory tracking vessel*
5.	*Human in the loop*
6.	*Human supervise the decisions making system*
7.	*Human supervise the actions making system*
8.	*Human supervise the exceptions handling system*
9.	*Human supervise actions, decision and exceptions*
10.	*Fully autonomous*

Table 6. Main autonomy level classes for ASVs

5 Conclusion and further research

ASVs have seen an increasing development in recent years. The rising number of projects leads to an increasingly higher autonomy level. To have a better understanding of autonomy of ASVs, the existing autonomy level categorizations related to the ASV domain have been presented and analyzed. The solutions proposed by Lloyd's Register [13] and by SAE International (related to the Autonomous Surface Vehicles) [2] assess the autonomy level of a specific sub-system of the ASV only. Even more, the solution proposed by Sheridan [23], which describe 10 levels of autonomy based on the amount of interactions required to the human operator, can be a viable alternative to describe the autonomy. However, an overall level to categorize the future vessels is lacking. Additionally, none of existing classifications considers the communication and cooperation between different agents in the transport system.

In this paper, a detailed definition and categorization of autonomy levels for ASVs are proposed based on the characteristics of ASVs and existing classification of autonomy. This new scale uses three subsystems proposed by Lloyd's Register and SAE International: Decision Making, Actions Taking and Exceptions Handling; a fourth newly added system takes care of the Cooperative Communication. This last aspect of the autonomy of a vessel has been actively researched through projects but only a few prototypes have implemented the solution. The integration of the cooperative sub-system in the new autonomy categorization wants to be an hint for the future development. The Decision, Actions and Exceptions subsystems are assessed by means of a scale from 1 to 10, where 1 is completely human operated and 10 is fully autonomous. The last subsystem, Cooperative, is evaluated from 1 to 5 based on the number of agents it is able to communicate with. After evaluating the subsystems, an overall autonomy level of the entire system can be determined. the overall autonomy level ranged from 0-10. In each autonomy level, sub-levels are designed consider different combinations of the four subsystems. In [22], we provide an extensive overview of existing ASV prototypes according to this innovative categorization. The tendency and

Autonomy Level	Sub level	Decision	Action	Exception	Cooperation
0	**1**	1	1	1	1
1	**1**	1	1	1	2
1	**2**	2-4	1	1	1
1	**3**	1	2-4	1	1
1	**4**	1	1	2	1
2	**1**	2-4	1	1	3-5
2	**2**	1	2-4	1	3-5
2	**3**	1	1	2	3-5
2	**4**	1	1	1	3-5
3	**1**	1	5	1	1
3	**2**	1	5	1	2
3	**3**	2-4	5	1	1
3	**4**	2-4	5	1	2
3	**5**	2-4	5	1	3-5
3	**6**	2-4	5	2	2
3	**7**	2-4	5	2	3-5
4	**1**	1	6	1	1-2
4	**2**	1	6	1	3-5
4	**3**	2-4	6	1	1
4	**4**	2-4	6	1	2
4	**5**	2-4	6	1	3-5
4	**6**	2-4	6	2	2
4	**7**	2-4	6	2	3-5
5	**1**	5-6	5	1	1
5	**2**	5-6	5	2	2
5	**3**	5-6	5	2	3-5
5	**4**	5-6	5	3	2
5	**5**	5-6	5	3	3-5
5	**6**	5-6	5	4	2
5	**7**	5-6	5	4	3-5
5	**8**	5-6	5	5-6	2
5	**9**	5-6	5	5-6	3-5
5	**10**	5-6	6	1	1
5	**11**	5-6	6	2	2
5	**12**	5-6	6	2	3-5
5	**13**	5-6	6	3	2
5	**14**	5-6	6	3	3-5
5	**15**	5-6	6	4	2
5	**16**	5-6	6	4	3-5
5	**17**	5-6	6	5-6	2
5	**18**	5-6	6	5-6	3-5
6	**1**	7-8	5	1	1
6	**2**	7-8	5	2	2
6	**3**	7-8	5	2	3-5
6	**4**	7-8	5	3	2
6	**5**	7-8	5	3	3-5
6	**6**	7-8	5	4	2
6	**7**	7-8	5	4	3-5
6	**8**	7-8	5	5-6	2
6	**9**	7-8	5	5-6	3-5
6	**10**	7-8	6	1	1
6	**11**	7-8	6	2	2
6	**12**	7-8	6	2	3-5
6	**13**	7-8	6	3	2
6	**14**	7-8	6	3	3-5
6	**15**	7-8	6	4	2
6	**16**	7-8	6	4	3-5
6	**17**	7-8	6	5-6	2
6	**18**	7-8	6	5-6	3-5
7	**1**	5-6	7-8	1	1
7	**2**	5-6	7-8	1	2
7	**3**	5-6	7-8	1	3-5
7	**4**	5-6	7-8	2	2
7	**5**	5-6	7-8	2	3-5
7	**6**	5-6	7-8	3	2
7	**7**	5-6	7-8	3	3-5
7	**8**	5-6	7-8	4	2
7	**9**	5-6	7-8	4	3-5
7	**10**	5-6	7-8	5-6	2
7	**11**	5-6	7-8	5-6	3-5
8	**1**	5-6	5	7-8	2
8	**2**	5-6	5	7-8	3-5
8	**3**	5-6	6	7-8	2
8	**4**	5-6	6	7-8	3-5
9	**1**	7-8	7-8	7-8	2
9	**2**	7-8	7-8	7-8	3-5
10	**1**	9-10	9-10	9-10	2
10	**2**	9-10	9-10	9-10	3-5

Table 7. Main autonomy level classes and corresponding sub-level

possible future developments of ASVs are analyzed according to the divisions obtained.

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